DEINKING STUDIES OF ONP AND ITS BLENDS WITH OTHER RECYCLED PAPERS

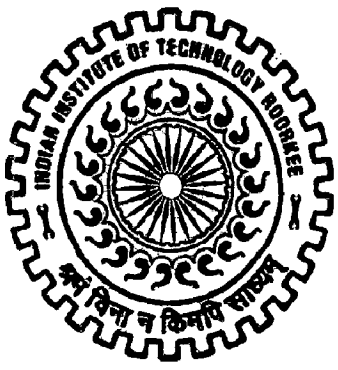
A THESIS

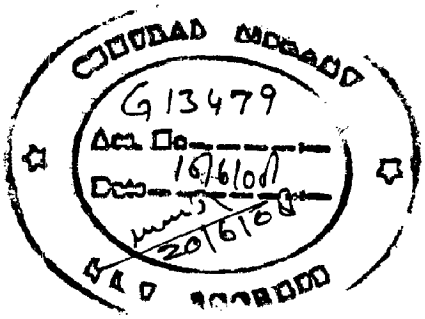
Submitted in partial fulfilment of the requirements for the award of the degree of

DOCTOR OF PHILOSOPHY

by

PUNEET KUMAR AGNIHOTRI





DEPARTMENT OF PAPER TECHNOLOGY
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SAHARANPUR CAMPUS
SAHARANPUR-247 001 (INDIA)

JANUARY, 2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **DEINKING STUDIES OF ONP AND ITS BLENDS WITH OTHER RECYCLED PAPERS** in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of Paper Technology of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during a period from August, 2003 to January, 2007 under the supervision of Dr. M.C. Bansal, Professor and Dr (Mrs.) Chayya Sharma, Assistant Professor, Department of Paper Technology, Indian Institute of Technology Roorkee, Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other Institute.

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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ABSTRACT

Chapter 1 indicates the importance of Recycled fibers in paper making globally. The source of global fiber supply is becoming an increasing concern due to deforestation and for the impact of fiber extraction on the environment. The use of recycled fibers, in the manufacture of paper, is both economical and environment friendly. Recycled fibers help in reducing deforestation, consumption of energy and chemicals for papermaking.

Chapter 2 indicates the importance of Deinking process in paper making. It is a sophisticated process for facilitating the recycling of printed recycled paper. Deinking operation utilizes chemicals, mechanical and thermal energies to produce a fibrous suspension from printed recycled paper, which is sufficiently clean and bright for use to manufacture various high quality papers. The chapter covers the work carried out by different researchers in this area.

Deinking is a two-step process. In the first step, the ink particles are detached from the fibers using thermo-chemi-mechanical action in the presence of chemicals in the pulper. In the second step, the ink particles detached from the fibers are removed from the pulp suspension by froth flotation.

Flotation deinking process is an extremely complicated process to analyze and model. Many processes occur simultaneously during flotation where chemical, physical and hydrodynamic aspects are involved.

The objective of the present work was to develop suitable Deinking technology for the uncoated Old newsprints (ONP) and its blends with other recycled papers

Chapter 3 covers details of the raw materials used, their analysis and experimental plan in the work. The different chemicals used in the pulper and flotation cell are selected as per the raw materials and process conditions. The experimental plan is discussed for both the stages i.e. pulping stage and flotation stage, to obtain the desired data. The experimental plan to measure the optical and strength properties of the hand sheets made are discussed.

Chapter 4 covers experimental, results obtained and their critical analysis. The deinking formulations and process conditions for use of deinking chemicals for deinking of offset printed recycled grades [(ONP) & Old uncoated and coated Magazines (OMG)] made from Indian mixed hardwoods and agricultural residues have been optimized, and the effect of processing conditions on pulp properties has also been studied.

As the blending of different grades of ONP with other recycled papers may create some operational problems, an effort has been made to develop some specifications for proper blending of different grades to get the desired quality of finished paper.

Laboratory-scale batch flotation experiments were carried out using ONP, OMG and their blends as raw material. Pulping was carried out in the hydropulper under suitable process conditions of temperature, consistency, pulping time, flotation time and proper dosages of active deinking chemicals. The ERIC values and brightness etc. of the hand sheets made from the slushed pulp are estimated, before and after flotation in the flotation cell.

Recycled papers have been used with different operating conditions and dosages of active deinking chemicals (Fatty acids / surfactants / collector) with sodium hydroxide, sodium silicate, hydrogen peroxide, DTPA, during pulping /

slushing operation and flotation deinking operation. The effects on optical properties (ISO brightness, ERIC values) and other strength properties are estimated due to the changes in operating conditions and dosages of active deinking chemicals.

The effects of dimensionless temperature, consistency, pulping / flotation time and chemical dosages of active deinking chemicals in the pulper were studied by using polynomial regression program - Compaq Visual FORTRAN, to predict the quality of the resulting pulp in terms of the process variables.

In chapter 5 major conclusions of the study have been listed, based on the laboratory investigations for ONP, OMG and their blends. From the experimental studies, it is concluded that the amount of ink removal increases with the increase in pulp temperature, pulp consistency, active deinking chemical dosages added in pulper upto the optimum conditions and then it decreases, as indicated by Deinkability factors based on ERIC and ISO brightness. Temperature has a significant effect on hand-sheet brightness. 65 ^{0}C is found to be the optimum temperature for ONP, OMG and their blends. Increasing the consistency in the pulping step improves hand-sheet brightness up to the point where agitation becomes materially impaired. For the existing system, 6% consistency for ONP, OMG and its blends gives better results. Pulping time of 15 minutes and Flotation time of 10 minutes have given better results. The effects of different active deinking chemicals (Fatty acids / Surfactants / Collector chemicals) during pulping operation and flotation deinking operation have been discussed. 1.2% Active deinking Chemical dosages for ONP, OMG and their blends have given optimum operation. Stearic acid gives better results in comparison with other active deinking chemicals.

Using Effective Residual Ink Concentration (ERIC) and ISO Brightness of the product samples, the practical values of Deinkibility Factors were obtained.

Mathematical models were then used to develop empirical equations to predict the Deinkability factors. The Program is used to calculate the coefficients for the desired degree of polynomial equations and a comparison is carried out between the experimental and predicted deinkability factors D_B and D_E to show the advantage of the proposed deinkability model.

Effect of operating variables and active deinking chemicals on the blending of ONP was studied with mixture of OMG for 100/0, 80/20, 70/30, 60/40, 50/50, and 0/100. Addition of 70% ONP with 30% OMG was found to be optimum among the four furnishes of ONP/OMG and their blends.

The blends of the mixed ONP and OMG were also examined to investigate the change in proportion of mechanical and chemical fibers, fillers, fines, and ink during flotation. After the pulping stage, filler and fiber components from magazines influenced the trends in strength properties. After the flotation stage, enhancement in all strength properties occurred probably due to the loss of most filler and fines during flotation.

For all the 124 experimental runs, a relationship is found between D_B and D_E as **y = mx+c** and is as given below:

$$\boxed{D_E = 0.9992D_B + 2.9622 \text{ or approximately } D_E = D_B + 3}$$

$$\boxed{R^2 = 0.9856}$$

The correlation coefficient R^2 gives a good fit of all the experimental data and thus the equation no. 5.3 can be used to predict the other value, if one of the two i.e. either D_B or D_E is known.

ACKNOWLEDGEMENTS

"Gurur Brhama, Gurur Vishnu, Gurur Devo Maheshwara,

Gurur Sakshaat Param Brhama, Tasmai Shree Gurve Namaha"

This Ph.D. thesis is dedicated to my parents who sacrificed their today for my tomorrow.

This is a narration of my experiences, during my research programme. I have made an attempt to study the deinking behavior of Old newsprints and Old magazines on flotation deinking and have compiled my efforts in the form of this thesis. It would have not been possible for me to make it without the support of some excellent people; I have come across during this time. It gives me an immense pleasure in placing on record my gratitude and sincere thanks to:

Dr. M.C. Bansal, Professor, Department of Paper Technology, IIT Roorkee, an excellent teacher and a critical supervisor. I am highly indebted to Dr. M. C. Bansal whose astute research methodology and profound knowledge of the subject have greatly benefited me in easy grasping of this interdisciplinary subject. His invaluable help, meticulous guidance, constructive suggestions and continued reviewing of the work, could only give final shape to the thesis. I greatly appreciate his patience for very careful multiple reading of the entire manuscript. A single word of thanks to him is no way near to his constant help, fruitful discussions and inspiration towards the perfection.

I acknowledge with a sense of deep and sincere gratitude, the meticulous guidance and encouragement rendered by Dr. (Mrs.) Chhaya Sharma, Assistant Professor, Department of Paper Technology, IIT Roorkee for her constant counseling and help during the work.

I am grateful to Prof., A. K. Ray Head of Department of Paper Technology, IIT Roorkee, for providing all the required research facilities during the course of this study. I am also grateful to Former Head, Prof. J. S. Upadhayaya, Prof. A. K. Singh, Prof. Satish Kumar; Chairman D. R. C. Prof. V. P. Singh, Dr. S. P. Singh, Dr. Vivek Kumar, Dr. S. C. Sharma and all other faculty and staff of the Department of Paper Technology, IIT Roorkee, for their invaluable guidance and help during the course of this research programme.

The financial assistance from University Grants Commission and MHRD, New Delhi is gratefully acknowledged.

I owe my indebtedness to my father Shri. H.K. Agnihotri for being a guiding and moving force for me, for his untiring efforts and for helping me to achieve what I wished. It is his constant encouragement through various stages of the work, and a strong faith in me, which has made this day possible in my life. I am deeply indebted to my Late mother Smt. Raj. Kumari Agnihotri for her unconditional blessings as she had always been an eternal source of inspiration and encouragement for me.

Words cannot express my gratitude and feelings for my younger brother Prabhat, youngest sister Priyanka and my wife Jyoti, whose continued active support made it possible for me to complete my work. Their continued encouragement boosted my moral during the most difficult phases of the research.

I am also grateful to Mrs. Chitra Rekha Bansal, wife of Dr. M.C. Bansal, for her moral support given to me throughout this work.

My tender sentiments are also for Dr. Mayank Garg, and my affectionate friends group of DPT research scholars and personal that helped me in one way or other and provided the necessary friendly environment for work.

I am grateful to the laboratory officials of DPT who have spared their invaluable time in participating and helping me in the various experiments undertaken. My sincere thanks are due to the library staff and others too for their timely help.

In the end but not the least I am thankful to IIT Roorkee and its officials especially from Dean, PGS&R office for their timely help all through the work.

Finally, I would like to thank all the individuals who have helped me directly or indirectly in completing this arduous task.

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CONTENTS

INTRODUCTION

Paper recycling, in an increasingly environmentally conscious world, is gaining importance. The use of de-inked fibers in the paper industry has increased dramatically in recent years, and with the current environmental awareness and legislation, this trend is expected to continue. The importance of recycling is increasing for the pulp and paper industry because of decreasing forest resources, landfill problems, pressure from the environmental regulations and associated legislation. There is strong and growing pressure from public interest groups and governments to increase the recycling of waste paper. The environmental organizations emphasize the conservation of natural resources; government and local authorities are concerned with finding alternative outlets for various components of solid waste, including waste paper. The ecological arguments put forward including the saving of forest and natural resources. The most important factor, which will decide the growth rate of paper industry in the coming years, is the availability of suitable raw materials economically on sustained basis. The use of recycled fibers has now been established as an important source of furnish for the paper industry worldwide. The demand of paper has been continuously increasing at a pace much faster than the availability of fibers from the natural sources. With rapid developments in deinking processes for the reuse of secondary fibers, the recycling process is becoming more and more efficient. Recycling of waste paper, after its intendment use, has been found to be more economical and eco-friendly. Without recycling, the fiber supply from the world's natural sources shall not be sufficient to keep up with the demand. Secondary fiber has become a major source of raw material for the paper industry. The quality of paper made from secondary fibers is approaching that of virgin paper. Selecting the recovered paper based on proper grade and reusing high value papers can increase recycling efficiency. The reuse of

the paper fibers is essentially dependent on their deinking. Only after the ink has been removed selectively from the fibers, we can use them again to make a good paper. Forest based pulp is continuously loosing its share, out of the total pulp and paper furnish, in the global paper industry for the last few years. The use of recovered paper preserves forest resources, reduces environmental pollution and saves water and energy. Collection of waste paper, obviously, thus is a large enterprise and suppliers/ exporters / importers are now well established in this field too. It is further observed that deinked pulp suitable for use in printing papers usually imparts special properties to the finished papers compared with papers made from wood pulp.

Recycled paper collection and sorting are high labor-intensive process (58). The collector of recycled papers does much of the sorting because this allows him to obtain best price for the waste product. The waste paper dealer pays less for unclassified materials, and thus the supplier must sort out the waste paper to extract the better quality waste. About 80 % of all waste paper comes from three sources: - corrugated boxes, newspapers, and office papers. Old newsprints (ONP) are usually made into new newsprint, egg cartons, or paperboard. High-grade white office paper can be made into almost any new paper product stationery, newsprint, or paper for magazines and books.

Almost all papers can be recycled today, but some types are harder to recycle than others. Papers that are waxed, pasted, or gummed or papers that are coated with plastic or aluminum foil are usually cooked in digester. In India, some mills are using such coated imported papers, which are first cooked in digester before pulping in hydropulpers. Waste papers are manually sorted first before processing in these mills.

1.1 ADVANTAGES OF RECYCLING

Although the raw material for making paper is predominantly trees, it is a common conception that recycling of waste paper saves trees. Trees for papermaking are grown and harvested as a long-term crop with new trees planted to replace those cut down. Nearly all the paper is made from wood grown in these "sustainable" forests worldwide. There have always been some myths about using recycled paper, which contributed towards the low rate of growth of waste paper consumption. It has been always considered that everything that has been thrown out is just trash but the other side of this illusion is that we have been throwing the resources rather than trash. Therefore recycling of waste paper facilitates the utilization of thrown and unutilized resources in the manufacturing of paper. According to *Ko. kurek (75)* the recycling of waste paper offers several advantages and some of the advantages are as follows:

- Environmental Considerations.
- Protect valuable wildlife habitats and ecosystems.
- By using recycled paper to produce new paper, disposal problems are reduced.
- Lower energy requirements.
- Reduces air, water and soil pollution.
- Decreasing availability of conventional raw materials.
- Reduces the demand for virgin fiber, and thus reducing deforestation.
- Reducing Consumption of water (75% less water than making it from virgin fiber).
- Reducing Consumption of Chemicals for pulping and bleaching.
- Reducing Formation of toxic byproducts during pulping and bleaching.
- Reducing Cost of treatment of effluents (90% less aqueous effluent).

- Improved technology available for reuse of secondary fibers, to obtain better quality products.
- Reliable source of pulp in times of market pulp shortage.
- Price is usually favorable in comparison with that of corresponding grades of market pulp.

1.2 PROCESSING OF RECYCLED PAPER

Kanhekar et al. (74) have reported in their study that the process is very chemistry intensive and has been studied extensively. Conventional processes use chemicals that are easily available and are cheap. The standards to be met for the quality of the deinked pulp are the same as those for virgin paper pulp. However, there are still a few rough edges in the processes being used commercially today that need to be smoothened out. Deinking processes, though far more eco-friendly than virgin-paper-making processes usually are, still use some chemicals that are harmful when released as effluents. As the processes generally used are highly proprietary, not all the industries are being run at an optimal level. Besides, some very promising results obtained at the laboratory level, if incorporated into industrial processes, could be of great benefit. If the waste paper contains ink, the paper must be deinked and also remove fillers, clays, and fiber fragments, depending upon the processes involved or end product desired.

Deinking is a sophisticated process for the benefits of recycling the paper. Deinking operations utilize chemical, mechanical and thermal energies to produce a fibrous suspension from printed wastepaper, which is sufficiently clean and bright for use in various high quality grades of paper. The technology advancement has given us opportunity to use waste paper in manufacturing specialty papers too, like writing and printing grades. For manufacturing writing and printing grades, efficient deinking

of the waste paper is an essential operation of the paper making process. Flotation deinking operation is found to be the most efficient process now a days.

Many authors (3,72,110,131) have explained in their studies that deinking is a two-step process. In the first step, the ink particles are detached from the fibers using thermo chemi-mechanical action with the presence of chemicals in the pulper. In the second step, the ink particles detached from fibers are removed from the pulp suspension by froth flotation. In flotation deinking, initially the ink particles are dispersed by breaking up the recovered paper in an alkaline solution with the aid of surfactants and other additives.

Flotation deinking process is an extremely complicated process to analyze and model. Many processes occur simultaneously during flotation where chemical, physical and hydrodynamic aspects are involved.

1.3 SELECTION OF THE PROBLEM

1. The problems facing the waste paper utilization are due to insufficient brightness, grey pulp, smeared pulp, colored pulp, specks, dirt, stickies, contaminants, less yield, etc. The main cause of defects in deinked pulps is related to inks and chemical adhesives used for printing and converting paper and board material. The development of inks easier to deink, and glues and adhesives less detrimental for paper recycling, are the major subjects of many research programs.
2. The recycling of wastepaper started from packaging grades. Now, the use of wastepaper has expanded through the tissues and the newsprint to the fine writing and printing papers. Deinking systems are more complex than wastepaper based plants for packaging grade, requiring lesser treatments.

3. The effluent from deinking plant is increasingly becoming an object of scrutiny by the public in general and the environmental regulatory authorities in particular. The next generation of deinking chemicals will not only have to work better than the current ones, but will also have to comply with a myriad of anti-pollution regulations.
4. The objective of the present work is to develop a suitable Deinking technology for the uncoated ONP and its blends with other recycled papers and make some new developments in the area of Secondary fiber processing.
5. To optimize deinking formulations and process conditions for use of deinking chemicals for deinking of offset printed recycled grades [(ONP) & Old uncoated and coated Magazines (OMG)] made from Indian mixed hardwoods and agricultural residues. The effect of processing conditions on pulp properties shall also be studied.
6. The blending of different grades of ONP with other recycled papers may create some operational problems. An effort is being made to develop some specifications for proper blending of different grades to get the desired quality of finished paper.
7. The main objective of this present work is to advance the status of the secondary fiber utilization technology by improving the existing deinking methods and processes. This work will help create the scientific and engineering base for developing mathematical models by using Effective Residual Ink Concentration (ERIC) and ISO Brightness to predict Deinkibility Factors. The deinkability factor is the ratio of amount of ink removed to the amount of the ink present in the pulp before deinking by flotation cell, which is estimated by using ERIC values or ISO brightness.

1.4 SCOPE

Current methods and technologies used in recycling of secondary fiber are limited in scope and application. The environmental and economic impact of this problem is huge. Clearly, new methods and applications are needed to advance the current status of the recycling technology.

The results of this study suggest that the secondary fiber pulps, especially old newsprint pulps and its blends with other recycled papers can be deinked effectively and used in the manufacture of new paper products. The results will be useful for evolving suitable strategies for increasing usage of recycled fiber, especially from ONP pulps and its blends, in the manufacture of different grades of paper.

1.5 LIMITATIONS

In the present study, all the recycling experiments, from pulping to sheet making have been conducted in the laboratory. The mill conditions differ from the laboratory conditions at almost each step. Further, the recycled sheets in these experiments were not subjected to those operations to which actual paper undergoes during papermaking and printing. These conditions may influence the recycling behavior and physical properties of the paper, under those conditions.

CHAPTER 2

LITERATURE REVIEW

LITERATURE REVIEW

Recycled fibers have established themselves as a potential raw material for paper industry globally. The source of global fiber supply is becoming an increasing concern due to deforestation and for the impact of fiber extraction on the environment. Forest preservation and sustainability of the environment, is an important burning issue in today's world. This has resulted extensive change on the global fiber supply. At the same time forest preservation by many National Governments and increasing environmental awareness on the part of large public sectors have led to renewable fiber resources. Asia, despite having the world's fastest increase in local wood production, is likely to experience shortfalls in the supply of all wood products.

Shortages of wood fiber could encourage greater use of non-wood fibers for paper making, which is already a significant raw material in China and India. The increasing shortage of virgin fiber and higher demand of pulp and paper making fiber, have shown that the recovered or recycled fiber and non-wood fibers are the possible out come and have become more prevalent and desirable.

2.1 GLOBAL SCENARIO

According to *Misra (100)* the use of secondary fiber supply may be more than 55% of the total Global pulp production by the year 2010.

ÅF-QPS (4) in their study reported that in the future, levels of recovery of secondary fiber should be close to 70% in Europe and 55% in North America. In most other (often developing) countries, where the recovery rate is still low (<40%) the recovery rate is likely to increase more slowly but steadily during the next 15 years.

Viswanathan (140) have stated that the recycling percentage of waste paper is over 40% in developed countries like US, Europe and Japan. It is said to be as low as 20% in developing countries like India. Today waste paper is used to the extent of 70 to 90% (there are mills using even 100%) in furnish for the manufacture of fine papers.

Tandon et al. (134) have indicated that France has recycling rate 84%, and Japan has recycling rate upto 60% in domestic paper production.

According to *Kulkarni et al. (76)* a comparison of World and the Indian Paper industry is given in the Table – 2.1, and World Paper Production distribution and Per Capita Consumption is shown in the figures 2.1 and 2.2.

The demand for paper continues to be strong despite beliefs that advances in IT would result in a paperless global society. The fact is that the world paper and paperboard demand, which was 313.3 million metric tonnes in the year 2000, has exceeded to 320 million metric tonnes by the end of 2006. The demand growth, however, has shifted to the emerging market in Asia, which is anticipated to account for a third of the world's paper consumption within the next 15 years.

Toepfer (136) have indicated that, Industrialized nations with 20 percent of the world's population, consume 87 percent of the world's printing and writing papers. Global production in the pulp, paper and publishing sector is expected to increase by 77% from 1995 to 2020 (101).

Lopez et al. (84) in their study reported that in 2000, more than 41 million tonnes of recycled paper were used as raw material by the paper industry in Western Europe, the recycling rate for the region being 49.8%. At present about 50% of the fiber used in Europe is derived from recycled paper. In Spain the utilization rate is as high as 79.7%. In Denmark it is around 62%.

2.2 INDIAN SCENARIO

Indian paper industry is also modernizing actively its fiber lines in order to improve its competitiveness. The growth and development of the paper industry is taken as a benchmark of the status of socio-economic activities of a country. Globalization has finally caught up with the Indian paper industry, and it is now adopting ways and means for making itself more competitive. In the recent past, the Indian paper industry has undergone many changes with many companies opting for consolidation, expansion and technological up gradation.

During 70S, a lot many small and medium size (upto 80TPD) agro based paper mills had been installed in India. None of such mills had chemical recovery plant and with time became major source of liquid effluents polluting surrounding areas and rivers. With a great pressure from environmentalists and Pollution Control Boards, they are shifting to recycle fibers as raw materials.

According to *Chatterjee et al. (36)* India ranks second for having largest number of paper mills in the world, after China. A portion of the paper industry producing low-grade papers and paper boards has been recycling for decades but the paper mills manufacturing high grade papers such as writing and printing paper have done very little effort in this direction.

Kulkarni et al. (76) have stated that in the recent past, the Indian paper sector has maintained a growth rate around 6.5%, which is way above the world average of about 2.8%. There are more than 600 pulps and paper mills having 6.5 million tonnes of production and 0.68 million tonnes of newsprint against the present installed capacity of 7.6 million tonnes of paper and paperboard and about 1.3 million tonnes of newsprint. The projected demand for the paper, paperboard and newsprint is expected to touch 8.3 million tonnes by the year 2010. The growth of newsprint

industry in India based on installed capacity in million tonnes is given in figure 2.3.

Sankara et al. (119), Tandon et al. (134) and Jain et al. (68) reported in their studies that today share of paper production in India, based on recycled fiber is about one third, which amounts to approximately 2.2 million tonnes per annum. The size of recycled fiber based mills varies from 10 tonnes to 900 tonnes per day, producing a variety of paper and paperboard. Currently, Indian paper industry utilizes 36% of recycled recovered fiber, which is expected to a level of 44% by 2015 (figure 2.4). The present recovery rate stands at 20% against the world average of 50%. Taking into account the increased uses possible from agro-based and waste paper, the paper industry will require nearly 9.0 million tonnes of wood per annum by the year 2010 in India.

According to *Chowdhary (37)* India is currently using 3 million tonnes of recovered paper annually (both imported & domestic). Annual import 1.5 million tonnes currently increasing at 7% annually. Consumption of recovered paper estimated at 5-6 million tonnes by 2010. Indian Paper & Board consumption is growing at about 6.4% annually.

Jain et al. (68) have stated that the domestic demand for paper and paperboard has been rising in the past three years at a rate of around 5.5% and is now touching the 6% mark. The total demand of paper and paperboard, writing and printing grades of paper accounts for nearly 45%, industrial paper for nearly 50% and the remaining 5% for other grades including tissue paper. Recently, the government has put 2% cess on the value of all imports coming into India.

The newsprint sector in India has been through some turbulent times in the recent past and production has been nearly stagnant. Total Import of newsprint in India has been around 0.76 million tonnes. Total Exports of newsprint from India has been around 0.004 million tonnes only. The import of raw material for paper including

pulp, waste paper and newsprint is likely to increase by at least 15% to 20% in 2005 - 06 to keep up with growing demand for paper in the domestic market. Figure 2.5 gives the distribution of the variety wise availability of waste paper in India.

Pundir et al. (113) reported that in India, the addition level of recovered fiber is increased after 1980. Presently India is producing approx. 1.2 million tonnes paper per annum with recycled fiber.

A number of research studies dealing with deinking of wastepaper are in progress in R&D institutions and research laboratories. In most of these studies, mill operations have been simulated in the laboratory. The effect of grade of wastepaper, type of fiber, and the type of commercially available deinking chemicals on the extent and rate of ink removal has been studied. In these studies, deinking effectiveness is evaluated based on paper brightness and residual ink concentration.

Research is still going on for improving the flotation deinking cell technology and the responsibility for successful flotation lies with printing ink & printing equipment manufacturers. It is essential that deinking be considered, with the inks being developed which should be easily recycled. Not much technical information is currently available to the mills for optimizing the use of deinking chemicals and other processing variables. Even in many cases the mills are reluctant to use the available new technology because of lack of confidence. Therefore, the fiber yield has been low and the paper quality poor and inconsistent. This will become critical for the survival of the mills as the consumer demands better quality paper and cleaner environment.

2.3 RAW MATERIALS

McKinney (98) has indicated that magazine is a generic term, which refers to coated and uncoated paper that is bound with staples or glue. Magazine is a highly variable raw material. The fiber components of the magazine can range from 100% Kraft to 100% ground-wood pulp. Fillers such as clay and precipitated calcium carbonate (pcc) are added in the paper making process, to improve the sheet characteristics. In magazine stock, the inorganic portion of the furnish can range from 10 weight % in the uncoated sheet to as high as 40 weight % in a sheet that is coated on both sides. The addition of dye is also common in the production of magazine grade papers.

Old newsprints (ONP) represent a major source of raw material for the reproduction of newsprints grade papers. ONP is widely available and is usually of uniform quality, which makes it valuable. The technology for removing conventional oil-based inks such as offset and letterpress is well established, reported by *Biermann (23) and Agnihotri et al. (5)*. The newsprint portion is mostly mechanical fiber, containing most of the dry content of wood. In the original production of the pulp, the wood is converted either Chemi Thermo Mechanical Pulping (CTMP) or by Thermo Mechanical refining of chips (TMP). These mechanical pulping processes produce a wide distribution of fibers. If ONP is exposed to sunlight some of it may be considerably more yellow than fresh newsprint pulp. The most common form of ink applied to newsprints consists mainly of carbon black particles dispersed in heavy oil. Only in the case of premium newsprints does the ink contain soyabean oil or additives to promote drying or setting. Rather, the oil mainly absorbs into the fibers.

Olson et al. (102), McKinney (99) and Gurnagul (61) reported in their studies that, the lower cost secondary fiber furnishes, such as ONP and its blends are of particular interest to the mills. These types of furnishes require deinking and

contaminant control to be used at appreciable levels of substitution. Therefore, the mills are faced with the challenge of developing a program that will allow them to produce a pulp with suitable quality for their particular application. Flotation deinking is used primarily in deinking combinations of newsprints and magazines.

Borchardt (29) have stated that the filler from magazines is believed to have desirable effects for effective removal of ink from the ONP. Clays and other ash components are believed to provide sites for ink attachment and ink particle agglomeration. The ink-coated particle is then trapped in the foam layer and separated from the pulp slurry.

Grieg-Gran (60) reported in their study that production of newsprints based on recycled fiber generally requires less energy than production based on virgin fiber. There may be environmental benefits too as more newsprint is diverted from landfilling.

Shrinath et al. (128) have stated that evaluating the suitability of deinked fiber for the manufacture of particular grades of paper involves two main considerations:

- The quality requirements for the grade being manufactured. These requirements determine whether deinked fiber can be incorporated into the furnish and in what percentage.
- The deinked fiber must meet certain quality requirements before it can be used in the manufacture of a given grade of paper. The effectiveness of the deinking operation is largely a function of the types of inks and contaminants contained in the wastepaper.

Mahagaonkar et al. (87) and Letscher et al. (81) found that addition of old magazines improves the optical and strength properties of recycled papers (ONP) because of the introduction of fillers and chemical fiber.

Offset printing has become the dominant printing process. The papers used in offset printing must be strong enough for their intended end use while providing adequate print quality. Several authors *(30,92,107,114)* have noted that some offset papers can be printed and deinked to produce a second generation of offset-quality papers.

2.4 CHEMICAL REAGENTS

A wide variety of chemicals are used to facilitate the deinking process. The choice is based mainly on the type of raw material to be treated, the separation method (flotation), and the desired quality of the end product.

Alkaline deinking is widely used and generally considered as more efficient in respect of ink detachment than neutral. Ink detachment is performed by the combination of mechanical forces (agitation during slushing) and chemical action due to chemicals added in the pulper, which contributes to the disintegration of recovered paper. Chemistry plays an important role in fiber swelling, ink removal, wetting, anti-redeposition, dispersion, flocculation, agglomeration, oxidation, reduction of chromophores, etc. The principal chemicals involved in the deinking process are sodium hydroxide, sodium silicate, chelating agents, hydrogen peroxide, surfactants and collector chemicals. The type of ink present in the waste paper determines the equipment and chemicals required for selection of deinking processes.

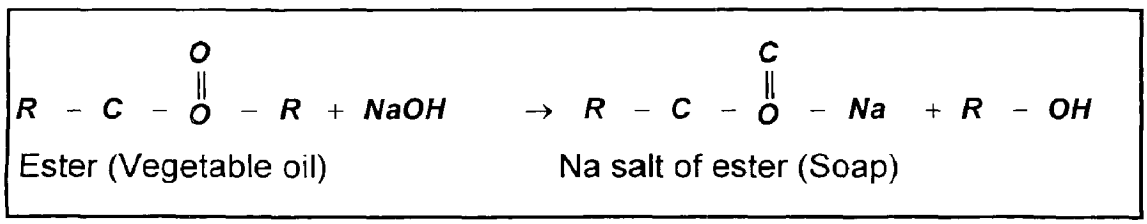
Chemical action applied during disintegration of recovered papers has changed in recent years due to the development of new process equipments and also due to the intensive research done in the field of chemical surfactant formulations. As the composition of used recovered paper is going to be controlled in a more sophisticated way to guarantee a more homogenous raw material quality to produce a final deinked pulp, the influence of chemicals on specific papers has to be

evaluated. Many good review papers (*9,8,13,11,16,20,46,48,49,50,63,65,80,89,91, 93,102,111, 115,116,124,125,142)* have been written on deinking chemistry.

Each such chemical contributes differently with different functions as detailed below:

2.4.1 Sodium Hydroxide (NaOH)

Sodium hydroxide is used not only to adjust the pH to the alkaline region, but also to saponify and / or hydrolyze the ink resins. The alkaline environment is often reported to "swell "the fibers. At the pH conventionally used for pulping 9.5 -11.0, the fibers would take up some water and become more flexible, rather than puff up like cellulose balloons. The addition of caustic soda to wood containing furnishes will cause the pulp to yellow and darken. This is the phenomena that are often referred to as "alkali darkening". The problem with alkali darkening is only of concern with wood containing furnishes. Higher pH can be used with wood free furnishes with no Alkali darkening. The adsorption of hydroxide ion is thought to increase the electrostatic repulsion between the fibers and the ink particles, thus resulting in greater ink detachment. The pigment in ink is released by breaking down the oil-based vehicle carrying the pigment. NaOH reacts with oil-based inks giving out soap and alcohol through saponification reaction (2.1) as follows:



[2.1]

2.4.2 Hydrogen Peroxide (H_2O_2)

Hydrogen peroxide is usually added to prevent Yellowness, to strip the color and to increase the brightness. Hydrogen peroxide is used to decolorize the chromophores

generated by the alkaline pH in a wood-containing pulper. Hydrogen peroxide is also used as post bleaching agent. The balances between how much peroxide should be added in the pulper versus how much in the bleaching stage must be optimized for each furnish. The peroxide reaction with caustic soda is shown in equation (2.2):

$$H_2O_2 + NaOH \Leftrightarrow HOO^- + Na^+ + H_2O \quad [2.2]$$

The per-hydroxyl anion (HOO^-) is the active bleaching agent. Peroxide can be decomposed by the presence of heavy metal ions (e.g. Mn++, Cu++, Fe++), and high pH or temperature. The decomposition reaction is shown in equation (2.3):

$$H_2O_2 \rightarrow \frac{1}{2} O_2 + H_2O \quad [2.3]$$

The decomposition of peroxide can be reduced by the addition of "stabilizing "agents such as chelants and Sodium silicate. It is known to be effective at stopping darkening of mechanical fibers carried by sodium hydroxide. Peroxide helps in ink removal by penetrating into the fiber subsequent decomposition. Peroxide addition to pulper can give higher final stock brightness than peroxide addition to a post flotation bleach tower.

2.4.3 Sodium Silicate (Na_2SiO_3)

The Sodium silicate most commonly used in deinking mills is at 41.6^0 Baume solution of sodium meta-silicate, which contains roughly equal amounts of SiO_2 and Na_2O. Silicate aids in deinking through an ink dispersant action or by preventing the ink from redepositing on the fiber surface. The anti – redeposition effect is what made silicate popular in laundry soaps. The dirt or soil was emulsified and prevented from sticking back on the clean wash. Silicate affect the pulper chemistry, increasing the silicate will increase the pH and this may call for a reduction in the sodium hydroxide addition rate. Silicate is often referred to as peroxide "stabilizer" effects

positively for separation of ink from fiber. The sodium silicate solution is a source of alkalinity, derived from free hydroxyl groups, as well as a pH-buffering agent, which operates around pH 11.3. The source of alkalinity can be noted from equation (2.4), which shows the reaction of silicate with water:

$$Na_2SiO_3 + H_2O \Leftrightarrow 2Na^+ + OH^- + HSiO_3^- \quad [2.4]$$

Many authors *(6,48,62,78,117,118,120)* who have studied the properties of sodium silicate attribute it to a collecting effect. Other authors specify dispersant properties to the sodium silicate in the deinking flotation process. Sodium silicate is source of alkalinity and the high dosage of sodium silicate in the pulping operation creates high alkalinity will cause undesirable yellowing referred to as alkali darkening.

According to *Liphard et al. (83) and Mathur (94)* statistical analysis to inorganic losses verified that sodium silicate is the most significant factor influencing fiber loss and filler removal during flotation. It has been observed that there is a decrease in filler removal when the presence of sodium silicate increases. This behavior is due to the absorption of sodium silicate on the pigment surface, preventing air bubbles to carry them to the surface.

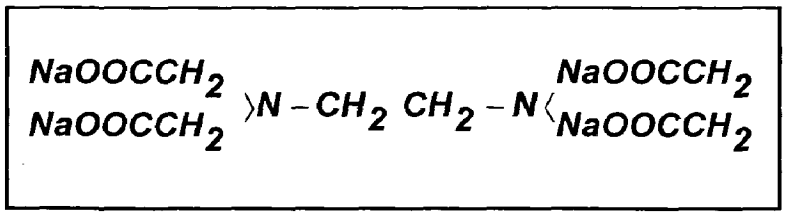
Pelach et al. (111) have reported in their study that the deinkability factor decreases when the percentage of sodium silicate increases.

2.4.4 Chelating Agents

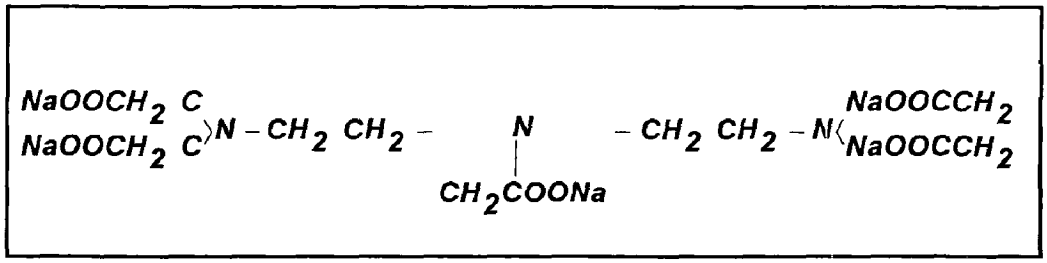
DTPA (diethylene triamine penta acetic acid) is the most commonly used chelant, but EDTA (ethylene diamine tetra acetic acid) is also used. The role of the chelant is to form soluble complexes with heavy metal ions. Complexates prevent these ions from decomposing the hydrogen peroxide. The five "legged" structure of DTPA is what contributes to the ability to chelate more strongly than the four "legged"

structure of EDTA. The amount of chelant that is necessary is directly dependent on the amount of heavy metal ions in the pulper. The metal ions can be sourced from the wastepaper or from the mill or fresh water.

EDTA



DTPA



2.4.5 Surfactants

Several researchers (48,49,82,137,142) have indicated in their studies that surfactants react on the surface of the fiber to release the ink particles and also help to disperse the ink particles in water so that they are not re-deposited on the fibers. The term surfactant is derived from their function as surface-active agents. "Surfactant" is a catch all term that covers uses like dispersants, collector, wetting agents, displectors, anti – redeposition aids. In general surfactants are applied with NaOH, Na_2SiO_3 and H_2O_2. Surfactants that are used for deinking will have two principal components – a hydrophilic and a hydrophobic component. During flotation, the hydrophobic end will associate with the ink oil and dirt while the hydrophilic end will remain in the water. Surfactant action is the formation of "micelles," as shown in figure 2.6. In flotation deinking, surfactants are believed to work by reducing the surface tension of the water, thus allowing it to penetrate between the dirt particle and the fiber. Combined with mechanical agitation, this action leaves the dirt particle into the water. Dirt particles are usually covered with an oil film, and the oil loving part of the surfactant adheres to this surface. The other end of the surfactant

molecule remains in the water. The resulting complex is a dirt particle with a hydrophilic surface, which remains suspended in the water phase and can be removed by dewatering and rinsing. It is quite likely that this is the mechanism by which surfactants remove print particles in flotation deinking. A surfactant molecule typically has one extremity that is polarized and another that is not. The nonpolarized portion of the surfactant is adsorbing by hydrophobic substances (ink particles, fibers, fillers). The polarized portion is directed outward, thus enhancing the wettability and dispersion of hydrophobic substances in an aqueous environment. The polarized and nonpolarized portions of a typical surfactant, in this case sodium oleate, are illustrated in figure 2.7. The figure also depicts an ink particle and an air bubble with the polarized portions of the surfactant directed outward. During the deinking process, surfactants are adsorbing the solids (fibers, ink, fillers), which enhances fiber swelling and expedites dispersion of the ink after separation from the fiber. Surfactants are classified as cationic, anionic, or nonionic. Those used in flotation deinking can be cationic (positive charge), anionic (negative charge), or nonionic (no charge). The most commonly used surfactant system in the flotation deinking process is fatty acid soap.

2.4.6 Collectors

Chemicals collect together the detached ink particles into greater particles while simultaneously giving these agglomerates a hydrophobic surface and are called collectors. Before addition of the collector, the ink particles for removal from the fibers are too small and their surface properties are too hydrophilic for flotation. Collector chemicals can be added either at the pulper or just before the flotation cells. Collectors can be made from naturally occurring materials, such as fatty acid soaps; synthetics such as Eo/Po (ethylene oxide/ propylene oxide copolymers) and

blends such as ethoxylated fatty acids. For ink removal to occur, the ink particles must come into contact with the collector chemicals, which in turn must come into contact with the air bubbles so that the ink agglomerates can be removed. The formulation of the collector chemical helps to adjust the surface tension of the air bubble to achieve this. One of the early downfalls of surfactants used for collector chemicals is that too high a portion was carried over and began to build up into the backwater causing either too great or insufficient foam stability. Different types of collector chemicals are available. They are fatty acids, soaps, semi-synthetic and synthetic collectors.

Fatty acids have been successfully implemented in the paper recycling as a de-inking flotation collector. Fatty acids alone are ineffective in improving the attractive forces between bubble and hydrophobic ink particles. Fatty acids are primarily blends of 16 -18 cabon atom chains such as stearic, oleic, linolenic acid etc. The increase of double bonds in the carbon chain promotes ink detachment. One feature of the use of soap is that its Ca salt form is well known as a defoamer. In addition to this, it also gives brighter stock. Originally, soap was created in-situ by running fatty acid into the pulper where it was saponified by sodium hydroxide present. In deinking plant, soap is added to the pulper or to the flotation cell. To function as deinking chemical, calcium ions must be present in the water. Calcium soap salt improves deinking by adhering to the ink particle surface in some way. This action can give the ink particle a waxy coating which will increase its adherence to the air bubbles. Chemicals that collect ink into greater particles while simultaneously giving these agglomerates a hydrophobic surface are collectors.

Pelach et al. (111) have reported that soap is an anionic surfactant that consists of a long hydrocarbon chain to which a water-soluble (hydrophilic) group attaches. The water-soluble group tries to orient itself toward water. The

hydrocarbon group is water insoluble (hydrophobic) and tries to orient away from water. The sodium soaps of fatty acids are water-soluble. Soaps working as collector chemical in flotation deinking are shown in figure 2.8.

2.5 DEINKING PROCESS

According to *Marchildon et al. (91)* deinking has improved since the description of the first patent by *Koops* in 1800 *(40)*. In the 1960s and in the 1970s, there were many installations and deinking by notation was studied seriously. Many researchers *(22,56,77,88)* have worked mostly on the economical and environmental problems involved with the use of such a flotation deinking process. De-inking efficiency depends in part upon the particle size of the solid ink and the ink agglomerates to be removed.

Many researchers (20,35,45,48,64,90,102) have reported in their studies that conventional deinking is necessary for large-scale secondary fiber utilization. Deinking is the process of removing ink and other contaminants from printed-paper. Inks are separated from the pulp suspension by flotation. When the printed papers are repulped, ink is broken down into particles with a wide size range, which are suspended in the pulping liquid. Deinking is the separation of these particles from fibers, ideally with no loss of useful fibers. For the detachment of ink particles from the fibers, the presence of shearing forces is necessary. The purpose of deinking is to remove printing inks and other substances that might affect the papermaking process or final properties of paper. Deinking process was studied in two stages – first defiberization at high temperature and with suitable chemicals in hydropulper (Pulping), and then removal of separated ink as foam in a flotation cell (Flotation).

2.5.1 Pulping Operation

In the pulping operation, the ink particles are detached from the fibers using thermo chem-mechanical action with the presence of chemicals in the pulper. The first stage in the deinking process is referred as pulping or repulping. The secondary fiber is defibrated and the ink is removed from the fibers and dispersed. Pulping is critical operation in deinking because in this stage, ink is removed from fiber and the particle size is controlled. A pulper is operated under alkaline conditions (pH 9 -11) and at low temperature (45 – 75 °C). Pulping may be achieved by batch or continuous methods. Chemicals are normally added to the pulper just prior to the addition of furnish. Chemicals are added to help destroy the ink's binding agent and promote the swelling of the fibers, which creates a shearing action at the ink-fiber interface. The strong agitation in the pulper creates friction between fibers and generates hydrodynamic forces, both of which promote separation of ink particles from the fiber surface. Once the ink particles have been separated, they are coated and stabilized by the surfactant.

Lassus (80) have indicated that when ink particles have detached from the fibers and dispersed into the aqueous phase, a risk exists that they will redeposit on the fiber surfaces if the colloidal stability of the ink particles is not sufficiently high.

Bennington et al. (21) have stated that pulping can be broken down into two basic modes, batch pulping and continuous. Our experiments are conducted in batch pulping mode. In batch pulping, the device is loaded with a given amount of raw material and chemicals determined by weight, and the appropriate amount of water is added giving a predetermined pulping consistency. The mixture is blended for a predetermined length of time and processing conditions, or to a degree of defibering. When completed the pulped slurry is discharged from the pulper to flotation cell.

Pulping in our experiments is carried out in low consistency operational range. In low consistency pulping, mechanical defibering forces are high. With high rotor speed and pulp at a relatively low viscosity, mechanical forces tear papers and contaminants such plastics etc. Shear forces are created when the two ends of paper are caught in stock flows moving in different directions. The flow pattern creates a vortex around the rotor and baffles are used to improve mixing.

Holik (64) and Bennington (20) have described that pulping operation primarily comprises the following processes:

- Feed the system with a pre-determined rate
- Break down of the raw material into individual fibers
- Removal of solid contaminants such as foils, stickies, and printing ink from the fibers.
- Mixing of process chemicals into the suspension such as deinking chemicals.

Carre et al. (33) have reported in their work that in deinking process various kinds of devices could be used; machinery suppliers propose low consistency pulpers, medium consistency pulpers, high consistency pulpers and drums. The choice of the type of pulper has to be made by considering various parameters including the efficiency of defiberizing and energy consumption but mainly with respect to:

- Defibering kinetics
- Minimizing the breaking up of contaminants in order to improve their removal efficiency. Due to this requirement deflakers are no longer in use in deinking plants.
- Efficient ink detachment

2.5.2 Flotation Operation

In the flotation operation, the ink particles detached from fibers are removed from the pulp suspension by froth flotation. The flotation cell operations are greatly affected by the operating conditions; chemicals used and type of raw material. Flotation deinking is preferred over the washing process as it provides a high deinking efficiency and a high yield of fibers at low water consumption. The chemistry and theory of flotation deinking is well covered in the given literatures *(11,13,19,24,25,26,27,28,43,44, 47,48,49,52,53,59,65,72,77,78,79,96,108,112,121,123,129,132,133,138,135,142).*

Flotation deinking is a selective separation process that utilizes air to separate ink particles from a properly slushed pulp suspension. As the air bubbles rise through the flotation cell, ink particles become attached to the bubbles and are carried to the surface of the cell by trapping them in a froth layer. Flotation chemicals are added to the pulp to make the ink particles hydrophobic and increase the probability of flotation. Inky foam forms on the surface of the cell and is removed, while the fiber remains in the pulp and is accepted. In flotation deinking, once the ink has been separated from the fiber surface, the surfactant is deposited on the surface of the ink particles. Surfactants react to allow the small ink particles to agglomerate and form larger particles that can more easily latch onto gas bubbles raising from the bottom of the vessel. The ink-laden bubbles rise to the surface, where they create black foam that is raked off and separated from the suspension.

The flaky shape and the smooth surface of the ink particles slow down the process of ink collection by air bubbles in the flotation cell. The separation of ink particles from pulp is further complicated by the low inertia of ink particles caused by their low density, small sizes, low concentration of particles in the pulp, high viscosity of pulp, and the formation of a complex net of cellulose fibers that reduces the rising velocity for gas bubbles and entraps the ink particles. Therefore, it is still not

uncommon to test new chemicals and technological alternatives in an attempt to improve the flotation process, and our work is in this direction only. The equipment and the process of flotation deinking are shown in the figures 2.9 and 2.10.

Many researchers (38,72,104,112,122,135) reported in their studies that flotation deinking was first used well before the 1950s, but it was not until then that the practice began to gain wider acceptance in the paper processing industry. Flotation deinking is based on technology borrowed from the mineral processing industry in the 1960s. Flotation deinking has been used in paper recycling since the 1980's to remove contaminants such as waxes, stickies, and inks.

Sengupta et al. (126), have indicated that flo tation technique is generally used for removal of ink particles and more than 65% of the industrial practices for deinking use flotation process.

During the last ten years, the technology of flotation deinking cells probably been developed more aggressively than any other segment of the pulp and paper industry. Many competitive designs are now available. However, older flotation cells are also operating successfully in many modern deinking mills, so it is worthwhile to examine the history of this technology.

McCool (96) have stated that in the earlier 1950's, the Denver cell, originally designed for mineral flotation, was first used for the flotation of ink particles. The Denver cell is a rectangular tank containing a central agitator. The agitator is located within a shaft, and the impeller is close to a dispersing ring at the bottom of the tank. When the agitator is turned on, air is drawn down the shaft and is dispersed through the stock. The ink particles collide with the air bubbles and are carried to the surface and removed as inky foam by paddles.

There has been considerable development in flotation units for deinking, from

the Denver cell initially used, with many modifications and new designs. In the period 1972 – 1993 there were many changes with at least ten equipment suppliers offering flotation systems. Our flotation experiments are carried out in Lamort type flotation cell, which is also on the same principle as the Denver Model.

Ortner (103) reported in their study that, flotation cell which were originally used in the mid 1970s, produce a brightness increase of 10 – 12 units, whereas redesigned cells, which were installed in the late 1980s, give an increase of 12 – 14 units using similar wastepaper grades (newprint and magazines).

In flotation deinking, the variables that affect ink removal include consistency; flotation time, yield, type and size distribution of inks present; mineral filler type and concentration; and the presence and concentration of ink collection chemicals.

J. Saint (65) has indicated that the flotation process can be influenced by the variance of physical chemical and hydrodynamic factors. Physical variables include ink particle size and density, slurry stock concentration and temperature. Chemical variables include water quality, slurry, pH and surface tension values governed by flotation chemical agents such as frothers and collectors. Hydrodynamic factors include the flow patterns of air bubbles and the slurry in the flotation cell.

Catsburg (34) has stated that, consistency is the most important parameter in controlling the efficiency of a flotation cell. A clear breaking point can be observed at a fiber consistency of approximately 1.1% for both the stock loss and the ink removal.

According to *Vidoui et al. (139)* in the flotation process as consistency increases the drag on the air / ink complex increases, since the fibers form a network. This reduces the rise velocity and in addition collisions with fiber may dislodge ink particles, especially if these are large. The optimal consistency varies with the design of individual units, but is usually in the range 0.8 – 1.2%. Air is

introduced into a diluted fiber suspension of 0.8 – 1.2% consistency. The water repelling ink particles attach to the air bubbles and rise to the surface. We have also carried out experiments at around 1% consistency.

J. Saint et al. (67) and Johansson et al. (70,71) reported in their studies that the pH is another important flotation parameter. There was a clear maximum flotation yield between pH 7 and 11, the reason being that agglomeration is favored by a high pH while the contact between air bubbles and the ink agglomerates is favored by a low pH.

Several authors (2,17,57,86) have indicated in their work that deinking plants producing recycled pulp for newspaper manufacture may experience significant loss of pulp brightness when the waste paper furnish contains aged offset inks or flexographic inks. Poor flotation efficiency has traditionally been blamed for this loss. However, there is growing evidence to show the irreversible ink redeposition during repulping.

2.5.2.1 Flotation Mechanism

Beneventi et al. (19) and Santos et al. (120) have stated that in flotation deinking, several models have been proposed to explain how ink particles agglomerate and attach to the air bubbles. A review by Carre identified six proposed models for flotation deinking. These models are attributed to' Schweizer, Bechstein, Ortner, Homfeck, Larsson and Putz. Five of the mechanisms discussed by Carre and Beneventi rely upon the precipitation of soaps to explain the mechanism of flotation deinking, while one (Putz) considers surfactant adsorption as the critical phenomenon.

Olson et al. (102), Larsson et al. (78) and Iiphard et al. (83) have reported in their studies that two of the most important features for particle flotation are their size

and the hydrophobicity of the particle surface. They influence the major sub-process which determine the rate of flotation and the recovery of fillers in different ways:

- The collision between air bubbles and particles;
- The drainage and rupture of the remaining thin water film between bubble and particle;
- The stability of the bubble/particle aggregate.

The particle size particularly influences the first sub-process, i.e. the collision between the particles and the air bubbles. Parallels can be drawn to the aggregation process of particles in dispersion. Here the collision between particles is also a prerequisite for the aggregation. The aggregation process is determined by several different interactions between the particles caused by internal and external forces.

Sridhar et al. (130) and J. Saint (65) have described that the principles of flotation and deinking are similar to those of conventional mineral flotation, where in the particles to be removed are naturally hydrophobic or are rendered hydrophobic by the adsorption of molecule of surfactant surface-active reagents (surfactants) on their surfaces.

Putz et al. (115) and Shrinath et al. (128) reported in their studies that air bubbles could only be attached to nonpolar particles because they show a non-polar character. It has to be taken into account that the interaction between air bubbles and ink particles take place in water, a polaric medium. At the surface between particles and water as well as between fibers and water, there is surface tension.

For flotation to be effective, the size of the ink particles must be maintained within an optimum range. The particles also must be water-repellent. Particles that are too small are not efficiently collected because of the low probability of encountering an air bubble; very large particles are likely to be too bulky to be successfully carried to the surface by the bubbles. Water-repellent particles are more

easily separated from the aqueous phase and carried to the surface by air bubbles. This mechanism is illustrated in figure 2.11.

Turvey (138) have indicated that the exception of water based inks; ink particles are more hydrophobic than paper fibers, which is the basis of separation by flotation. However, some fibers can be hydrophobic and hydrophilic.

Galland et al. (55) have reported that in the flotation deinking process are primarily involved in the removal of small ink particles for improving brightness, but particles in the visible range such as those produced by laser print and varnished papers are also eliminated by flotation.

According to *J. Saint et al. (66)* considering the flotation mechanisms of particle-bubble collision; attachment and detachment, a consistency increase is assumed to increase the detachment probability of the large particles in relation to the turbulence level and bubble size distribution and to have almost no effect on small particles integrated in the bubble surface.

Serres (127) and Bender et al. (18) have reported in their studies about a patented process for deinking paper to optimize the flow of air bubbles introduced into the pulp slurry. Mixed papers are slushed by stirring, screened to remove foreign materials such as staples, and finally floated to remove inks, fines, and fillers. The flotation stage is based upon a stream of air bubbles re-circulated through the pulp. Ink particles are carried along on the bubbles. A countercurrent flow of water also is re-circulated and eventually carries away ink-laden bubbles, separating the clean fibers and fillers. The combinations of low and high-intensity flotation stages offer to improve the removal of stickies and ink particles during recycling.

An awarded patent for removing wax from fiber used for papermaking may facilitate the reclamation of this fiber source. *Cao et al. (31)* have found that wax

could be removed effectively by froth flotation at low consistency alkaline repulping and screening.

Johansson et al. (69) and Schmidt et al. (121) have reported that some ink particles remain as primary particles throughout the entire deinking process. These ink particles are not removed because they are, too small to float without being agglomerated.

2.5.2.2 Role of Ink Particle Size in Deinking

Many researchers *(33,45,51,64,67,69,75,77,91,95,96,97,102,106,109,128)* have indicated that the ink particle size is important in determining ink removal efficiency by flotation cell. Different literature sources provide information about the optimum particle size of the various processes. Types of ink and the size of the ink particles to be removed is the primary basis for choosing the appropriate deinking equipment and chemicals. Flotation removes particles that are too small to be removed by screens and cleaners and yet are too big to remove by washing. Strategies for efficient deinking must therefore include an evaluation of both the chemicals and the equipment involved.

Results presented by McCool in 1987 show that each technique (including washing and flotation) is efficient for the removal of contaminants in a defined size range (figure 2.12). Washing efficiency is best at a range of 1–10μm (micron meter). Flotation efficiency is high through the next range of 10 –150μm. Cleaning equipment works best at 100 –1,000μm and screening at 1,000μm and above. As normally the printing ink particles can be easily agglomerated (50 – 150μm) during pulping operation by the addition of proper chemicals, their removal is easier by flotation method. In the offset printing, the ink particle size is in between 2 to 100μm and larger ink particles (>50μm) may not go out during flotation while small size (<10μm) is not preferred for flotation.

Borchardt (27), Beneventi et al. (19) and Azevedo et al. (7) have reported in their studies that in the flotation process, if the particle size is too small, the particle's inertia is negligible and it tends to follow streamlines around the air bubble. This leads to a smaller probability of collision with an air bubble and therefore the particle has less of a chance to be captured.

Pundir et al. (113) have indicated in their work that in the flotation deinking operation, sequence involves the agglomeration of small ink particles. Very small particles (<10μm) tend to diffuse into the fibers resulting in a gray finished sheet. Ink, which is not properly broken up during pulping, may produce particles greater than 200μm, which are too large to be removed efficiently by flotation.

Lassus (80) have stated that originally, the basic size of ink particles (carbon black and pigments) was 0.02 – 0.1μm. Water-based flexographic printing ink agglomerates are 1 – 5μm. Offset printing ink agglomerates can be up to about 100μm.

Doshi et al.(41,42) have reported in their studies the chemistry that promote agglomeration of ink particles and / or reinforce changes in the shape of ink particles and have indicated that the newsprint, writing and office papers, and tissue are made from de-inked recycled paper.

Economides et al. (45) have indicated that the laboratory methods commonly used to study flotation deinking are usually models of mill operations. Deinking effectiveness is evaluated on the basis of paper ISO brightness and effective residual ink concentration (ERIC values). While such tests are useful for studying the effects of deinking process variables, they provide little insight into the detailed nature of the physical and chemical events occurring during the deinking process.

2.6 ERIC (Effective Residual Ink Concentration)

Different researchers (13,73,96,105) have reported in their studies that ERIC values have been determined for repulper pulp and deinked pulp obtained after inked foam removal from flotation cell. The basic purpose of ERIC option is to determine how much residual ink remains in the sample of deinked paper. The unit of ERIC values is in part per million (ppm). This is accomplished by measuring the reflectance's in the infrared region of spectrum (950nm) and manipulating reflectances via Kubelka Munk analysis until the ERIC is computed.

Technibrite™ Micro ERIC 950 from *Technidyne Corporation, New Albany, Indian, USA* fitted with an IR filter uses this principle to provide values of ERIC in sheets of paper. Reflectance measurements of paper sheets at about 950 nano meter (nm) can give a useful measure of ERIC particles in the paper sheet. The concentration of ink particles ERIC also depends on the kind of ink particles, size of the ink particles, the dispersion or agglomeration of the ink and the distribution of the ink in the sheet of paper. In spite of these limitations, ERIC shows a better correlation with ink removal in a deinking operation than the brightness.

2.7 DEINKABILITY FACTORS

Many researchers (5,10,12,13,73,96,105) in their studies have stated that the efficiency of a deinking operation may be defined as the ratio of amount of ink removed by flotation cell, to the amount of ink present in the pulp before deinking by the flotation cell. Deinkability factor based on ERIC values D_E, for any process where ink particles have been removed, is defined as –

$$D_E = \frac{E_P - E_F}{E_P - E_B} \times 100 \quad [\%] \qquad [2.5]$$

D_E = Deinkability factor based on ERIC value, %

E_B = ERIC value in the absence of ink particles (blank)

E_F = ERIC value after flotation deinking

E_P = ERIC value of the sample sheet before ink removal (after pulping)

The ERIC values E_P and E_F were determined for the sheet before and after flotation process. E_B was measured for a hand sheet prepared from the cuttings of the unprinted portion of the waste paper taken for the study and pulped with the same chemical composition used for deinking of printed-paper.

Several researchers (10,12,14,32,74,111) have reported in their studies that the deinking ability of printed-paper depends mainly on three factors: ink formulation, printing conditions and paper surface. Ink composition and printing conditions are important since they strongly influence deinkability. The efficiency of the process has been evaluated by means of brightness measurement as indicated in TAPPI Standard T452. Deinkability factor based on handsheet brightness after pulping and after flotation was used to evaluate process efficiency and establish the optimum pulping and flotation deinking conditions. The ISO Brightness (spectral reflectance factor R_{457}) of the unprinted paper subjected to the same disintegration and flotation conditions is considered as a reference value, B_B. Therefore, global efficiency of the deinking process would be defined by the following deinkability factor based on ISO brightness:

$$D_B = \frac{B_F - B_P}{B_B - B_P} \times 100 \quad [\%] \qquad [2.6]$$

D_B = Deinkability Factor (%) based on ISO brightness.

B_p = brightness after pulping (%ISO)

B_F = brightness after Flotation (%ISO)

B_B = brightness of the sample paper without the presence of ink particles (Blank) (%ISO)

The ISO Brightness B_P and B_F were determined for the sheet before and after flotation process. B_B was measured for a hand sheet prepared from the cuttings of the unprinted portion of the waste paper taken for the study and pulped with the same chemical composition used for deinking of printed-paper.

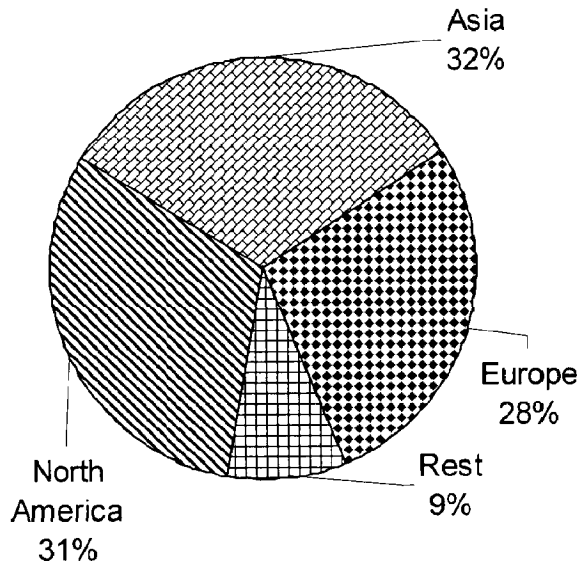


Fig. 2.1 World Paper Production Distribution

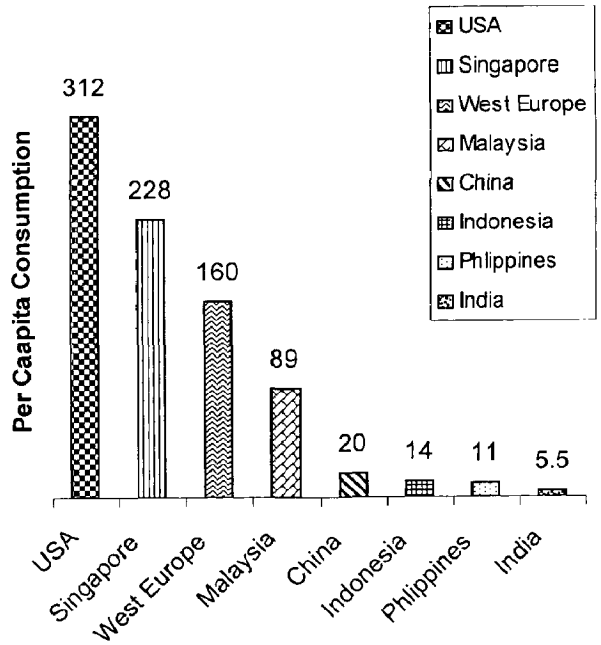


Fig. 2.2 Per Capita Consumption Comparison

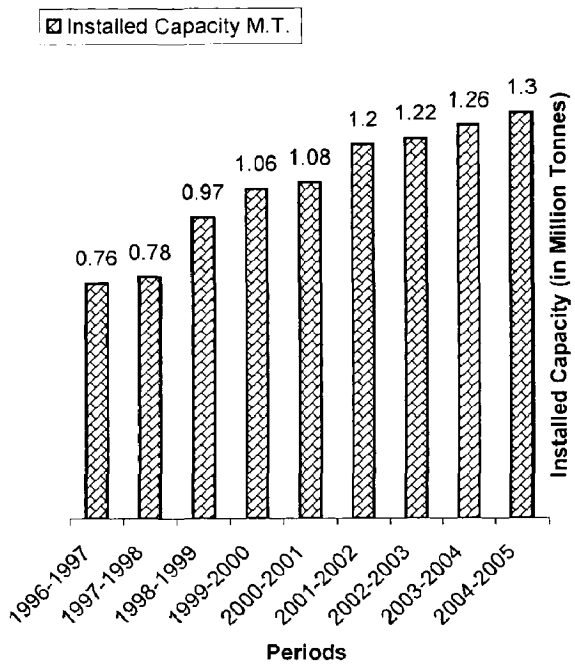


Fig. 2.3 Growth of Newsprint Industry in India

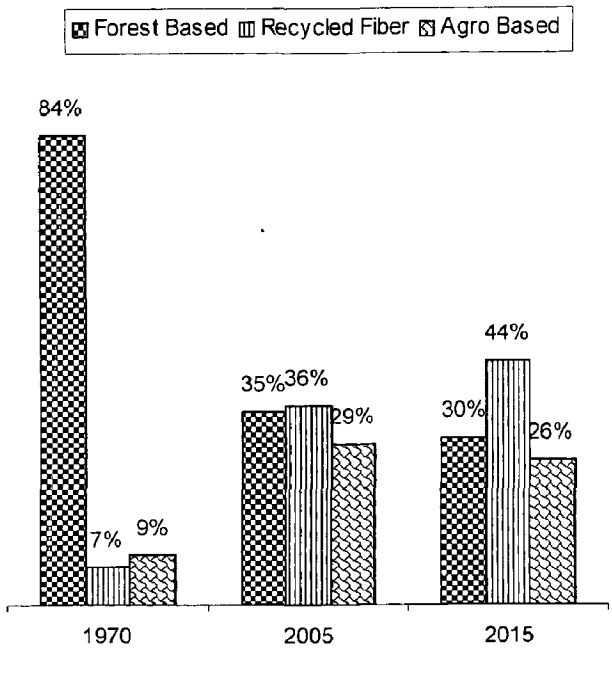


Fig. 2.4 Trends in the use of Raw Materials in India

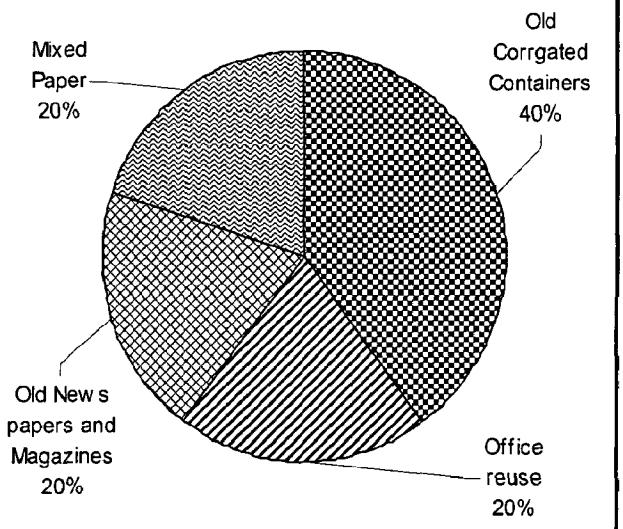


Fig. 2.5 Availability of Waste Paper

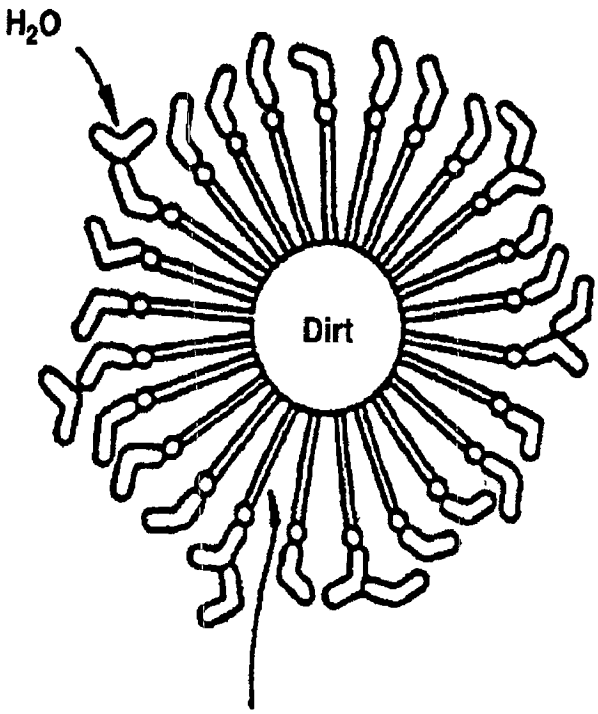


Fig. 2.6 Micelles

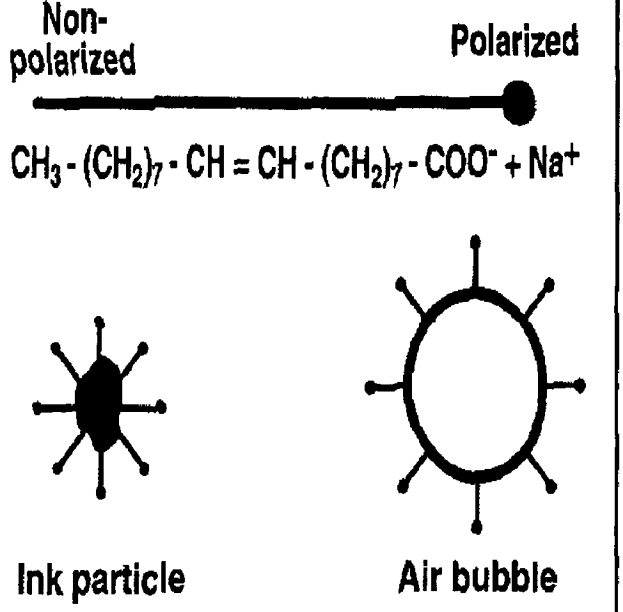


Fig. 2.7 Surfactant as Collector

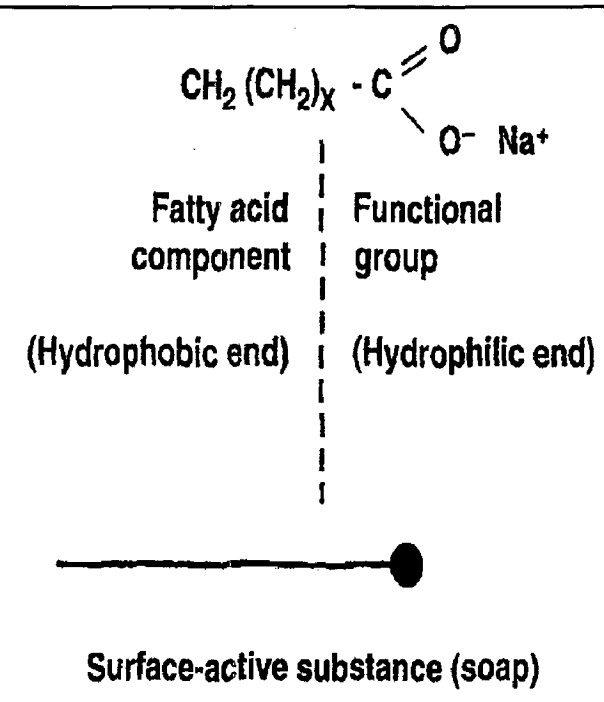


Fig. 2.8 Soap as Collector

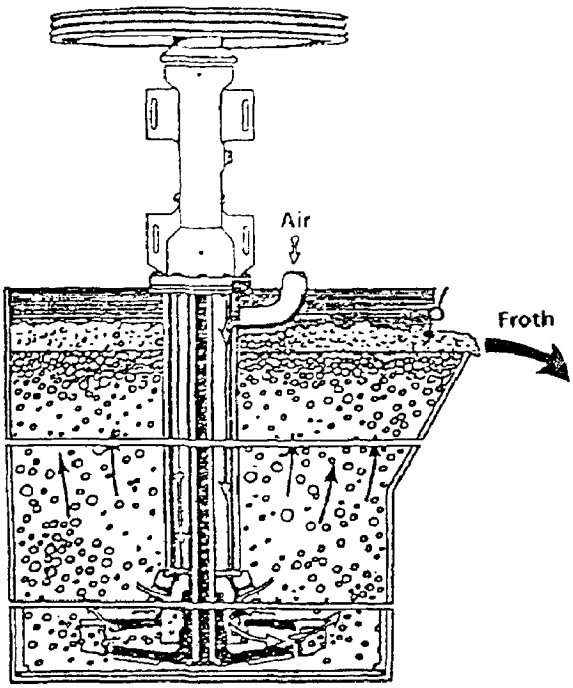


Fig. 2.9. Flotation Cell

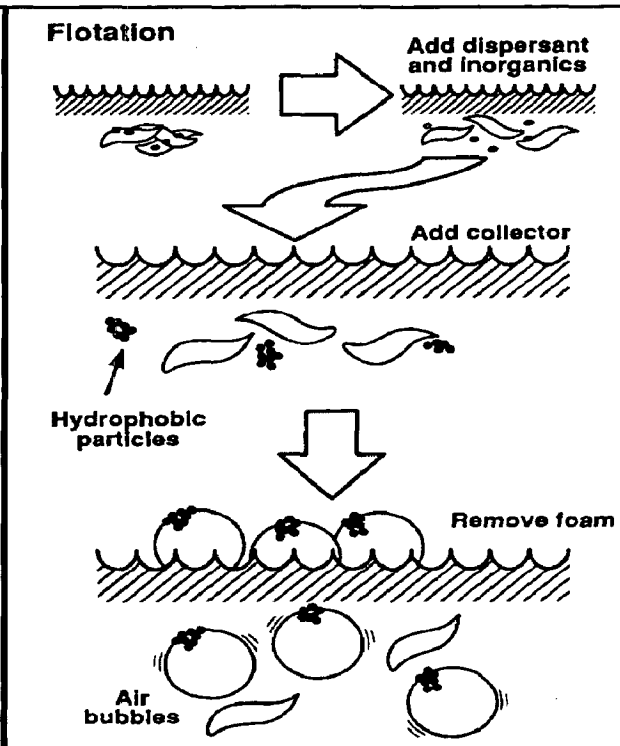


Fig. 2.10 Deinking by Flotation Process

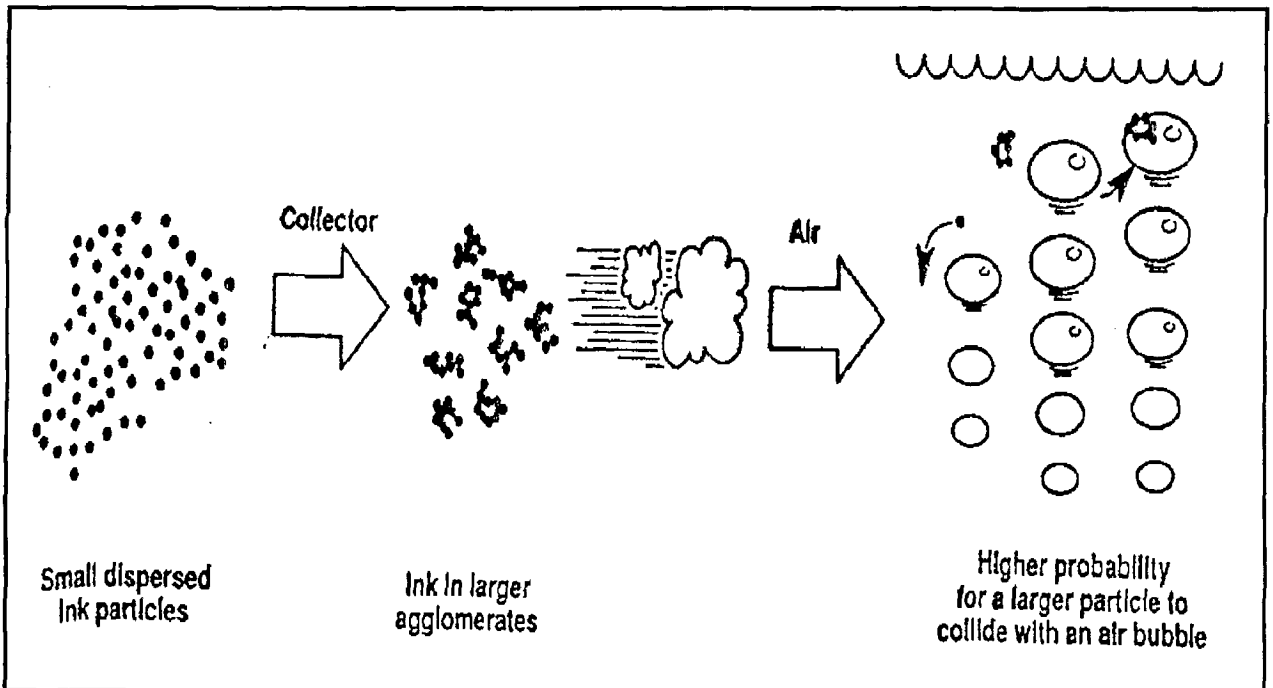


Fig. 2.11 Operating Principle of flotation deinking (128)

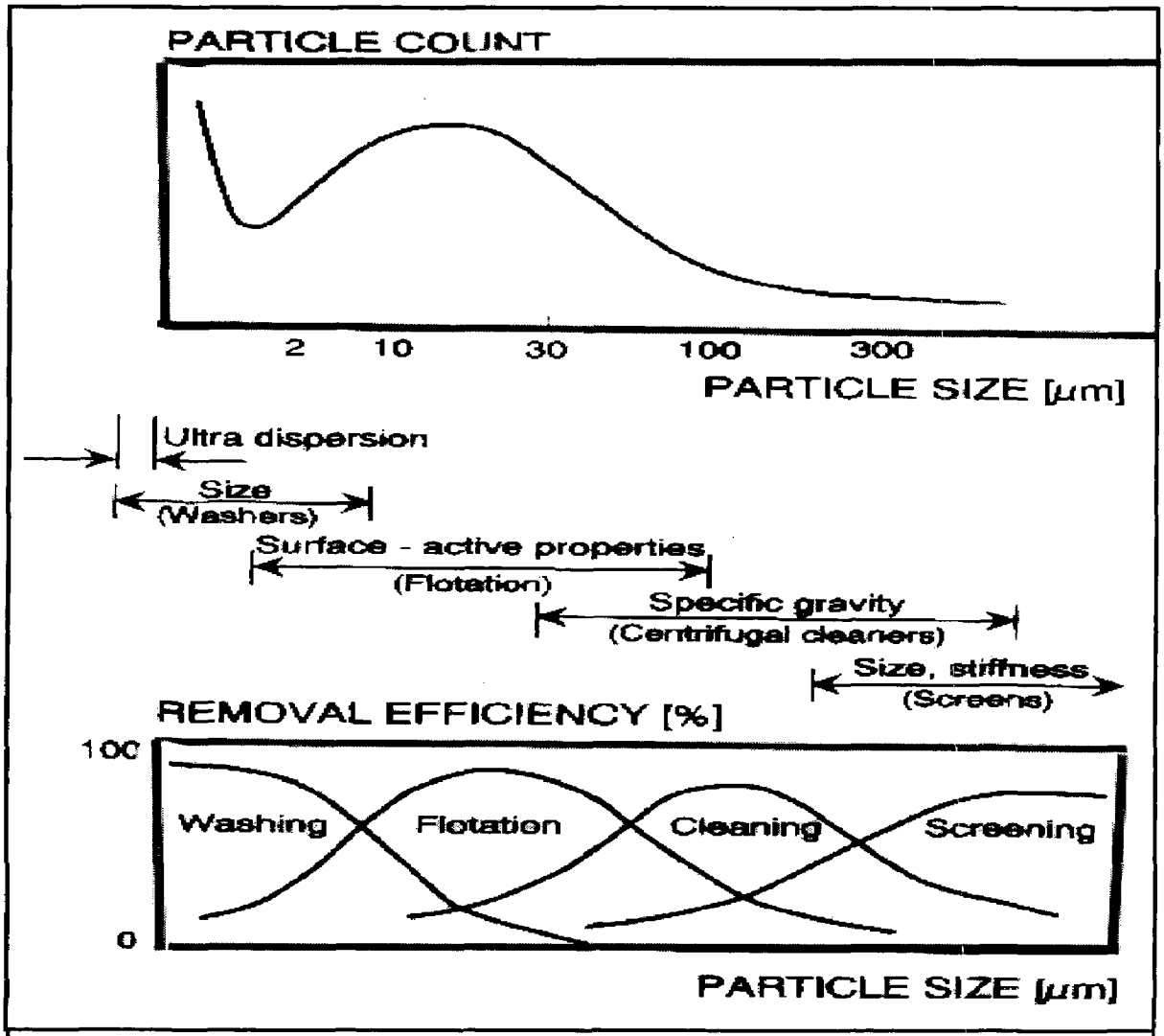


Fig. 2.12 Optimum particle – Size ranges for the various units operations in deinking (Mc. Cool 1987)

Table – 2.1 World and the Indian Paper Industry – A Comparison

	Global	India
Number of Paper and Board Mills	7745	~600
Installed Capacity (Millions Tons)	397	8.9
Production (Millions Tons)	33.8	7.18
Growth Rate	~ 2.8	~6.5

CHAPTER 3

MATERIALS AND METHODS

Chapter 3

MATERIALS AND METHODS

3.1 INTRODUCTION

The use of deinked fibers has increased substantially over the years for the manufacture of good quality newsprints and other grades of papers. Today, it is well established that old newsprints (ONP) and old magazines (OMG) can be deinked economically and used in the manufacture of new newsprints.

In deinking process, the pulping and flotation cell operations are greatly affected by the operating conditions, chemicals used and type of raw materials. These experiments were performed to consider the effects of operating variables and deinking chemicals on the blending of offset printed ONP with other recycled papers (OMG), on the quality of deinked pulp.

In the studies of ONP, OMG and their blends, different operating conditions (pulping temperature, pulping consistency, pulping time, flotation time) and dosages of deinking chemicals are used, to highlight the importance of related operating parameters. The effects on optical properties [ISO brightness, Effective Residual Ink Concentration (ERIC) values] and other strength properties have been estimated due to the changes in operating conditions and dosages of deinking chemicals, to a reasonable extent. In the optical properties, ERIC values and ISO brightness are used for estimating the Deinkability factors. Mathematical polynomial regression programme has been applied in the deinking process to predict the quality of the resulting pulp in terms of the process variables and to determine the coefficients for a degree of polynomial equation to develop the model to predict the Deinkability factors, D_B and D_E.

3.2 EXPERIMENTAL METHODOLOGY

3.2.1 Selection of Raw Materials

Several authors *(5,23,29,30,60,61,81,87,92,98,99,102,107,114,128)* have shown the significance of offset printed ONP and OMG as economic raw materials.

On the basis of these review studies of different authors, we have selected a combination of offset printed ONP and OMG as raw materials in these experiments. ONP is taken from batches of recently printed offset newspapers (eg. *The Indian Express, Hindustan Times and The Times of India)* and the age of this ONP was upto 6 months. OMG maplitho paper is also used for this study. A selection of uncoated OMG (*IPPTA Journal)* used for the study and its ash content is around 10%, another highly coated magazines (eg. *India Today, Business Today)* were taken as representative of coated OMG with high ash content of about 15%, and again the age of the magazines was upto 6 months. The moisture content of the air dry paper furnishes (ONP&OMG) was around 8 % approximately. The ash content of the magazine paper was estimated as per TAPPI method No. T 211 om – 93.

3.2.2 Fiber Analysis of Raw Materials

The fiber distribution of the ONP and OMG raw materials was determined by quantitative fiber analysis by Indian Standard IS: 5285 – 1969 (Methods of Tests for Fiber Analysis of Paper and Board). The fiber analysis of the ONP had shown that it contained blends of softwood chemical and mechanical fiber with some hardwood chemical fiber. The experimental data for fiber analysis is shown in the Table. 1 of the Appendix. ONP (eg. *The Indian Express, Hindustan Times and The Times of India)* samples consisted of approximately 30 % chemical pulp, 70 % mechanical pulp, and the coated OMG (eg. *India Today, Business Today)* sample contained

around 75% mechanical pulp and 25% chemical pulp and the uncoated OMG (*IPPTA Journal)* contained 100 % chemical pulp.

3.2.3 Flotation Deinking Chemicals

In experiments of flotation deinking operation, the deinking chemicals are laboratory makes and the quantities of the chemicals charged in the deinking formulations were calculated as a percentage of the oven dry weight of paper fed to the pulper. Sodium hydroxide (minimum assay 97%) and Hydrogen peroxide (minimum assay 59%) were from Qualigens Fine Chemicals, Mumbai (India). Sodium silicate (minimum assay 18.7 – 23.4%) and DTPA (Diethylene Triamine Penta Acetic Acid) Chelating agents (minimum assay 98%) were from Thomas Baker Chemicals Ltd. Mumbai (India). The active deinking surfactants employed were Stearic acid and Palmitic acid (minimum assay 99 – 101%) from Central Drug House (P) Ltd. New Delhi (India), Oleic acid (minimum assay 65 – 70%) S. D. Fine-Chemicals Ltd, Mumbai (India), Brij-35 (Polyoxy ethylene lauryl ether), Triton x 100 (Iso – octyl Phenoxy Polyethoxy Ethanol), Tween 80 (Polyoxyethylene sorbittan mono-oleate) from Loba chemie. (P). Ltd. Mumbai (India) and Flotation DI from Anmol Polymers (P). Ltd. Delhi (India).

3.2.4 Raw Material Preparation for Pulping

Waste papers (ONP, OMG separate and their combinations depended upon the requirement of experiments) used in different experiments were individually cut into 6 – 8 centimeter squares for the preparation of pulp. When OMG was used in experiments, all staples and glue were removed before pulping process. In all the experiments, pulping in hydropulper was carried out using 500 gram (g) air-dry mass at various consistencies from 2% to 8% depending upon the plan of experimental pulping conditions, with approximately 8% moisture content depending upon the whether conditions.

3.2.5 Experimental Plan

The experimental plan of the flotation deinking experiments is shown schematically in figure 3.1. Many researchers *(3,20,35,45,48,64,72,90,102,110,131)* have studied the flotation deinking process in two stages – In first stage pulping at high temperature and other process variables with suitable deinking chemicals in hydropulper, and in the second stage flotation deinking for removal of separated ink as foam in a flotation cell. After completing both the operations of pulping and flotation deinking, formation of handsheets / pads from both the pulps was carried out with, standard pressing, and drying of sheets to measure the paper properties.

3.2.5.1 Pulping Stage

In the first stage, the repulping experiments were carried out in a 35-litre capacity laboratory helico pulper supplied by Universal Engineering Corporation, Saharanpur. It has provision for controlling rotor speed and temperature, at varying conditions. The lower part of the vane is fitted with teeth to tear difficult material such as wet strength paper. It was adapted to operate at rotor speeds ranging from 0 to 650 rotations per minutes (rpm).

Ferguson (48) have reported that pulper as the "brain" of the system, If the pulper does not work properly, or if the chemistry of the chemicals added is unbalanced, the batch has little chance of success. The pulper has provisions for supplying heat to obtain and maintain the desired temperature at the desired mixing speed and consistency. Wastepaper was torn and added to the pulping solution when the required temperature and other process variables were maintained constant. Pulping Variables such as temperature, consistency, rotor speed and pH have a significant effect on both the speed of wetting and defibering as well as on ink and other contaminants dispersion. Chemicals dosages used in pulping operation: sodium

hydroxide 2.0%, sodium silicate 2.5%, hydrogen peroxide 1%, DTPA 0.5%, were maintained constant for all the experiments on the basis of different authors reviews *(32,48,50,91,93,102,105,111,118,128).*

Only different Fatty acids / surfactants / collectors were varied in the experiments, and they are added in the hydropulper at the desired pulping conditions, prior to the addition of the waste paper. All chemical dosages used in these experiments were based on oven dry paper basis. After all the paper had been added to the pulper, the rotor speed of hydropulper was increased and was maintained at 650rpm, to get the desired mixing conditions. Pulping was carried out using 500g air-dry masses at different varying operating pulping conditions that are:

- Pulping time variation from 5 minutes to 18 minutes
- Temperature variation range from 40 ^{0}C to 75 ^{0}C
- Pulp consistency variation range from 2% to 8%
- Chemical dosages variation of different fatty acids / surfactants / collectors

After the pulping process is complete, then the slurry from the hydropulper was sent to the second stage of flotation deinking.

3.2.5.2 Flotation Stage

In the flotation stage, the deinking experiments were performed in a Lamort type laboratory flotation cell supplied by Universal Engineering Corporation, Saharanpur. Its 15-litre capacity flotation cell has a provision for controlling agitation speed at varying conditions. In flotation process, about 100g oven dry pulp of the repulped stock from the hydropulper, was diluted to 1% consistency. 1% consistency has been reported as optimum after carrying out runs between 0.8% to 1.2% by different researchers *(3,32,34,87,93,110,139).*

About 10 litre-diluted stock is then sent in the batch flotation cell. The agitation speed was fixed at 1400 rpm. The reason for taking a reasonably high

agitation speed was that the air was sucked in through the tube and air bubbles went out through the annular holes from the nozzle plate in the bottom of this tube, as reported by *Bansal et al. (11)* in their study.

Ferguson (51) has reported in their study that the flow of the air is proportional to the speed and thus adequate flow rate was maintained for good flotation. Proper ink particle size and air bubble ratio is important for good flotation. *Szatkowki et al. (133)* have proposed that the optimum bubble size is approximately five times the size of ink particle to be removed. *Carrasco et al. (32)* have indicated in their study that deinking factor increased with increased agitation speed of rotor in flotation deinking.

Many researchers (29,32,69,87,93) reported in their studies that adequate flotation time should be provided so that the foam had sufficient time to float out. Flotation time variation from 2 minutes to 16 minutes was also studied to get optimum flotation time for flotation deinking.

In both pulping and flotation stages, tap water was used as it contains certain salts of Calcium and Magnesium which help in flotation process, as reported by Kanhekar *et al. (74)*.

3.2.6 Handsheets Preparation and Testing

The optical properties were measured for handsheets with a basis weight of around 60g/m^2, prepared before and after flotation on British Standard Handsheet Former according to TAPPI Standard method T-205. Brightness measured on both sides of the sheet, is reported as an average of the two. It is possible that some of the smaller size ink particles, which have been separated from the pulp, but have not agglomerated, may leave with the drained water during hand - sheet formation.

ISO Brightness and ERIC values have been measured by using standard TAPPI methods namely T – 452 om – 98 and T – 567 pm 97 respectively by using the instrument named Technibrite ERIC 950, Technidyne Corporation, New Albany, New York, USA as reported in the studies of *Ben et al. (16), Jordan et al. (73).*

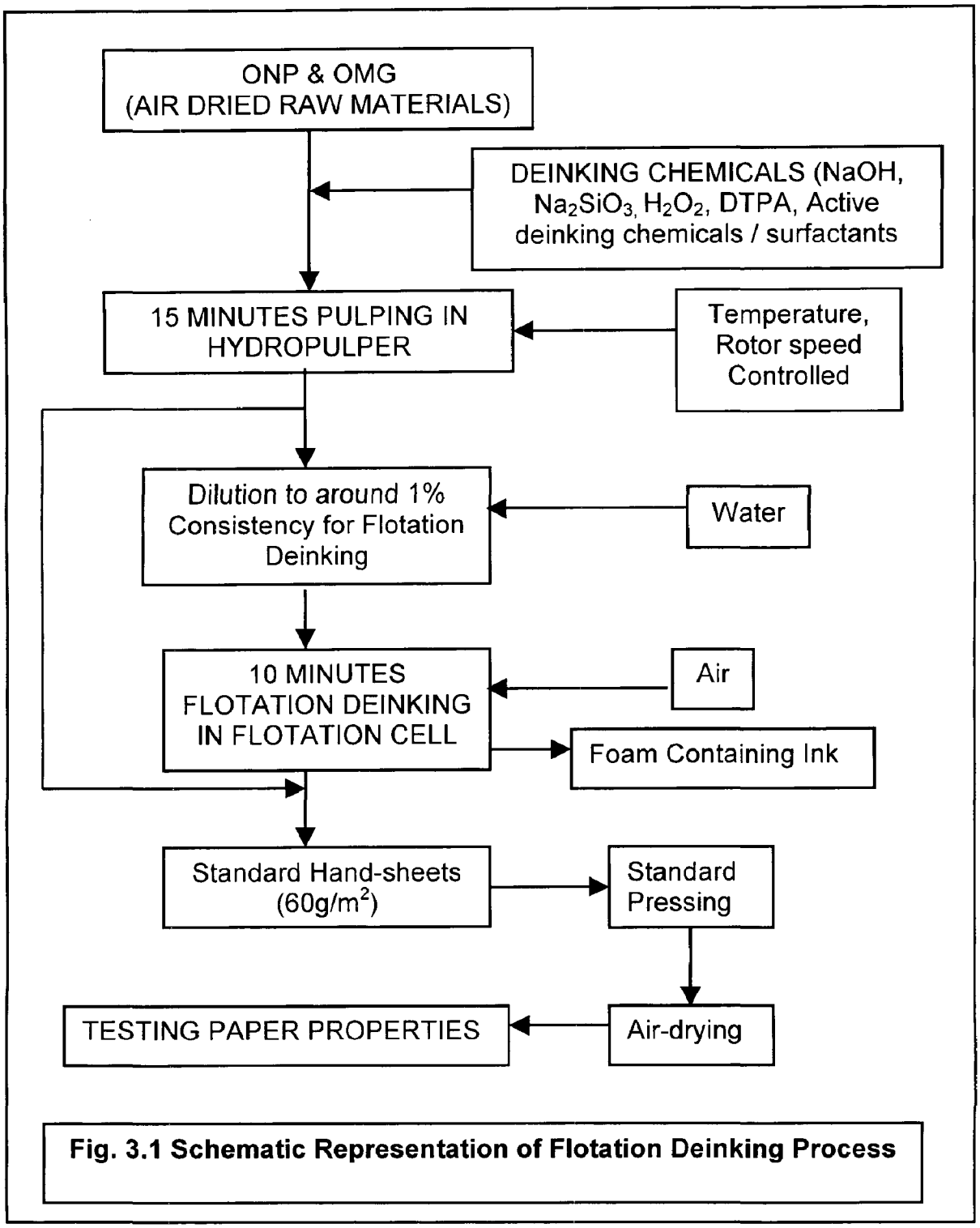


Fig. 3.1 Schematic Representation of Flotation Deinking Process

CHAPTER 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The experimental results for all the raw materials separately and in combination, for varying operating / processing conditions are being discussed in this chapter. The experimental data, with the help of mathematical program, is used to calculate the coefficients for a degree of polynomial equations. A comparison is carried out between the experimental and predicted deinkability factors on the basis of ISO brightness and ERIC values. As the pulping experiments are extremum type, no two sets can be identical therefore average of the three/ four sets of data are used only. In the present investigations data obtained from the laboratory experiments for specific set of input parameters such as temperature, consistency, process time and various chemical dosages variations of different fatty acids and surfactants etc. are presented.

4.1 DEINKING MODEL EQUATION DEVELOPMENT FOR FLOTATION DEINKING

Compaq Visual FORTRAN version 6.5 has been applied for mathematical polynomial regression analysis, and statistical modeling in the deinking process to predict the Deinkability factor D_B on the basis of ISO brightness and D_E on the basis of ERIC value with least regression error.

The experiments were performed for various process variables, namely temperature, consistency, pulping time, flotation time and active deinking chemical dosages of different fatty acids and surfactants used in flotation deinking, for estimating the deinkability factors D_B and D_E. Mathematical polynomial regression analysis was applied to the experimental data by converting the process variables in dimensionless parameters. The effects of dimensionless temperature, consistency, pulping / flotation time and active deinking chemical dosages in the pulper were

studied to predict the quality of the resulting pulp. The polynomial equation of the desired degree with least regression error was obtained to estimate the deinkability factors. A comparison is carried out between the experimental and predicted deinkability factors to show the advantage of the proposed deinkability model. This assumed general n^{th} order polynomial equation for the prediction by the deinkability factors D_B and D_E is as given below:

$$\ln D_B = a_0+a_1x+a_2x^2+a_3x^3+a_4x^4+a_5x^5+a_6x^6+\ldots\ldots\ldots\ldots a_nx^n \quad [4.1]$$

$$\ln D_E = a_0+a_1x+a_2x^2+a_3x^3+a_4x^4+a_5x^5+a_6x^6+\ldots\ldots\ldots\ldots a_nx^n \quad [4.2]$$

Where D_B = Deinkability Factor based on ISO Brightness

D_E = Deinkability Factor based on ERIC values

a_0, a_1.... a_n are empirical coefficients from the corresponding equations.

x = Dimensionless process variables such as Temperature, Consistency, Pulping / Flotation Time, Active Deinking Chemical Dosages as used in the respective equations. The dimensionless process variables (x) used in the above equations are as below:

T = Temperature ^0C

T_A = Average temperature of the runs conducted ^0C

x_1 = Dimensionless temperature is defined as [(T+273)/ (T_A+273)]

x_2 = Dimensionless consistency is defined as [consistency % in the pulper (g/ 100g oven dry fibers) / average consistency of the runs]

x_3 = Dimensionless dosage of active deinking chemicals is defined as [active deinking chemical dosage % in the pulper (g/100g Oven dry fibers) / average of active deinking chemical dosage of the runs]

x_4 = Dimensionless time is defined as [Time used in the pulping or flotation (minutes) / average of time of the runs(minutes)]

Thus all the models have been developed for the ln D_B or ln D_E Vs. x parameters.

4.2 EVALUATION OF OPTIMUM CONDITIONS FOR FLOTATION DEINKING OF UNCOATED ONP

For uncoated ONP, the experimental process conditions are pulping temperatures, pulping consistency, pulping time, Dosages of Active deinking chemicals in pulper and flotation time, object is to optimize these process variables in the flotation deinking process.

4.2.1 Effect of Pulping time variations on Deinkability Factors

The effect of pulping time on D_B and D_E, has been studied by keeping the temperature at 60 ^{0}C, consistency at 5%, flotation consistency around 1%, flotation time at 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%. The results have been shown in Table 2 and 3 in the Appendix and are plotted in figure 4.1 and 4.2 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 3 show that with the increase in pulping time, the ISO brightness increases and ERIC value decreases up to the optimum value and after optimum pulping time at 15 minutes, the ISO brightness decreases and ERIC value increases. Figures 4.1 and 4.2 show the effect of pulping time, in terms of deinkability factor D_B and D_E. In these figures, as the pulping time increases, the D_B and D_E increase to the optimum value and after optimum pulping time of 15 minutes, D_B and D_E decreases. Too long pulping time can induce a reduction of the ink particle size and a decrease in the flotation removal efficiency. Pulping time should be limited to the time required to get acceptable defibering of the processed raw material to minimize ink fragmentation and redeposition. Longer pulping time only break down detached ink particles that favor their entry in pits, which is introduced by rotor pulp suspension

interaction. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B and D_E:

$$\ln D_B = 5.744049 - 18.82874x + 31.44173x^2 - 7.589815x^3 - 19.54870x^4 + 16.69662x^5 - 4.115970x^6 \quad \text{.....(4.3)}$$

$$\ln D_E = -0.7852747 + 16.55022x - 27.86847x^2 + 12.98549x^3 + 17.20605x^4 - 19.58894x^5 + 5.273448x^6 \quad \text{.....(4.4)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B, the regression error is **0.023667186** and for D_E it is **0.016442778**. The predicted values of D_B and D_E plotted in the figure 4.1 and 4.2 also show the reasonable fit for the data.

Many researchers (15,32,83,84,99,111,131) have also indicated in their studies that the 15 minutes pulping time gives good results.

4.2.2 Effect of Pulping Temperature variations on Deinkability Factors

To consider the effects of pulping temperature on D_B and D_E, we have chosen the pulping time as 15 minutes, consistency as 5%, flotation consistency around 1%, flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%. The results have been shown in Table 4 and 5 in the Appendix and are plotted in figure 4.3 and 4.4 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 4 show that with the increase in temperature, the ISO brightness increases and ERIC value decreases up to the optimum value and after optimum pulping temperature at 65 ^{0}C, the ISO brightness increases and ERIC value decreases upto 70 ^{0}C.

Magnin (85) have also stated that high temperature beyond 65 ^{0}C had started

affecting the deinkability and the ink had started reversing back in the system, after dissociation from the pulp earlier. Pulping temperature above 70 ^{0}C is unsuitable as the thermal reversion and accelerated alkali darkening can occur. Figures 4.3 and 4.4 show the effect of pulping temperature, in terms of deinkability factor D_B and D_E. In these figures, as the pulping temperature increases, the D_B and D_E increase to the optimum value and after optimum pulping temperature of 65 ^{0}C, D_B and D_E decreases. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = -49.95959 + 53.84150x - 42.02831x^2 + 60.78446x^3 - 7.626383x^4 + 44.90076x^5 - 55.89888x^6 \quad \text{.....(4.5)}$$

$$\ln D_E = -45.40915 + 45.33973x - 33.44828x^2 + 56.05659x^3 - 6.079792x^4 + 36.97143x^5 - 49.40741x^6 \quad \text{.....(4.6)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B, the regression error is **0.04917258** and for D_E it is **0.038791925**. The predicted values of D_B and D_E plotted in the figure 4.3 and 4.4 also show a reasonable fit for the data.

Marchildon et al. (91) have concluded in their study that an adequate combination of pulping temperature and percentage of active deinking chemical favors the formation of big flocs of ink which are more easily removed by flotation and reduce the ink surface.

Basta et al. (15), Darlington (39) and Lopez et al. (84) have also indicated in their studies that 60 – 65 ^{0}C pulping temperature gives good results.

4.2.3 Effect of Pulp Consistency variations on Deinkability Factors

To consider the effect of pulp consistency on D_B and D_E, we have chosen the pulping temperature as 65 ^{0}C, pulping time as 15 minutes, flotation consistency around 1%,

and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%. The results have been shown in Table 6 and 7 in the Appendix and are plotted in figure 4.5 and 4.6 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 6 show that in our operational consistency range, which is upto 8% only. With the increase in pulp consistency, the ISO brightness increases and ERIC value decreases up to the optimum value and after optimum pulp consistency at 6%, the ISO brightness decreases and ERIC value increases.

Bansal et al. (12) have also reported in the study that hand sheet brightness increase significantly with increased pulp consistency provided the furnish is fully deflaked and defibered. It was observed that at 4% consistency, a vortex forms in the suspension. Thus the rotor is not in full contact with the suspension. As the suspension consistency is increased, it becomes more porridge like and its effective viscosity increases giving better results by higher shearing forces between fibers. Flow is slowed. If the suspension consistency is further increased, flow ceases. The rotor hollows out a cavity in the suspension and spins in it. Figures 4.5 and 4.6 show the effect of pulp consistency, in terms of deinkability factor D_B and D_E. In these figures, as the pulp consistency increases, the D_B and D_E increase to the optimum value and after optimum pulp consistency of 6%, D_B and D_E decreases. The following empirical equation was obtained by using experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = -2.016015 + 26.45634x - 52.08826x^2 + 53.11693x^3 - 26.29580x^4 + 4.923897x^5 \quad \text{.....(4.7)}$$

$$\ln D_E = 0.4828056 + 7.510474x - 2.490217x^2 - 4.086827x^3 + 2.989838x^4 + 0.039438318\,x^5 - 0.3198682x^6 \quad \text{.....(4.8)}$$

The predicted values of D_B with fifth order polynomial gives minimum regression error of **0.001984373** and for D_E it is **0.001416468** for sixth order polynomial. The predicted values of D_B and D_E plotted in the figure 4.5 and 4.6 also show the reasonable fit for the data.

Carre et al. (33) have stated that increasing pulp consistency upto an optimum induces an increase of the shearing forces, which disperses ink favorably but further increase may result in ink redeposition and reduction in the ink flotation removal efficiency.

Sridhar et al. (130) have also described in their study that with high consistency pulping and deinking effects in terms of detachment and dispersion is lower than low / medium consistency batch pulping.

4.2.4 Effect of Flotation Time variations on Deinkability Factors

To consider the effect of flotation time on D_B and D_E, we have chosen the pulping time as 15 minutes, pulping temperature as 65 ^{0}C, consistency as 6%, and flotation consistency around 1%. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%. The results have been shown in Table 8 and 9 in the Appendix and are plotted in figure 4.7 and 4.8 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 8 show that with the increase in flotation time, the ISO brightness increases and ERIC value decreases, consequently the ISO brightness go on increasing up to 10 minutes and ERIC value continue to decrease. After 10 minutes there is no substantial increase in brightness and decrease in ERIC value. Figures 4.7 and 4.8 show the effect of flotation time, in terms of deinkability factor D_B and D_E. In these figures, as the flotation time increases, the D_B and D_E increase; consequently the D_B and D_E go on increasing up to 10 minutes. After 10 minutes there is no substantial increase in D_B and D_E. Further time shall only use power with

no additional advantage in flotation efficiency. On the basis of review study, mentioned in section 3.2.5 chapter 3, flotation time of 10 minutes was adopted for all the flotation-deinking experiments of our studies, as further increase in flotation time produced minimal variation in efficiency with more fiber loss. The following empirical equation was obtained by using the experimental data for Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 2.493445 + 2.129581x - 2.006634x^2 + 2.975610x^3 - 1.684345x^4 - 0.047704782x^5 + 00.1679133x^6 \quad \text{.....(4.9)}$$

$$\ln D_E = 2.457300 + 3.042436x - 3.618542x^2 + 3.143022x^3 - 0.5433351x^4 - 0.7753222x^5 + 0.2971082x^6 \quad \text{.....(4.10)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B, the regression error is **0.002981075** and for D_E it is **0.007629357**. The predicted values of D_B and D_E plotted in the figure 4.7 and 4.8 also show the reasonable fit for the data.

Catsburg (34) and Mahagaonkar et al (87) have also indicated in their studies that increasing flotation time does not result in a higher removal efficiency of ink specks (50 -150 μm).

Borchardt (29) have also described in their study that with the increase in flotation time more than 10 minutes there is yield loss but the brightness increase is not substantial. Remaining ink if any is still attached to the fibers and is unavailable for removal by flotation.

Carrasco et al. (32) have also reported in their results that deinkability factor reached an asymptotic value of 88% after 10 minutes of flotation. Further increases in flotation time produce minimal variation in deinking efficiency. *Mathur (93)* have also reported in their study that 10 minutes flotation time gives good results.

4.2.5 Effect of Oleic acid dosages variations on Deinkability Factors

To consider the effect of oleic acid dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, consistency as 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 10 and 11 in the Appendix and are plotted in figure 4.9 and 4.10 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 10 show that with the increase in oleic acid dosages, the ISO brightness increases and the ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.9 and 4.10 show the effect of oleic acid dosages, in terms of deinkability factors D_B and D_E. In these figures, as the oleic acid dosages increases, the D_B and D_E increase to the optimum value and after optimum oleic acid dosage of 1.2%, the value of D_B and D_E decreases. This shows that high dosages of oleic acid beyond 1.2% has started affecting the deinkability and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 2.310135 + 2.041178x + 0.7089038x^2 - 2.077450x^3 + 1.220905x^4 - 0.2714882x^5 \quad \text{.....(4.11)}$$

$$\ln D_E = 1.196587 + 9.277725x - 13.98749x^2 + 7.742938x^3 + 3.222553x^4 - 4.760180x^5 + 1.239596x^6 \quad \text{.....(4.12)}$$

The predicted values of D_B with Fifth order polynomial give minimum regression error of **0.018109627** and for D_E, it is **0.014165095** for a sixth order polynomial. The predicted values of D_B and D_E plotted in the figure 4.9 and 4.10 also show the reasonable fit for the data.

Bansal et al. (5,10,12) have described in their studies that the function of active deinking chemical is to collect the separated ink particles and float them out from the system with foam. It appears that when the dosage is low, enough collection of particles is not there, and they may leave with the pulp. With the increase of collector chemical dosage, the ink agglomerate size increases. Initially, for small dosage, the size of the agglomerate is small (<50 μm), which negatively affects the brightness. With the increase of chemical dosages, size of the ink agglomerate increases (>50 μm) up to an optimum size. These large agglomerates are more easily removed by flotation and reduce the ink quantity from the surface of the fibers in the pulp. The deinkability factor is highest at this condition. On the other hand, if the size of agglomerated ink particle becomes too large in comparison to the bubble size, again it cannot be carried away by the foam and it remains back in the system, leading to lower deinkability. As these agglomerates are still with the pulp, but more staggered, thus there is a net over all gain in the brightness.

Darlington (39) have also indicated in their lab studies that with the agglomeration of ink particles, at a particular time and with specific conditions, the pulp may look brighter, even with larger toner agglomerates. Though, this separated ink is in the system, yet with the increased size of ink agglomerates, as indicated above, the ERIC value decreases up to the right size of ink agglomerates, and beyond this the ERIC value start increasing resulting in decreased deinkability. The ERIC value after pulping is higher than that after flotation, as relatively more debris, loading material, and ink etc. shall first get collected in pulping system itself leading to the higher ERIC value and then this all goes out with the foam in flotation process, resulting in decreased ERIC value of the product. During flotation, the hydrophobic component of the active chemical is responsible for removing the above materials

from the system, as it acts as a wetting agent in the operation. The continuous decrease of ERIC value after slushing with the increase in dosages of active deinking chemical also shows that the collection of ink particles probably starts in the slushing operation itself and some of the agglomerated ink particles leave the system during sheet formation leading to decrease in ERIC values. This trend is not observed in the pulp after flotation, where probably the proper size range of agglomerated ink particles have only gone out with the foam, leading to lowest ERIC values which ultimately gives highest deinkability factor.

4.2.6 Effect of Palmitic acid dosages variations on Deinkability Factors

To consider the effect of palmitic acid dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, consistency as 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 12 and 13 in the Appendix and are plotted in figure 4.11 and 4.12 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 12 show that with the increase in palmitic acid dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.11 and 4.12 show the effect of palmitic acid chemical dosages, in terms of deinkability factor D_B and D_E. In these figures, as the palmitic acid dosages increases, the D_B and D_E increase to the optimum value and after optimum palmitic acid dosage of 1.2%, D_B and D_E decreases. This shows that high dosages of palmitic acid beyond 1.2% has started affecting the deinkability and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the

Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 2.336846 + 3.606371x - 4.556270x^2 + 4.074256x^3 - 0.8487397x^4 - 0.9489073x^5 + 0.3816070x^6 \quad \text{.....(4.13)}$$

$$\ln D_E = 3.104293 - 1.179244x + 6.599288x^2 - 6.975546x^3 + 3.037416x^4 - 0.5113438x^5 \quad \text{.....(4.14)}$$

The predicted values of D_B with sixth order polynomial give minimum regression error of **0.013231776** and for D_E, it is **0.011362973** for a fifth order polynomial. The predicted values of D_B and D_E plotted in the figure 4.11 and 4.12 also show the reasonable fit for the data. The principal functions of active deinking collector chemicals are already discussed in the section 4.2.5. Palmitic acid gives better results in comparison to the oleic acid due to the nature discussed in the section 2.4.6 in chapter 2.

4.2.7 Effect of Stearic acid dosages variations on Deinkability Factors

To consider the effect of stearic acid dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, pulper consistency of 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 14 and 15 in the Appendix and are plotted in figure 4.13 and 4.14 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 14 show that with the increase in stearic acid dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.13 and 4.14 show the effect of stearic acid dosages, in terms of deinkability factor D_B and D_E. In these figures, as the stearic acid dosages

increases, the D_B and D_E increase to the optimum value and after optimum stearic acid dosage of 1.2%, D_B and D_E decreases. This shows that high dosages of stearic acid beyond 1.2% has started affecting the deinkability and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 2.302553 + 5.838259x - 10.39213x^2 + 9.550466x^3 - 2.647556x^4 - 0.9659649x^5 + 0.4526430x^6 \quad \text{.....(4.15)}$$

$$\ln D_E = 2.128415 + 7.057607x - 12.45960x^2 + 10.80175x^3 - 2.760718x^4 - 1.095829x^5 + 0.4833085x^6 \quad \text{.....(4.16)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.013919381** and for D_E it is **0.019092826**. The predicted values of D_B and D_E plotted in the figures 4.13 and 4.14 also show the reasonable fit for the data. The principal functions of active deinking collector chemical are already discussed in the section 4.2.5. Stearic acid gives better results in comparison to the palmitic and oleic acid due to the nature discussed in the section 2.4.6 in chapter 2.

Johansson et al. (69) have also stated in their study that the flotation efficiency is in the same order, *stearic acid > palmitic acid > oleic acid.*

4.2.8 Effect of Triton x 100 dosages variations on Deinkability Factors

To consider the effect of Triton x 100 (Iso – octyl phenoxy polyethoxy ethanol) dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, pulper consistency of 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 16 and 17 in the Appendix and are plotted in figure 4.15 and 4.16 for slushed pulp after pulping

and after flotation in the flotation cell respectively. The experimental data of Table 16 show that with the increase in Triton x 100 dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.15 and 4.16 show the effect of Triton x 100 dosages, in terms of deinkability factor D_B and D_E. In these figures, as the Triton x 100 dosages increases, the D_B and D_E increase to the optimum value and after optimum Triton x 100 dosage of 1.2%, D_B and D_E decreases. This shows that high dosages of Triton x 100 beyond 1.2% has started affecting the deinkability and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 1.355058 + 9.720243x - 16.38978x^2 + 12.32411x^3 - 1.766046x^4 - 2.097696x^5 + 0.7173430x^6 \quad \text{.....(4.17)}$$

$$\ln D_E = 1.323482 + 10.87295x - 19.25327x^2 + 14.61753x^3 - 1.927603x^4 - 2.630216x^5 + 0.8829733x^6 \quad \text{.....(4.18)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.011859977** and for D_E it is **0.017196603**. The predicted values of D_B and D_E plotted in the figures 4.15 and 4.16 also show the reasonable fit for the data. The principal functions of active deinking collector chemical are already discussed in the section 4.2.5.

Triton x 100 show a behavior where the ink goes on accumulating on the fixed size air bubbles with the increase in surfactant dosage and reaches to an optimum dosage of surfactant. Beyond this point, the ink agglomerate size is more and is not sustainable on the air bubble. This large size ink agglomerate goes back in the system leading to lower Deinkability Factors with increased dosages.

4.2.9 Effect of Brij - 35 dosages variations on Deinkability Factors

To consider the effect of Brij – 35 (Polyoxy ethylene lauryl ether) dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, pulper consistency of 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 18 and 19 in the Appendix and are plotted in Figure 4.17 and 4.18 for slushed pulp after pulping and after flotation in the flotation cell respectively, which include deinkability factors. The experimental data of Table 18 show that with the increase in Brij – 35 dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.17 and 4.18 show the effect of Brij – 35 dosages, in terms of deinkability factor D_B and D_E. In these figures, as the Brij – 35 dosages increases, the D_B and D_E increase to the optimum value and after optimum Brij – 35 dosages of 1% D_B and D_E decreases, but more fiber loss in flotation deinking. This shows that high dosages of Brij – 35 beyond 1% has started affecting the deinkability and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 2.579966 + 2.658944x - 4.061932x^2 + 5.577987x^3 - 3.817473x^4 + 0.8997067x^5 \quad \text{.....(4.19)}$$

$$\ln D_E = 2.297309 + 4.438357x - 7.851208x^2 + 9.484999x^3 - 5.751654x^4 + 1.266502x^5 \quad \text{.....(4.20)}$$

The predicted values of D_B and D_E with fifth order polynomial give minimum regression error. For D_B the regression error is **0.0213787761** and for D_E it is **0.017017426**. The predicted values of D_B and D_E plotted in the figures 4.17 and 4.18

also show the reasonable fit for the data. The principal functions of active deinking collector chemical are already discussed in the section 4.2.5. Brij – 35 also show a behavior like Triton x 100 is discussed earlier in the section 4.2.8.

4.2.10 Effect of Tween - 80 dosages variations on Deinkability Factors

To consider the effect of Tween – 80 (Polyoxyethylene sorbittan mono-oleate) dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, pulper consistency of 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 20 and 21 in the Appendix and are plotted in figure 4.19 and 4.20 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 20 show that with the increase in Tween – 80 dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.19 and 4.20 show the effect of Tween – 80 dosages, in terms of deinkability factor D_B and D_E. In these figures, as the Tween – 80 dosages increases, the D_B and D_E increase but after 1.2% further increase in chemical dosage produced minimal variation in D_B and D_E.

Tween – 80 show a behavior where perhaps the surfactant is not only helping the ink agglomeration but also forming intermediate size agglomerate with dust or fines. The size of agglomerate with dust, fines or ink is such that it goes out on the air bubbles forming foam and leads to relatively cleaner pulp resulting increasing Deinkability Factors. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 3.280489 - 1.634212x + 7.792870x^2 - 9.537314x^3 + 4.973911x^4 - 0.9572150x^5 \quad \text{.....(4.21)}$$

$$\ln D_E = 3.927662 - 6.643931x + 21.28267x^2 - 25.34314x^3 + 13.30505x^4 - 2.576072x^5 \quad \text{.....(4.22)}$$

The predicted values of D_B and D_E with fifth order polynomial give minimum regression error. For D_B the regression error is **0.012285935** and for D_E it is **0.020000696**. The predicted values of D_B and D_E plotted in the figures 4.19 and 4.20 also show the reasonable fit for the data.

4.2.11 Effect of Anmol Flotation DI dosages variations on Deinkability Factors

To consider the effect of Anmol Flotation DI dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, pulper consistency of 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 22 and 23 in the Appendix and are plotted in figure 4.21 and 4.22 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 22 show that with the increase in Anmol Flotation DI dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.21 and 4.22 show the effect of Anmol Flotation DI dosages, in terms of deinkability factor D_B and D_E. In these figures, as the Anmol Flotation DI dosages increases, the D_B and D_E increase but after 1.2% further increase in chemical dosage produced minimal variation in D_B and D_E. Anmol Flotation DI also shows a behavior like Tween 80 is discussed earlier in the section 4.2.10. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B and D_E:

$$\ln D_B = 2.869750 + 0.3485945x + 2.699374x^2 - 2.746326x^3 + 0.1876796x^4 + 0.6991158x^5 - 0.2177725x^6 \quad \text{.....(4.23)}$$

$$\ln D_E = 3.188022 - 1.122469x + 5.202624x^2 - 4.430919x^3 + 0.4460279x^4 + 0.8503559x^5 - 0.2621725x^6 \quad \text{.....(4.24)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.00182349** and for D_E it is **0.005697254**. The predicted values of D_B and D_E plotted in the figures 4.21 and 4.22 also show the reasonable fit for the data.

4.3 EVALUATION OF OPTIMUM CONDITIONS FOR FLOTATION DEINKING OF UNCOATED OMG

For uncoated OMG, the experimental process conditions are pulping temperatures, pulping consistency and Dosages of Active deinking chemicals in pulper and object is to optimize these process variables in the flotation deinking process.

4.3.1 Effect of Pulping Temperature variations on Deinkability Factors

The effect of pulping temperature on D_B and D_E, has been studied by keeping the pulping time as 15 minutes, consistency as 5%, flotation consistency around 1%, flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%. The results have been shown in Table 24 and 25 in the Appendix and are plotted in figure 4.23 and 4.24 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 24 show that with the increase in temperature, the ISO brightness increases and ERIC value decreases up to the optimum value and after optimum pulping temperature at 65 ^{0}C, the ISO brightness increases and ERIC value decreases. In the case of OMG also same type of behavior of temperature is

observed as in the case of ONP as already discussed in the section 4.2.2. Figures 4.23 and 4.24 show the effect of pulping temperature, in terms of deinkability factor D_B and D_E. In these figures, as the pulping temperature increases, the D_B and D_E increase to the optimum value and after optimum pulping temperature of 65 ^{0}C, D_B and D_E decreases. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = -426.9571 + 1557.329x - 1695.203x^2 + 43.01301x^3 + 347.5124x^4 + 739.7183x^5 - 561.4681x^6 \quad \text{.....(4.25)}$$

$$\ln D_E = -366.0204 + 1341.200x - 1468.345x^2 + 43.22482x^3 + 301.3088x^4 + 641.9248x^5 - 489.2790x^6 \quad \text{.....(4.26)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.033344861** and for D_E it is **0.03623224**. The predicted values of D_B and D_E plotted in the figure 4.23 and 4.24 also show a reasonable fit for the data.

4.3.2 Effect of Pulp Consistency variations on Deinkability Factors

To consider the effect of pulp consistency on D_B and D_E, we have chosen the pulping temperature as 65 ^{0}C, pulping time as 15 minutes, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%. The results have been shown in Table 26 and 27 in the Appendix and are plotted in figure 4.25 and 4.26 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 26 show that in our operational consistency range, which is upto 8% only. With the increase in pulp consistency the ISO brightness increases and ERIC value decreases up to the optimum value and after optimum pulp consistency at 6%, the ISO brightness decreases and ERIC

value increases. Figures 4.25 and 4.26 show the effect of pulp consistency, in terms of deinkability factor D_B and D_E. In these figures, as the pulp consistency increases, the D_B and D_E increase to the optimum value and after optimum pulp consistency of 6%, D_B and D_E decreases. The following empirical equation was obtained by using experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 4.088702 - 1.437059x + 2.444971x^2 - 0.9324297x^3 + 0.3083206x^4 - 0.1750301x^5 - 0.095338278x^6 \quad \text{.....(4.27)}$$

$$\ln D_E = 3.641596 + 1.330463x - 2.320573x^2 + 2.364233x^3 - 0.7552014x^4 + 0.2505895x^5 - 0.2636611x^6 \quad \text{.....(4.28)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.000006289** and for D_E it is **0.000003765**.The predicted values of D_B and D_E plotted in the figure 4.25 and 4.26 also show the reasonable fit for the data. In the case of OMG also same type of behavior of pulp consistency is observed as in the case of ONP as already discussed in the section 4.2.3.

4.3.3 Effect of Oleic acid dosages variations on Deinkability Factors

To consider the effect of oleic acid dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, consistency as 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 28 and 29 in the Appendix and are plotted in figure 4.27 and 4.28 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 28 show that with the increase in oleic acid dosages, the ISO brightness increases and the ERIC value decreases as

further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.27 and 4.28 show the effect of oleic acid dosages, in terms of deinkability factors D_B and D_E. In these figures, as the oleic acid dosages on increases, the D_B and D_E increase to the optimum value and after optimum oleic acid dosage of 1.2%, the value of D_B and D_E decreases. This shows that high dosages of oleic acid beyond 1.2% has started affecting the deinkability and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 0.1882956 + 5.472208x + 0.5634977x^2 + 0.6795633x^3 - 3.411189x^4 - 0.9214668x^5 + 1.530503x^6 \quad \text{.....(4.29)}$$

$$\ln D_E = 1.166344 + 2.669981x + 3.387081x^2 - 0.9785916x^3 - 2.172049x^4 - 1.525654x^5 + 1.588922x^6 \quad \text{.....(4.30)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.000026155** and for D_E it is **0.000007181**. The predicted values of D_B and D_E plotted in the figure 4.27 and 4.28 also show the reasonable fit for the data. In the case of OMG also same type of behavior of oleic acid is observed as in the case of ONP and the principal functions of active deinking collector chemicals as already discussed in the section 4.2.5.

4.3.4 Effect of Palmitic acid dosages variations on Deinkability Factors

To consider the effect of palmitic acid dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, consistency as 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 30 and 31 in the Appendix and are plotted in figure 4.29 and 4.30 for slushed pulp after pulping and after flotation in the flotation cell

respectively. The experimental data of Table 30 show that with the increase in palmitic acid dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.29 and 4.30 show the effect of palmitic acid chemical dosages, in terms of deinkability factor D_B and D_E. In these figures, as the palmitic acid dosages increases, the D_B and D_E increase to the optimum value and after optimum palmitic acid dosage of 1.2%, D_B and D_E decreases. This shows that high dosages of palmitic acid beyond 1.2% has started affecting the deinkability and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 0.5136948 + 7.001228x - 2.814336x^2 + 1.053671x^3 - 2.800184x^4 - 0.7543843x^5 + 0.4288025x^6 \quad \text{.....(4.31)}$$

$$\ln D_E = 0.9058597 + 6.123609x - 2.398235x^2 + 1.393589x^3 - 2.131567x^4 - 1.008178x^5 + 1.268355x^6 \quad \text{.....(4.32)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.000015865** and for D_E it is **0.000022103**. The predicted values of D_B and D_E plotted in the figure 4.29 and 4.30 also show the reasonable fit for the data. In the case of OMG also same type of behavior of palmitic acid is observed as in the case of ONP and the principal functions of active deinking collector chemicals as already discussed in the section 4.2.5. Palmitic acid gives better results in comparison to the oleic acid due to the nature discussed in the section 2.4.6 in chapter 2.

4.3.5 Effect of Stearic acid dosages variations on Deinkability Factors

To consider the effect of stearic acid dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, pulper consistency of 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 32 and 33 in the Appendix and are plotted in figure 4.31 and 4.32 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 32 show that with the increase in stearic acid dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.31 and 4.32 show the effect of stearic acid dosages, in terms of deinkability factor D_B and D_E. In these figures, as the stearic acid dosages increases, the D_B and D_E increase to the optimum value and after optimum stearic acid dosages of 1.2%, D_B and D_E decreases. This shows that high dosage of stearic acid beyond 1.2% has started affecting the deinkability and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 1.766834 + 3.425249x + 1.254466x^2 - 0.6515508x^3 - 2.189677x^4 - 0.1009950x^5 + 0.7932102x^6 \quad \text{.....(4.33)}$$

$$\ln D_E = 1.299472 + 5.352495x - 1.403288x^2 + 1.328356x^3 - 3.227050x^4 + 0.042076547x^5 + 0.9224352x^6 \quad \text{.....(4.34)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.000041408** and for D_E it is **0.000044294**. The predicted values of D_B and D_E plotted in the figure 4.31 and 4.32 also show the reasonable fit for the data. In the case of OMG also same type of

behavior of stearic acid is observed as in the case of ONP and the principal functions of active deinking collector chemicals as already discussed in the section 4.2.5 and 4.2.7. Stearic acid gives better results in comparison to the palmitic and oleic acid due to the nature discussed in the section 2.4.6 in chapter 2.

Mahagaonkar et al. (87) have also indicated in their study that after flotation of OMG still showed the highest ink speck count despite the highest value of brightness are also similar as in our results.

4.3.6 Effect of Triton x 100 dosages variations on Deinkability Factors

To consider the effect of Triton x 100 dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, pulper consistency of 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 34 and 35 in the Appendix and are plotted in figure 4.33 and 4.35 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 34 show that with the increase in Triton x 100 dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.33 and 4.34 show the effect of Triton x 100 dosages, in terms of deinkability factor D_B and D_E. In these figures, as the Triton x 100 dosages increases, the D_B and D_E increase to the optimum value and after optimum Triton x 100 dosage of 1.2%, D_B and D_E decreases. This shows that high dosages of Triton x 100 beyond 1.2% has started affecting the deinkability and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = -0.099619389 + 5.111335x + 3.988174x^2 - 2.977027x^3 - 3.273194x^4 - 0.3362645x^5 + 1.658214x^6 \quad \text{.....(4.35)}$$

$$\ln D_E = 0.068022966 + 5.482190x + 2.087236x^2 - 1.386584x^3 - 3.231467x^4 - 0.3868325x^5 + 1.477451x^6 \quad \text{.....(4.36)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.000020362** and for D_E it is **0.000007561**. The predicted values of D_B and D_E plotted in the figures 4.33 and 4.34 also show the reasonable fit for the data. In the case of OMG also same type of behavior of Triton x 100 is observed as in the case of ONP and the principal functions of active deinking collector chemicals as already discussed in the section 4.2.5 and 4.2.8.

4.3.7 Effect of Brij - 35 dosages variations on Deinkability Factors

To consider the effect of Brij – 35 dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, pulper consistency of 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 36 and 37 in the Appendix and are plotted in figure 4.35 and 4.36 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 36 show that with the increase in Brij – 35 dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.35 and 4.36 show the effect of Brij – 35 dosages, in terms of deinkability factor D_B and D_E. In these figures, as the Brij – 35 dosages increases, the D_B and D_E increase to the optimum value and after optimum Brij – 35 dosage of 1% D_B and D_E decreases, but more fiber loss in flotation deinking. This shows that high dosages of Brij – 35 beyond 1% has started affecting the deinkability

and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = 1.667401 + 4.523274x - 1.915928x^2 + 1.092303x^3 - 2.373182x^4 + 0.7397105x^5 + 0.2550220x^6 \quad \text{.....(4.37)}$$

$$\ln D_E = 2.531446 + 1.092325x + 3.483934x^2 - 3.064700x^3 - 0.2371840x^4 - 0.4084351x^5 + 0.6242126x^6 \quad \text{.....(4.38)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.000017502** and for D_E it is **0.000002478**. The predicted values of D_B and D_E plotted in the figures 4.35 and 4.36 also show the reasonable fit for the data. In the case of OMG also same type of behavior of Brij – 35 is observed as in the case of ONP and the principal functions of active deinking collector chemicals as already discussed in the section 4.2.5 and 4.2.10.

4.4 EVALUATION OF OPTIMUM CONDITIONS FOR FLOTATION DEINKING OF COATED OMG

For coated OMG also the optimum process conditions are same as obtained earlier for the uncoated ONP and OMG. Results for coated OMG were obtained to observe the effect of stearic acid dosages variations, in the flotation deinking process.

4.4.1 Effect of Stearic acid dosages variations on Deinkability Factors

To consider the effect of stearic acid dosages on D_B and D_E, we have chosen the pulping time as 15 minutes, temperature as 65 ^{0}C, pulper consistency of 6%, flotation consistency around 1%, and flotation time as 10 minutes. The chemicals

added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%. The results have been shown in Table 38 and 39 in the Appendix and are plotted in figure 4.37 and 4.38 for slushed pulp after pulping and after flotation in the flotation cell respectively. The experimental data of Table 38 show that with the increase in stearic acid dosages, the ISO brightness increases and ERIC value decreases as further increase in chemical dosages produced minimal variation in ISO brightness and ERIC values. Figures 4.37 and 4.38 show the effect of stearic acid dosages, in terms of deinkability factor D_B and D_E. In these figures, as the stearic acid dosages increases, the D_B and D_E increase to the optimum value and after optimum stearic acid dosage of 1.2%, D_B and D_E decreases. This shows that high dosages of stearic acid beyond 1.2% has started affecting the deinkability and the ink has started reversing back in the system, after dissociation from the pulp earlier. The following empirical equation was obtained by using the experimental data for the Compaq Visual FORTRAN mathematical polynomial regression program to predict D_B, and D_E:

$$\ln D_B = -1.758388 + 8.935340x - 0.3562429x^2 + 1.892513x^3 - 5.957330x^4 - 1.148041x^5 + 2.451529x^6 \quad \text{.....(4.39)}$$

$$\ln D_E = -3.388903 + 12.29810x - 0.6898659x^2 - 0.030626897x^3 - 6.237463x^4 - 0.021050805x^5 + 2.189287x^6 \quad \text{.....(4.40)}$$

The predicted values of D_B and D_E with sixth order polynomial give minimum regression error. For D_B the regression error is **0.000030018** and for D_E it is **0.000011794**. The predicted values of D_B and D_E plotted in the figure 4.37 and 4.38 also show the reasonable fit for the data. In the case of coated OMG also same type of behavior of stearic acid is observed as in the case of uncoated ONP or OMG and the principal functions of active deinking collector chemicals as already discussed in the section 4.2.5 and 4.2.7.

4.5 EVALUATION OF OPTIMUM CONDITIONS FOR FLOTATION DEINKING OF ONP/OMG BLENDS

For ONP/OMG blends also the optimum process conditions are same as obtained earlier for the uncoated ONP and OMG. Results for ONP/OMG blends were obtained to observe the effect of ratios variations, in the flotation deinking process.

4.5.1 Effects of ONP/OMG Blends variations in Flotation deinking on Deinkability factor

The process conditions for the blends already same as those for ONP and OMG obtained earlier. The pulping time is 15 minutes, temperature at 65 ^{0}C, consistency at 6%, flotation consistency around 1%, and flotation time at 10 minutes. The chemicals added in the pulper are NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1.2 %. The results have been shown in Table 40 and 41 in the Appendix and are plotted in figure 4.39 for slushed pulp after pulping and after flotation in the flotation cell respectively. Four ONP/OMG blends chosen for the study are 0/100, 80/20, 70/30, 60/40, 50/50 and 100/0. The experimental data of Table 40, 41 and figure 4.39 show that among the above four furnishes, addition of 30% OMG with 70% ONP was found to give better results at the given pulper conditions in terms of deinkability factors D_B and D_E. This is due to the removal of ink, filler retention and chromophore removal and retention of brighter chemical pulp originating from OMG in deinked pulp. Generally, white pigments like calcium carbonate and titanium-di-oxide and other coating component present in the coated OMG increase the brightness of paper, as can be seen for the case of 70/30 mixtures too.

Mahagaonkar et al. (87) have also indicated that addition of 30% OMG in ONP was optimum. Interestingly, further increase in OMG could increase the yield

only with minimal improvement in optical properties and loss in strength. The yield increase could be due to the retention of filler or coating material with the final pulp. This could be a reason for selecting 70/30 ratio of ONP/OMG in commercial deinking processes to obtain good results.

4.5.2 Effects of ONP/OMG Blends on Strength properties

The properties of the pulp obtained from the above blends and the results was also studied for strength properties have been shown in Table 42 in the Appendix and are plotted in figures 4.40 to 4.42 for slushed pulp after pulping and after flotation in the flotation cell respectively.

Bansal et al. (12) have stated that the price paid for improvement of optical properties of paper through addition of filler from coated magazines results in a significant loss in paper strength. The strength of paper is mainly due to the fiber-fiber bonds. Pigment particles occupy space between fibers and interface with fiber bonding hence a significant reduction in strength occurs. The results show that there is relative increase in strength properties with the rise in OMG percentage with ONP after flotation and similar trend is found by other researchers *Wultsch et al. (141) and Ackermann (1).*

The results plotted in figures 4.40 to 4.42 also show that after the pulping stage, the trend of decreasing tear, tensile, burst with increasing percentage of OMG can be attributed to the filler and coating materials present in OMG, which has more mechanical pulp too in comparison to the ONP used in the experiments. A continuous reduction in all strength properties occurred despite the addition of chemical pulp from OMG. This suggests that the filler component caused an overriding negative influence and suppressed the effect by chemical pulp. After the pulping stage, the 100% OMG furnish showed the lowest value of burst, tear and tensile strength because of the high percentage of ash or filler.

The improvement in tear, tensile and burst strength occurring after flotation may be due to filler and fines. The improvement can also depend on the combined effect created by mechanical fiber, chemical fiber, filler and fines retained in deinked pulp. Due to the complexity of the system, the effect of the loss of fillers on the total improvement of strength properties was difficult to quantify. This shows that among the above four furnishes, 70/30 furnish ratio of ONP/OMG gives better results of tear, tensile and burst strength.

Results of *Mahagaonkar et al. (87)* have also indicated that the deinking process of ONP with OMG is affected by the filler content of coated magazines. They have also indicated that after the flotation stage, an enhancement in all the strength properties was occurred.

4.6 RELATIONSHIP BETWEEN D_B AND D_E

We have obtained 124 experimental runs with uncoated ONP, coated or uncoated OMG and their blends. No information is available from literature for relationship between D_B and D_E. All these 124 results have been plotted on figure no. 4.43 at one place for all the above four furnishes. A relationship of the type **y = mx+c** has been estimated as given below in the equation 4.41:

$$\boxed{D_E = 0.9992D_B + 2.962 \quad .....(4.41)}$$

$$\boxed{R^2 = 0.9856}$$

The correlation coefficient R^2 gives a good fit of all the experimental data and thus the equation no. 4.41 can be used to predict the other value, if one of the two i.e. either D_B or D_E is known. The above equation can be approximated as below:

$$\boxed{D_E = D_B + 3 \quad ..... \quad (4.42)}$$

4.7 YIELD & pH

The average yield for one flotation step in case of uncoated ONP over all experimental rage it is around 85%. For uncoated OMG average yield for one flotation step in our overall experimental rage it is around 77%. For coated OMG average yield for one flotation step in our overall experimental rage it is around 69%. The average yield for one flotation step in case of ONP/OMG blends of over all experimental range is around 74% depending on the recovered paper mixture used.

Yield loss is due to removal of ink, mineral filler, fines, debris, clays and other coating component present in coated OMG, ONP/OMG blends and other furnishes. The yield increase is due to the increased availability of fiber after deinking operation. The ERIC value after pulping is higher than that after flotation, as relatively more debris, loading material and ink etc shall first get collected in pulping system itself leading to the higher ERIC value and then this all goes out with the foam in flotation process resulting in decreased ERIC value of the product. During flotation, the hydrophobic component of the active chemical is responsible for removing the above materials from the system, as it acts as a wetting agent in the operation.

The pH value for ONP, OMG and their blends in these experiments after pulping are between 9.0 to 10.5 in the hydropulper and between 8.0 to 9.5 in the flotation cell.

Fig. 4.1- Pulping Time Vs. Deinkability Factor for ONP

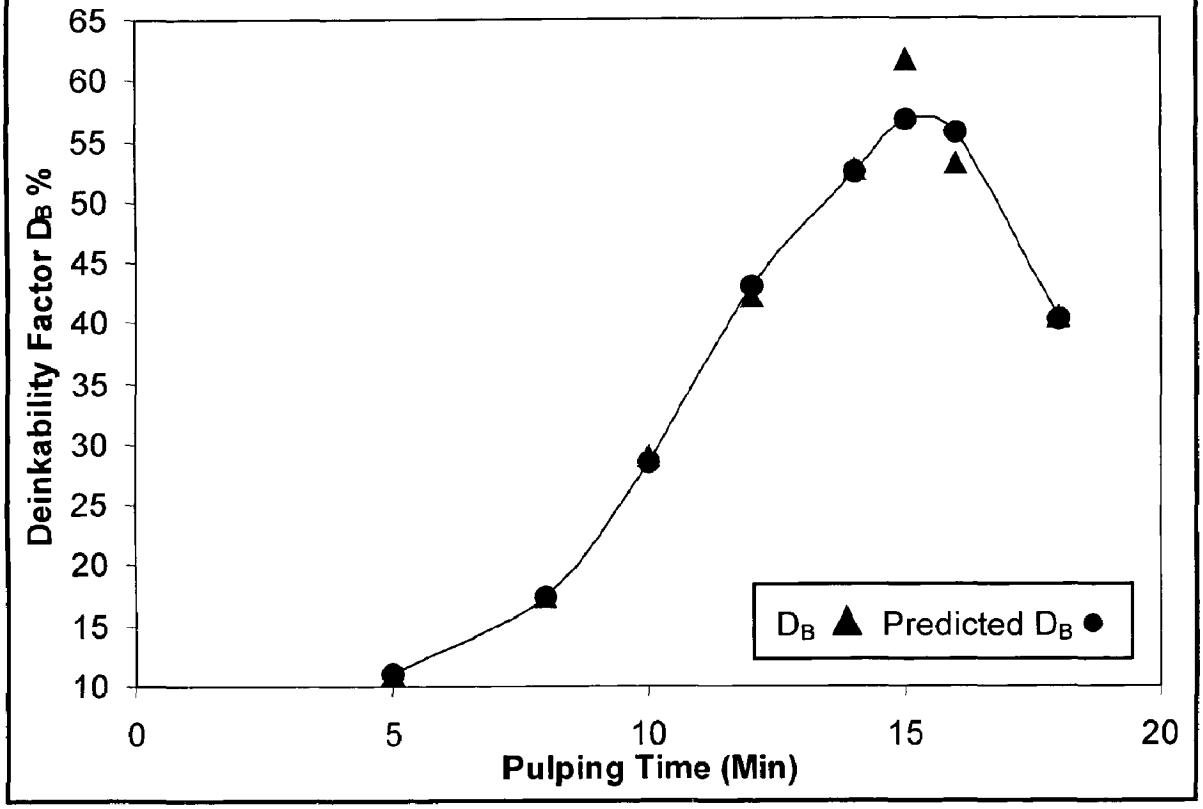


Fig. 4.2 - Pulping Time Vs. Deinkability Factor for ONP

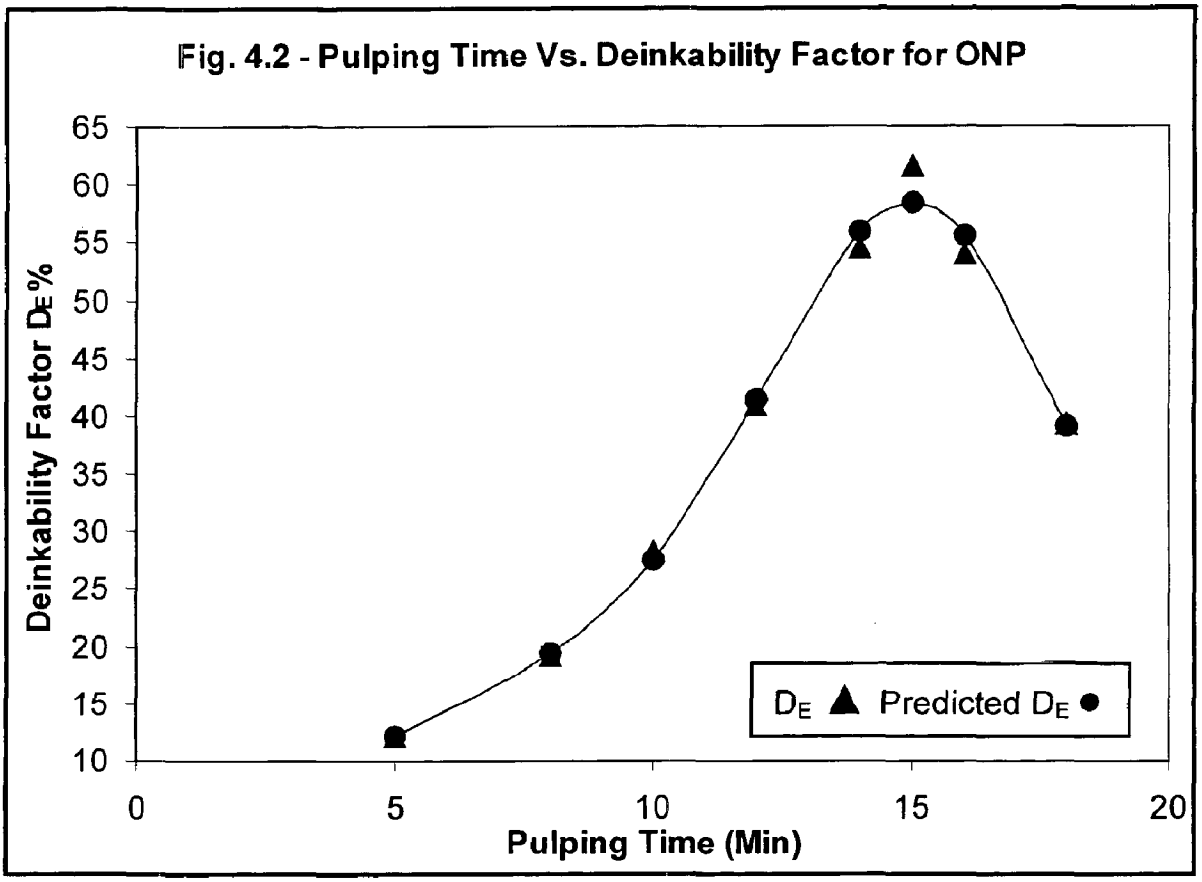


Fig. 4.3 - Pulping Temperature Vs. Deinkability Factor D_B for ONP

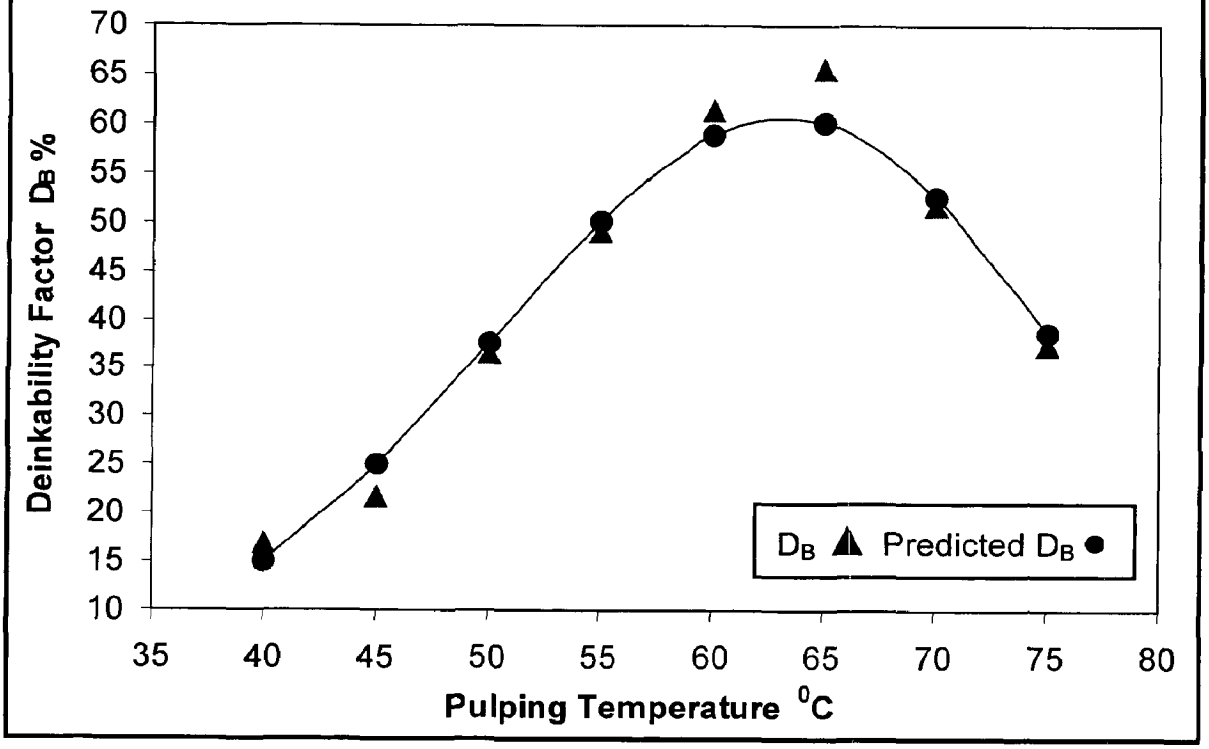


Fig. 4.4 - Pulping Temperature Vs. Deinkability Factor D_E for ONP

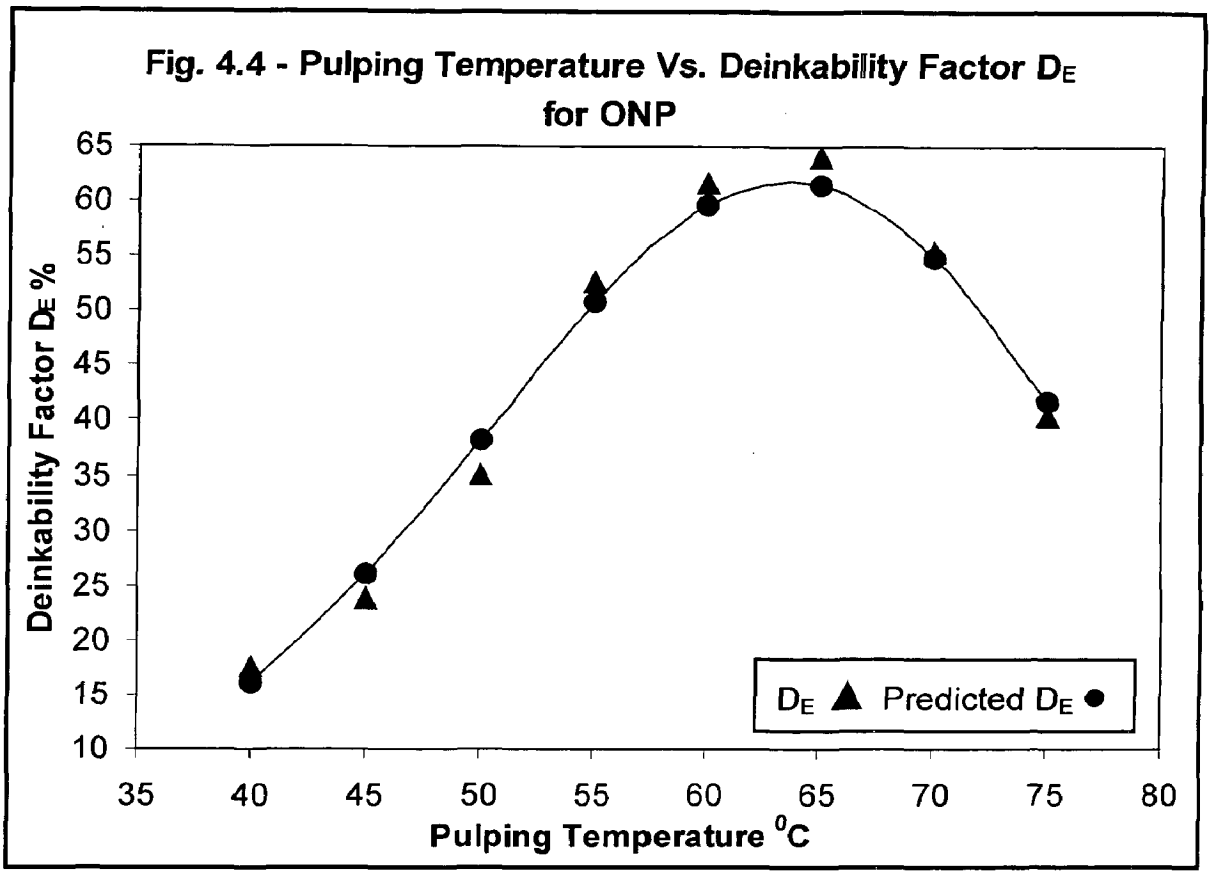


Fig. 4. 5 - Pulping Consistency Vs. Deinkability Factor D_B for ONP

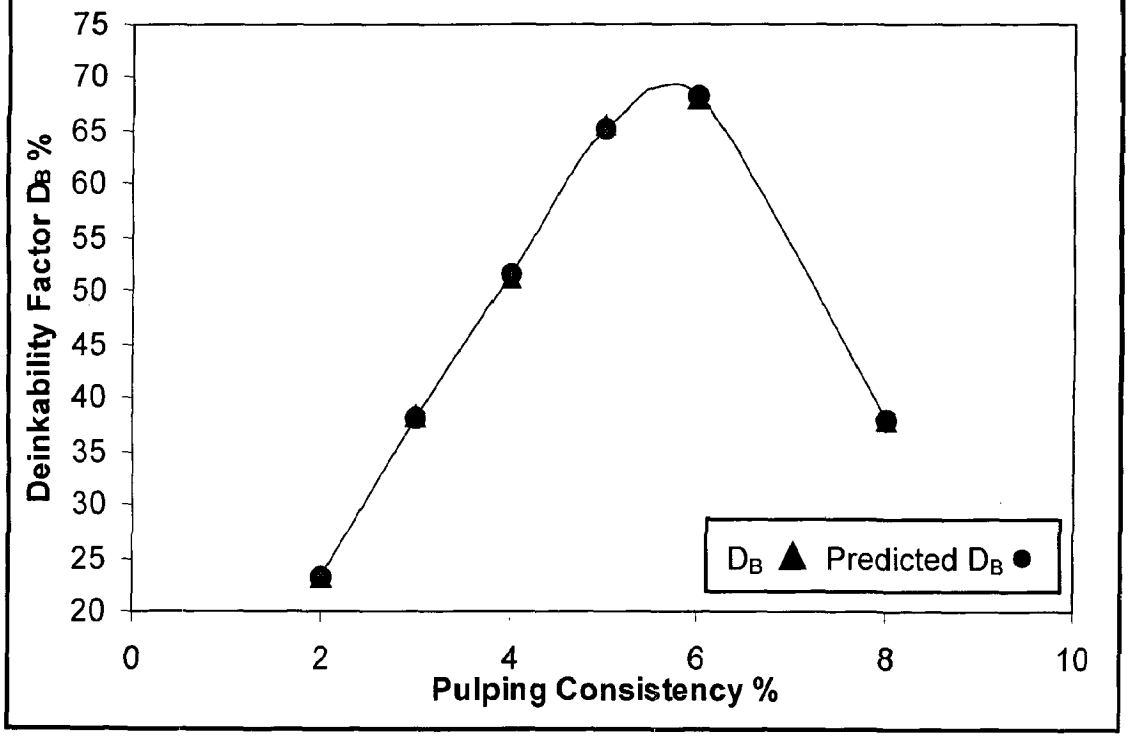


Fig. 4.6 - Pulping Consistency Vs. Deinkability Factor D_E for ONP

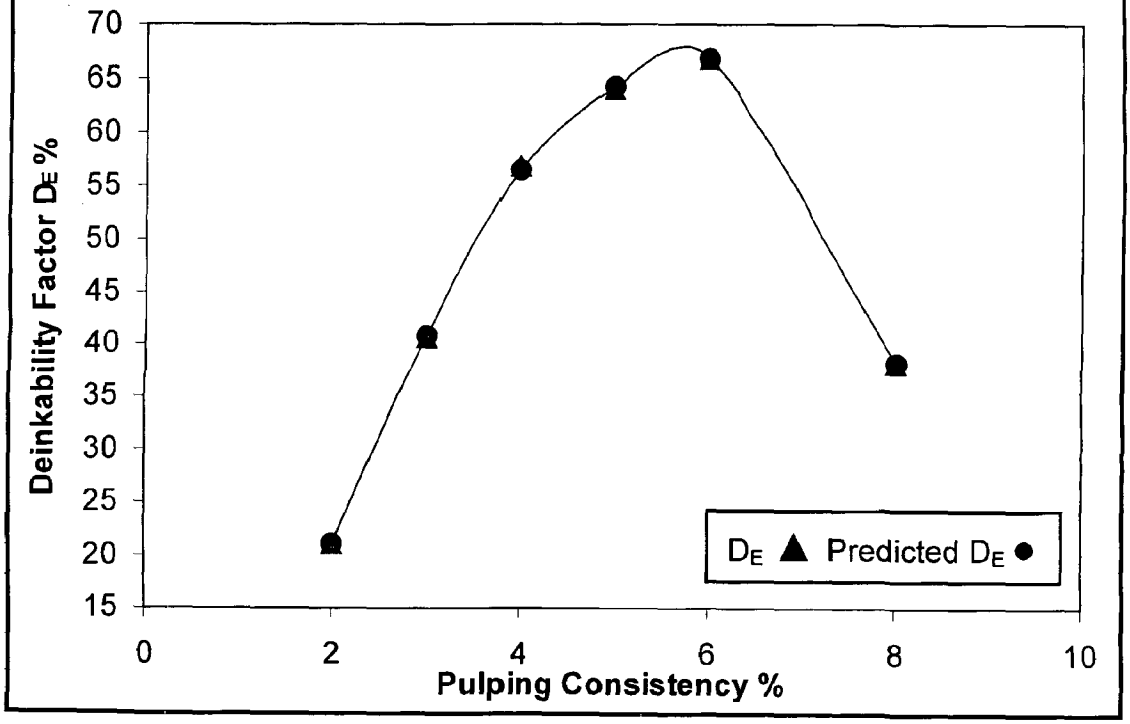


Fig. 4.7 - Flotation Time Vs. Deinkability Factor D_B for ONP

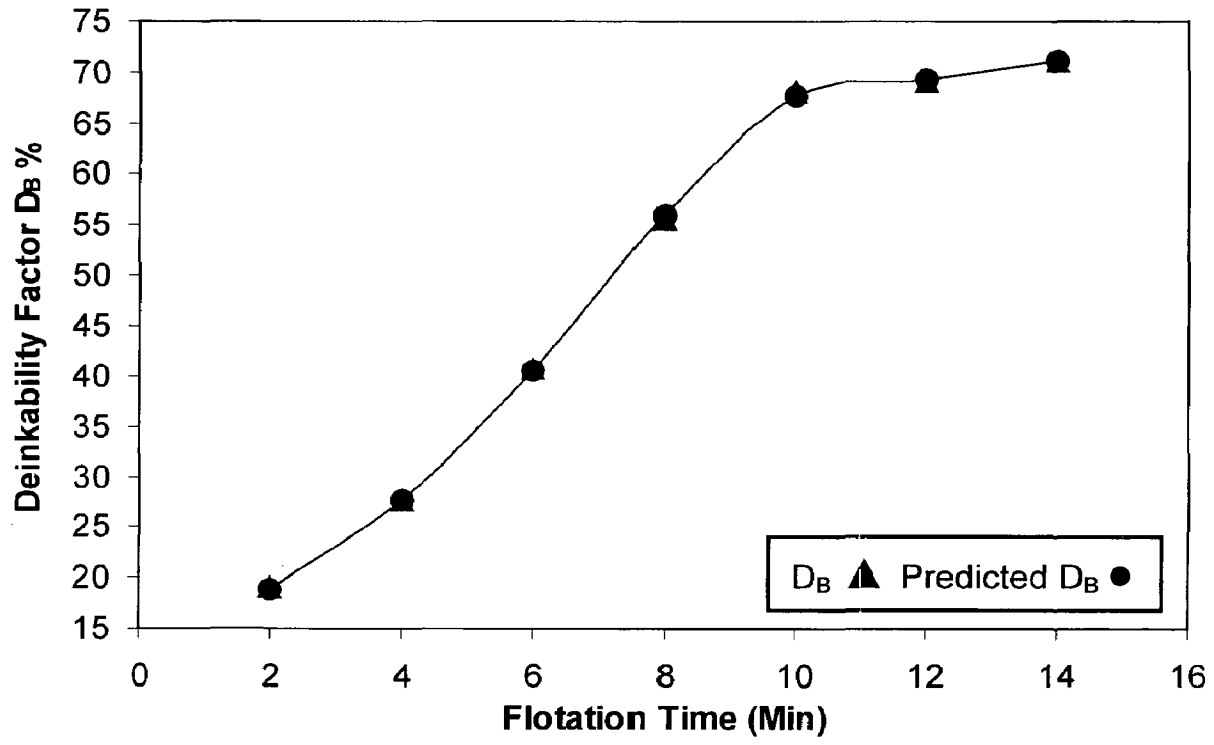


Fig. 4.8 - Flotation Time Vs. Deinkability Factor D_E for ONP

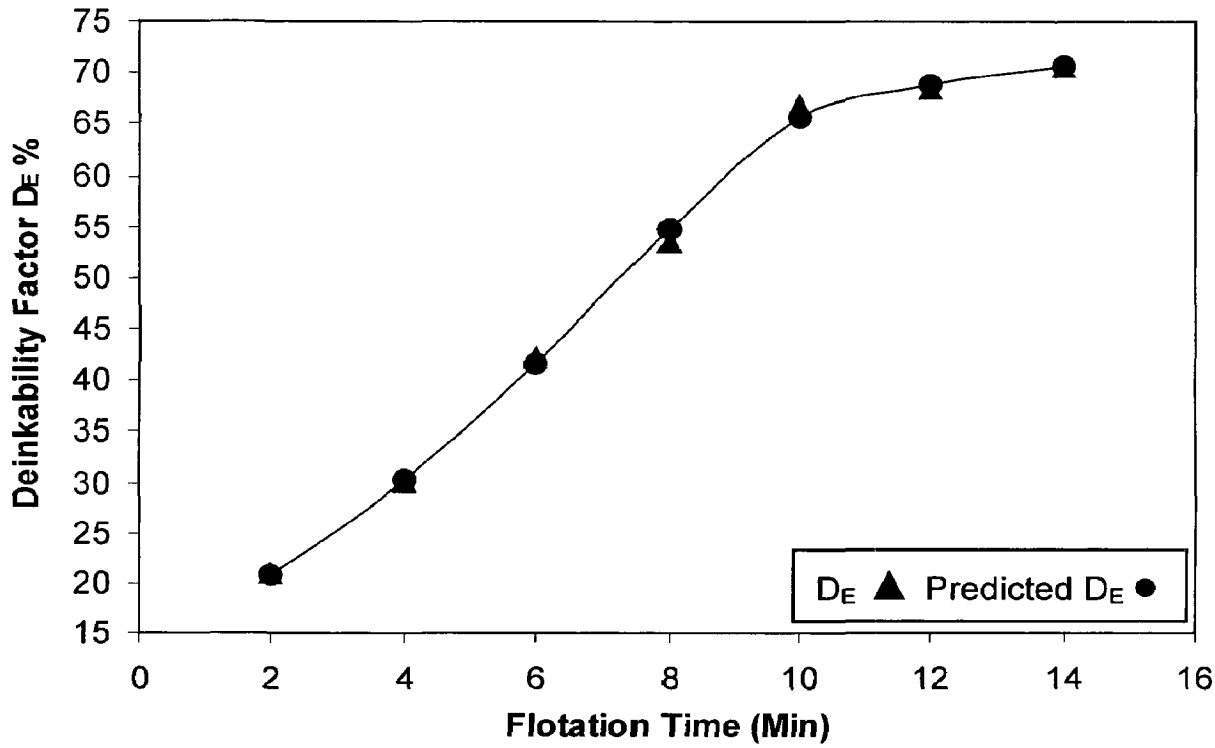


Fig. 4.9 - Oleic acid Dosages Vs. Deinkability Factor D_B for ONP

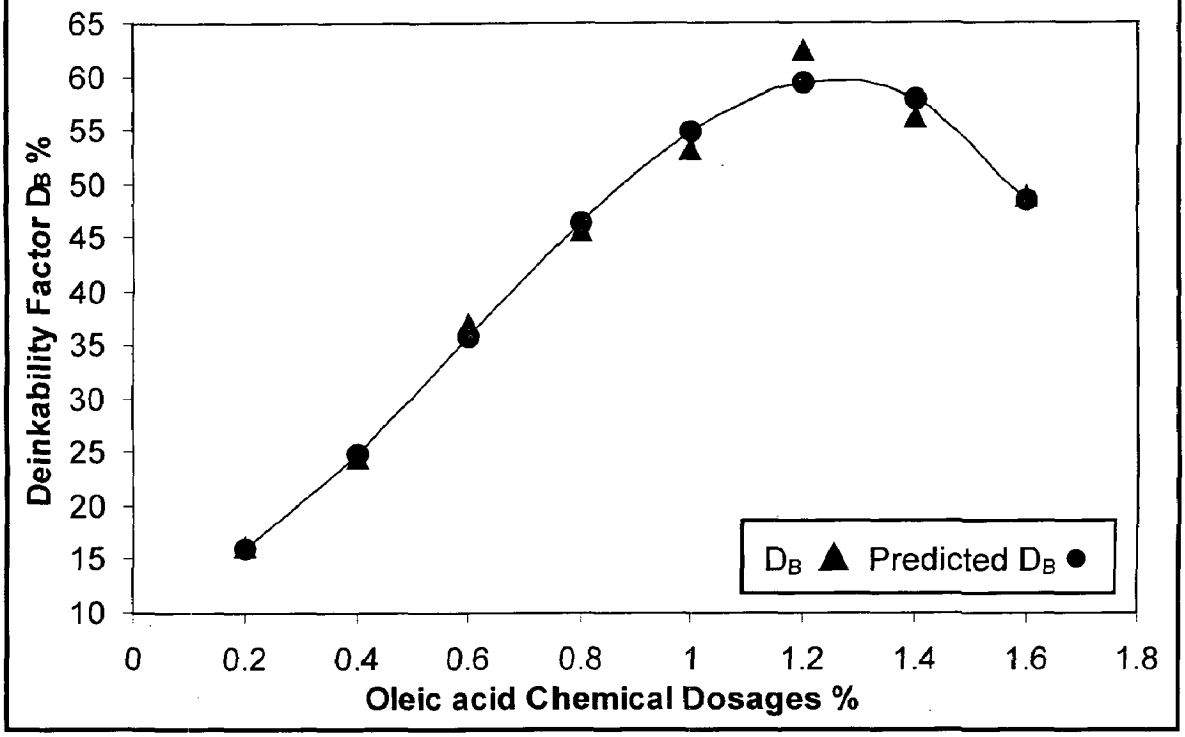
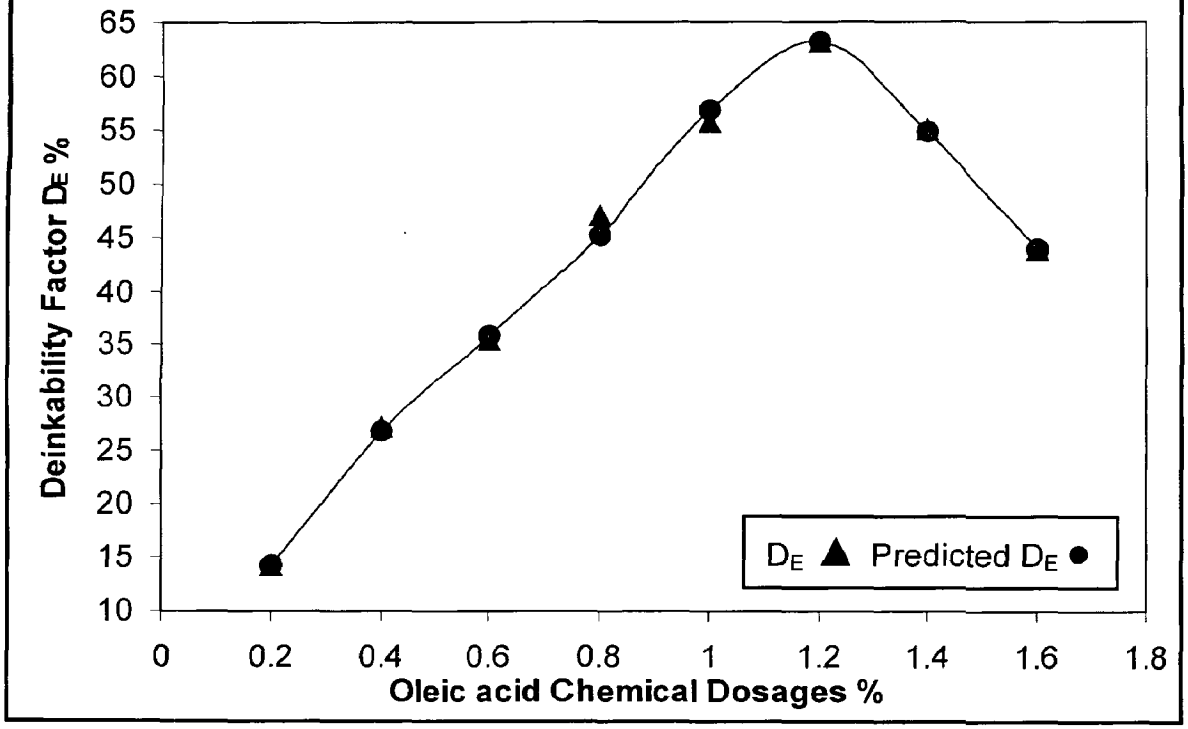


Fig. 4.10 - Oleic acid Dosages Vs. Deinkability Factor D_E for ONP



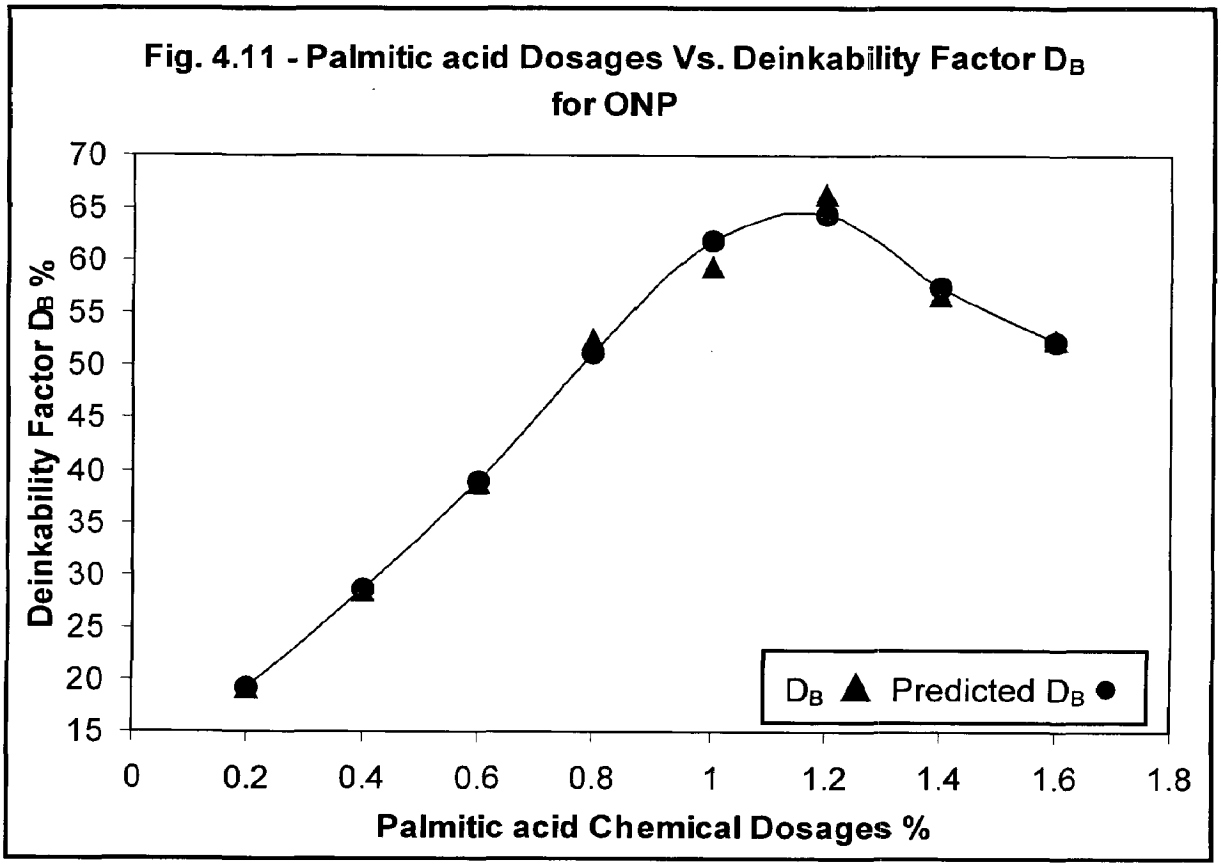


Fig. 4.11 - Palmitic acid Dosages Vs. Deinkability Factor D_B for ONP
Deinkability Factor D_B %
70
65
60
55
50
45
40
35
30
25
20
15
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Palmitic acid Chemical Dosages %
D_B ▲ Predicted D_B ●

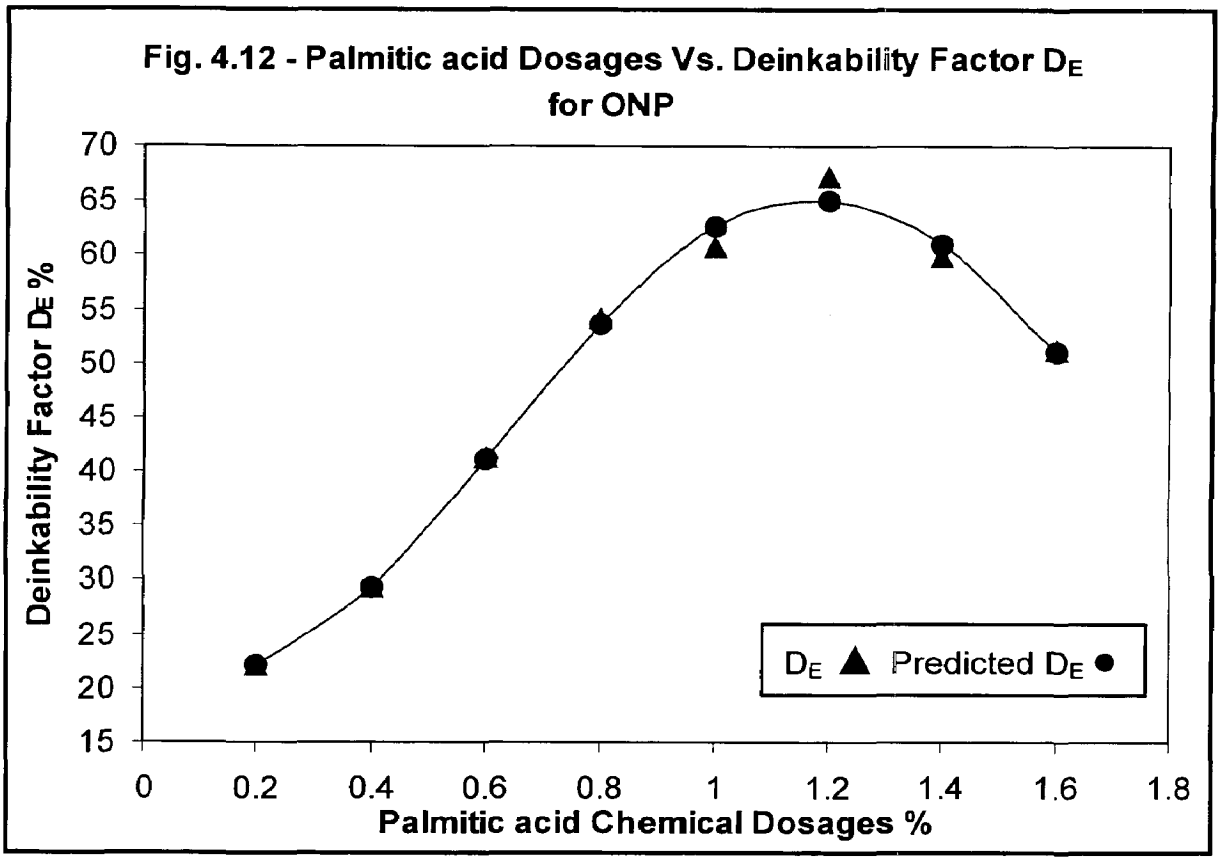


Fig. 4.12 - Palmitic acid Dosages Vs. Deinkability Factor D_E for ONP
Deinkability Factor D_E %
70
65
60
55
50
45
40
35
30
25
20
15
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Palmitic acid Chemical Dosages %
D_E ▲ Predicted D_E ●

Fig. 4.13 - Stearic acid Dosages Vs. Deinkability Factor D_B for ONP

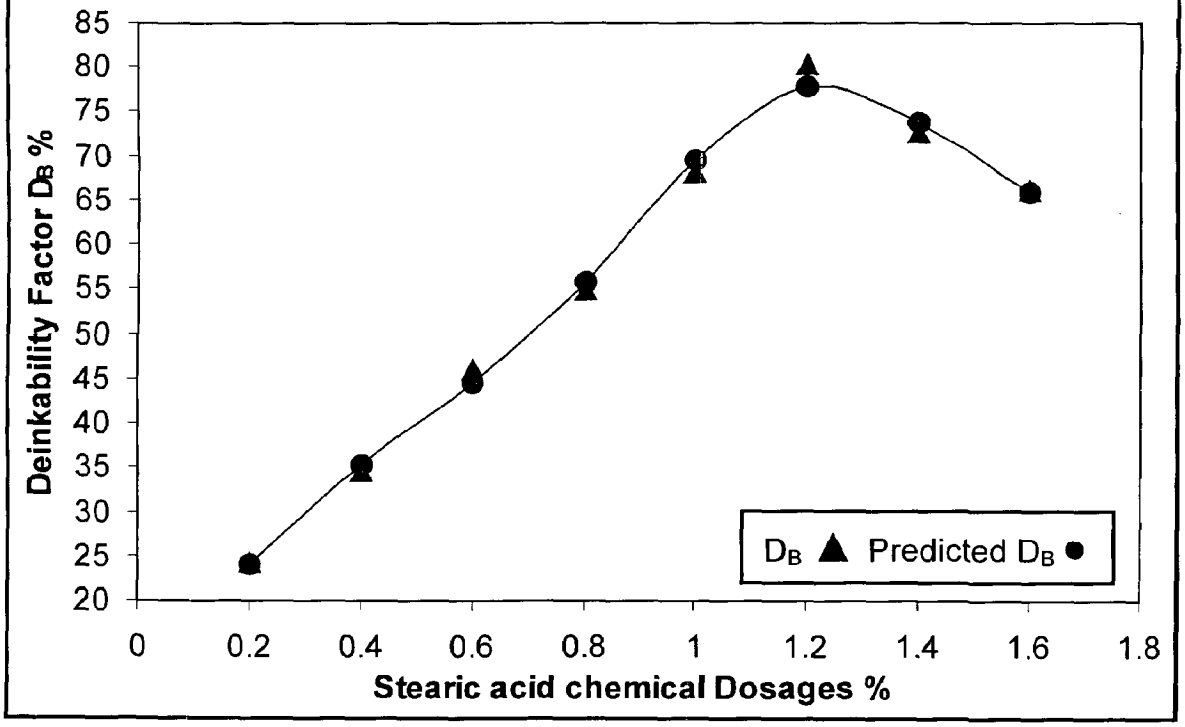


Fig. 4.14 - Stearic acid Dosages Vs. Deinkability Factor D_E for ONP

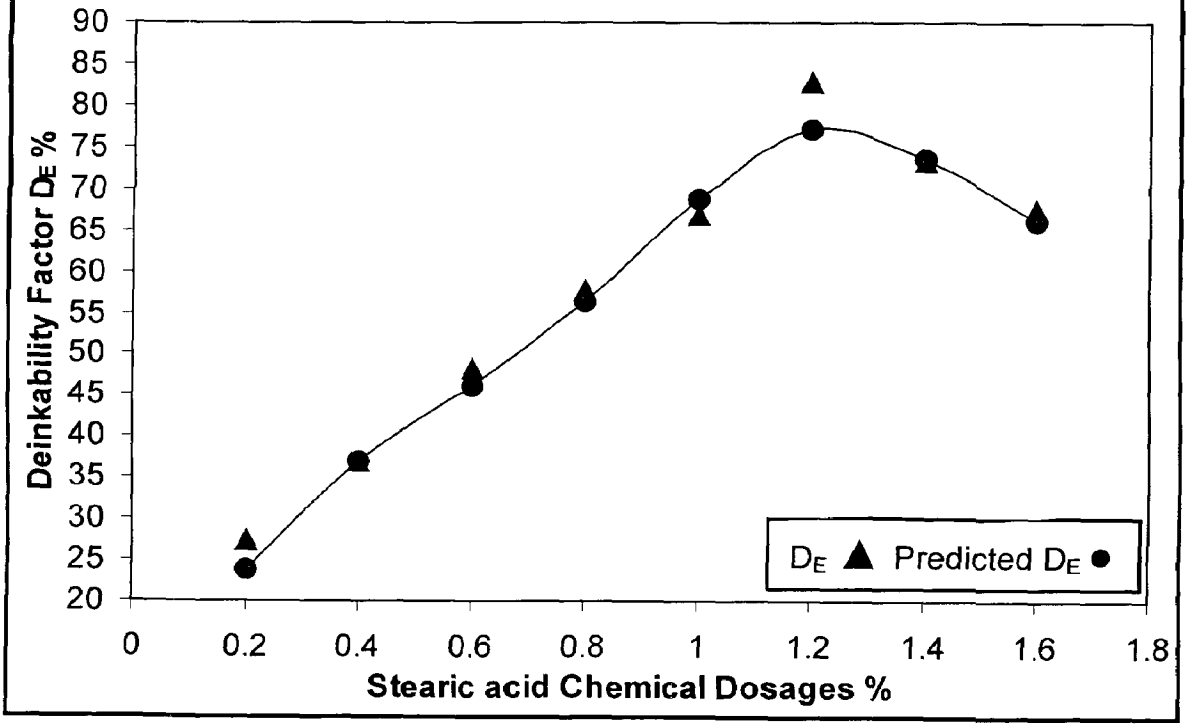


Fig. 4.15 - Triton x 100 dosages Vs. Deinkability Factor D_B for ONP

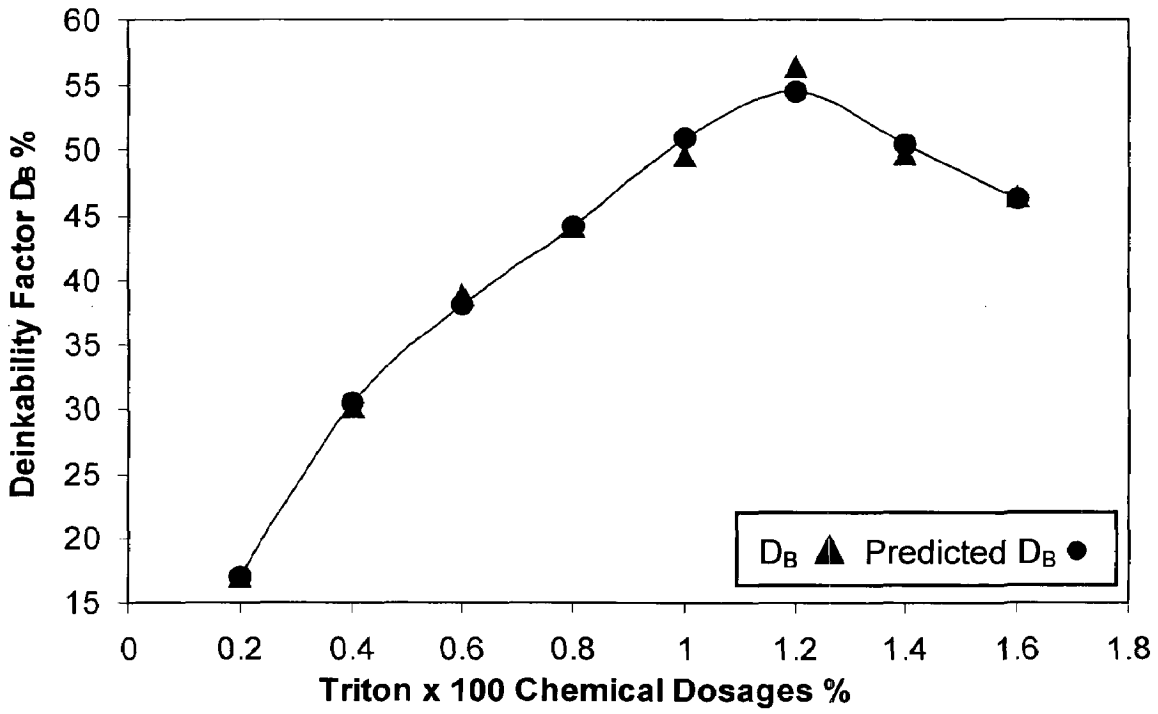
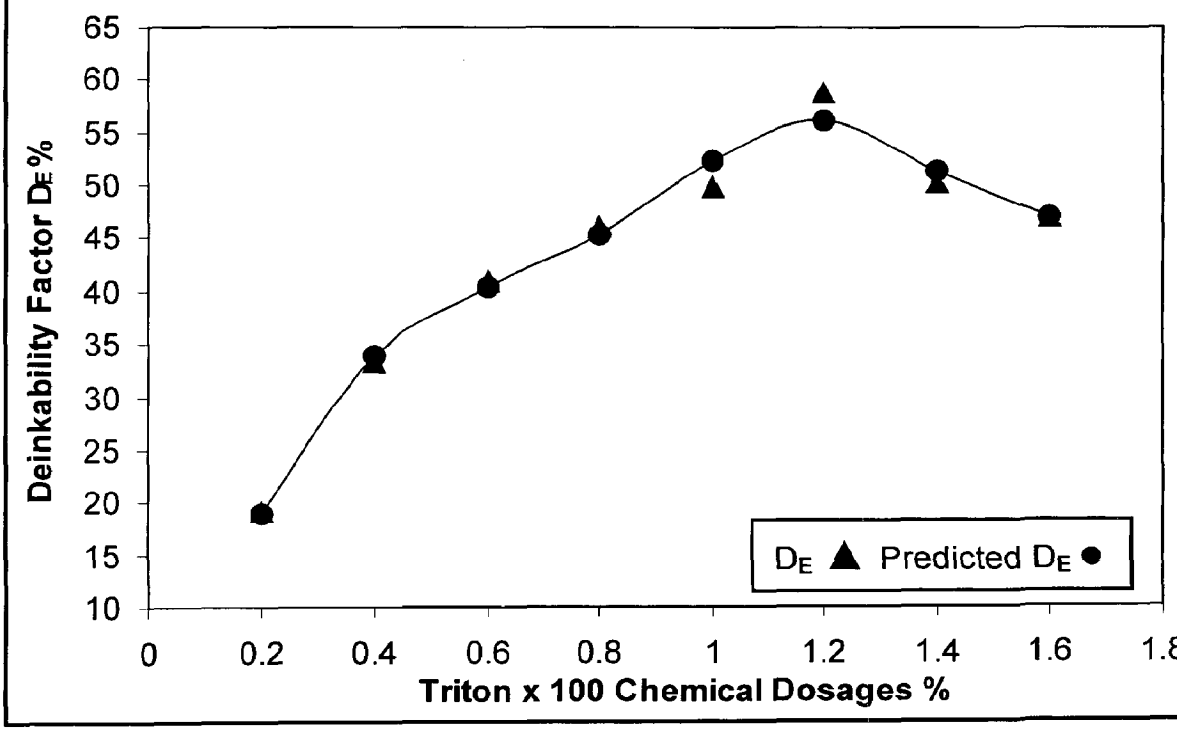


Fig. 4.16 - Triton x 100 Dosages Vs. Deinkability Factor D_E for ONP



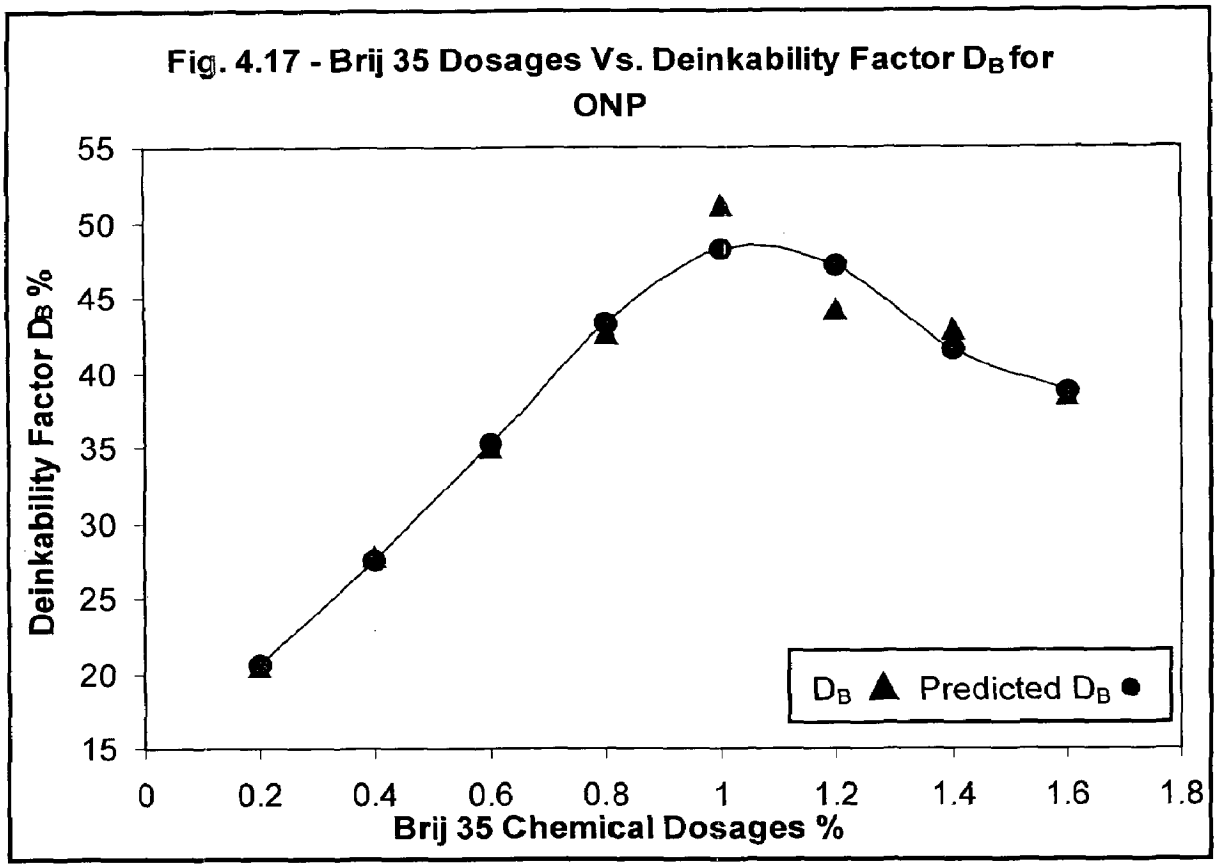


Fig. 4.17 - Brij 35 Dosages Vs. Deinkability Factor D_B for ONP
Deinkability Factor D_B %
55
50
45
40
35
30
25
20
15
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Brij 35 Chemical Dosages %
D_B
Predicted D_B

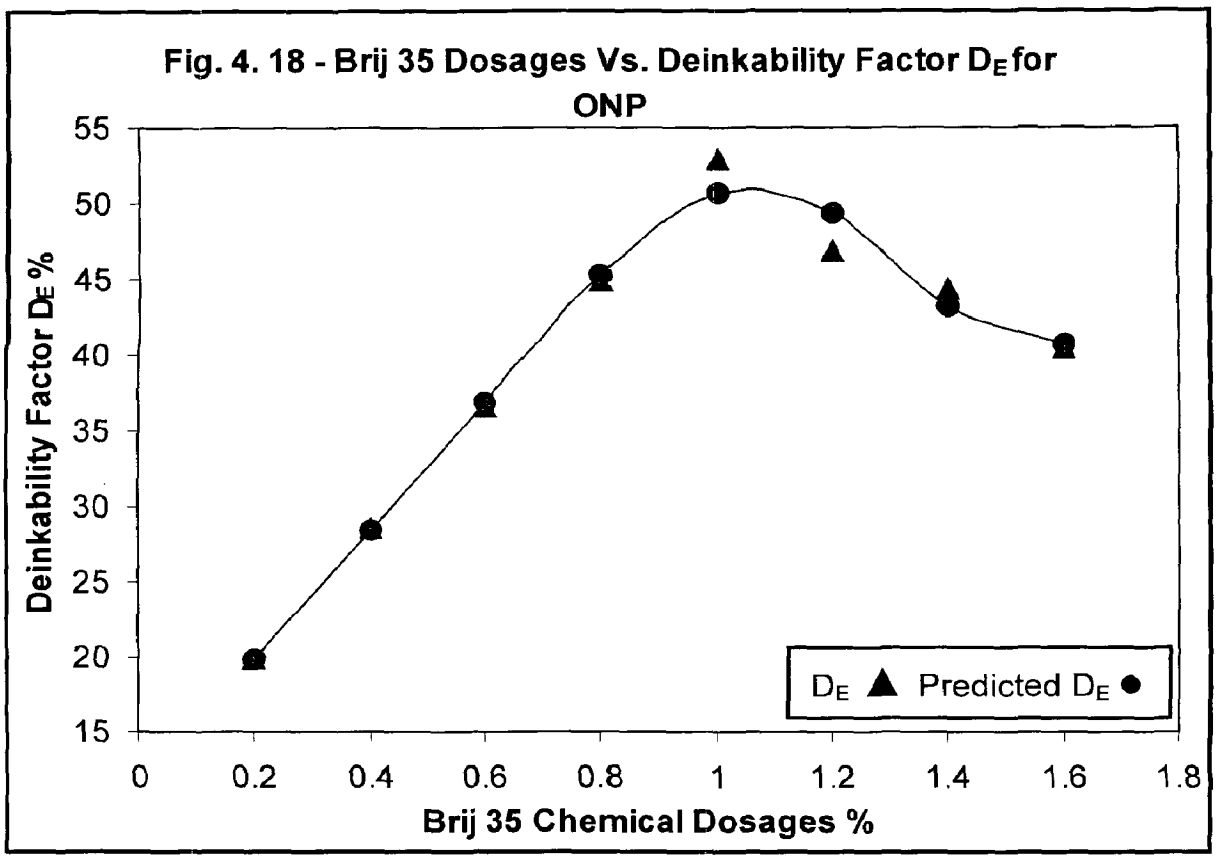


Fig. 4. 18 - Brij 35 Dosages Vs. Deinkability Factor D_E for ONP
Deinkability Factor D_E %
55
50
45
40
35
30
25
20
15
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Brij 35 Chemical Dosages %
D_E
Predicted D_E

Fig. 4.19 - Tween 80 Dosages Vs. Deinkability Factor D_B for ONP

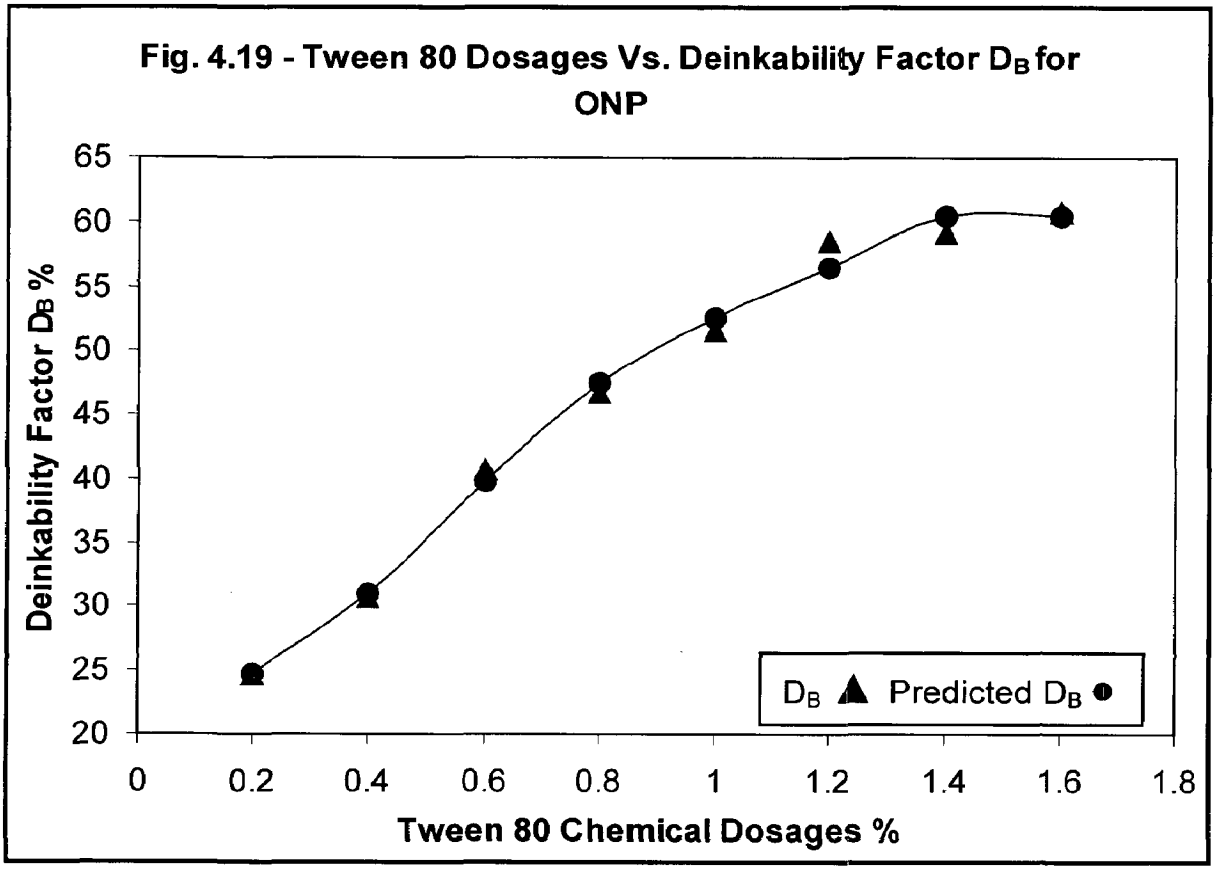


Fig. 4.20 - Tween 80 Dosages Vs. Deinkability Factor D_E for ONP

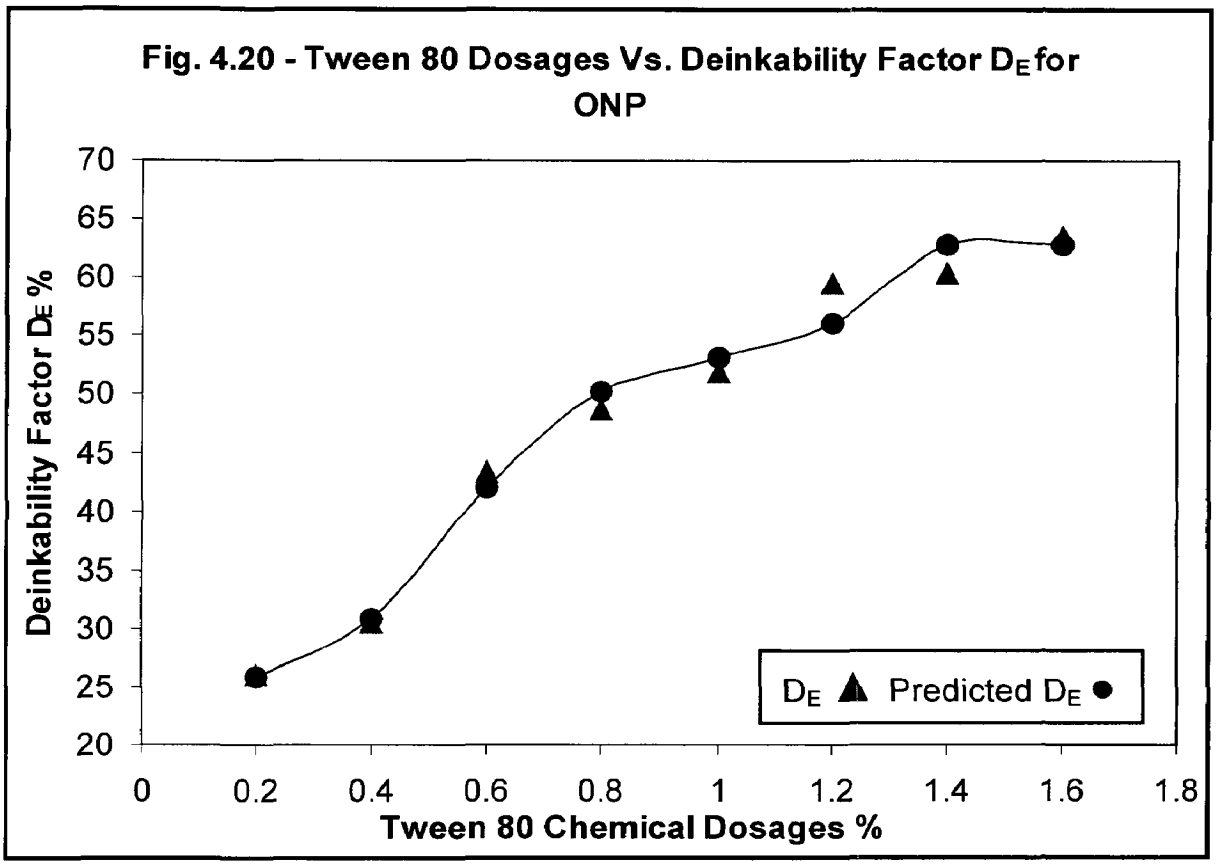


Fig. 4.21- Anmol Flotation DI Dosages Vs. Deinkability Factor D_B for ONP

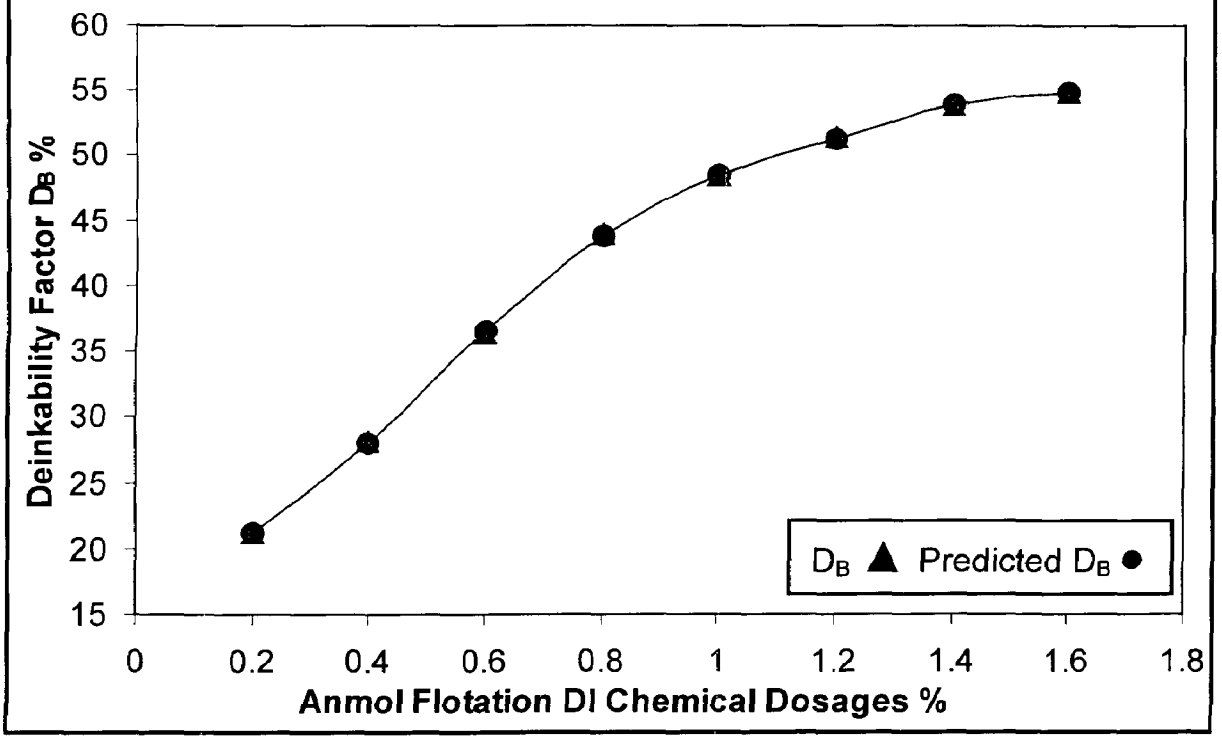


Fig. 4.22 - Anmol Flotation DI dosages Vs. Deinkability Factor D_E for ONP

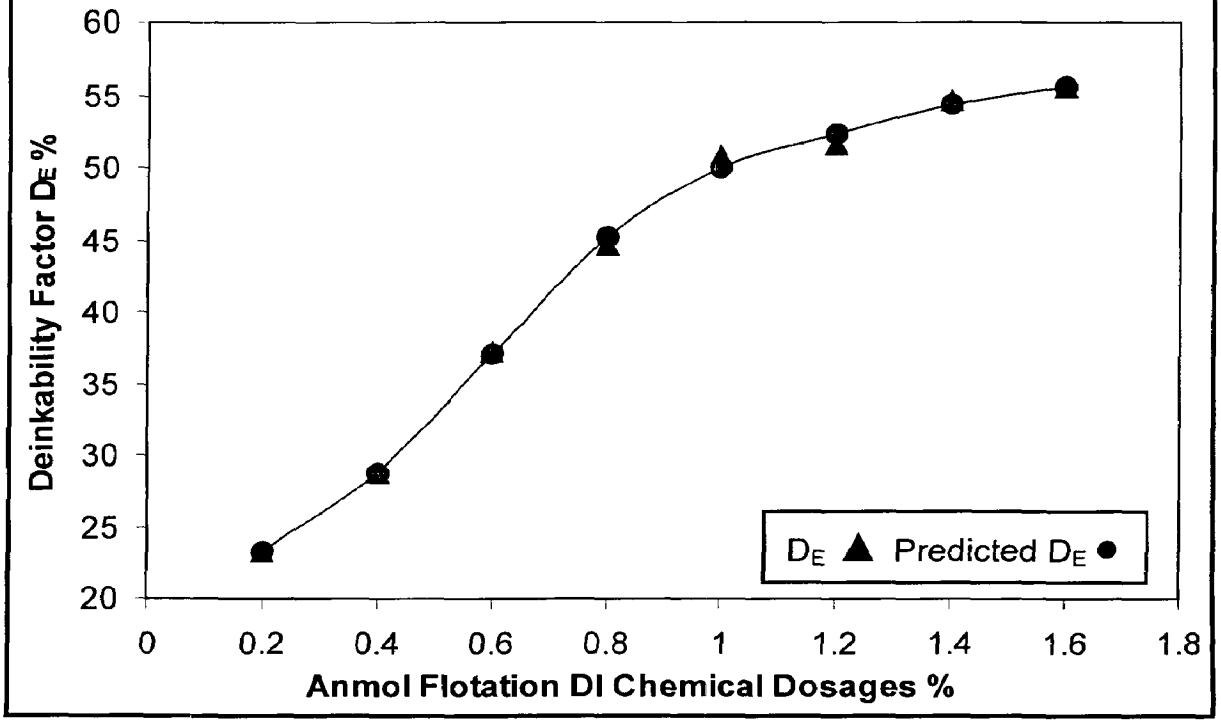


Fig. 4.23 - Pulping Temperature Vs. Deinkability Factor D_B for OMG

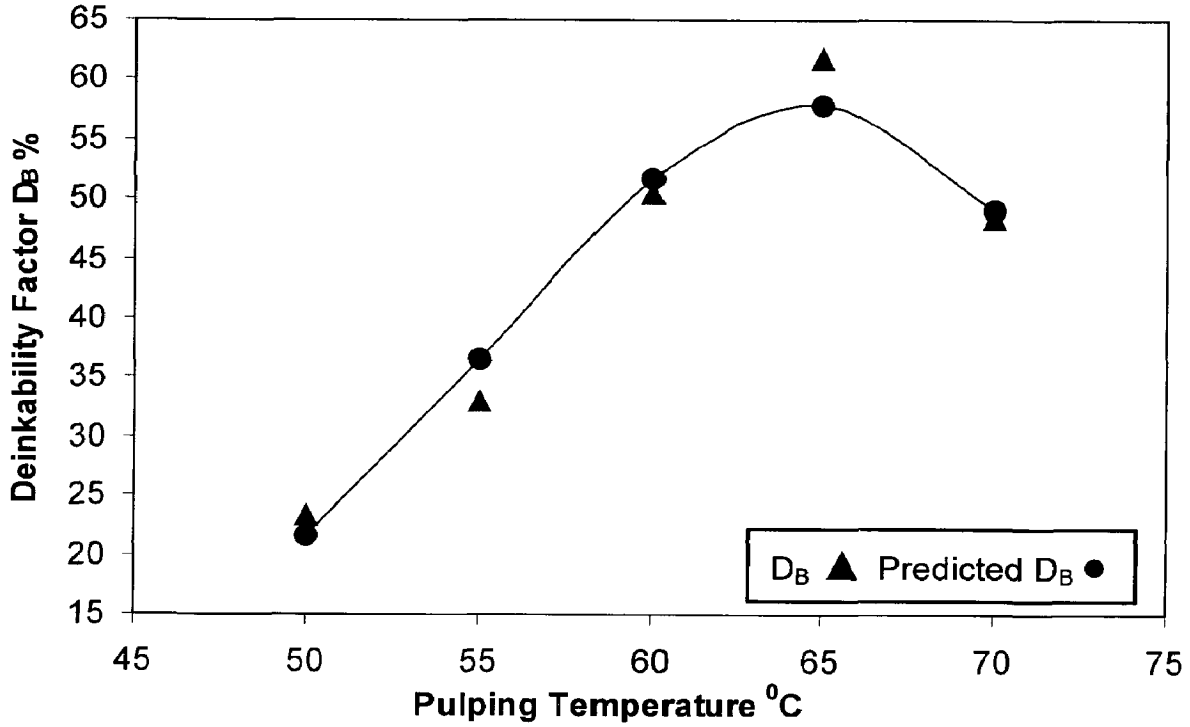
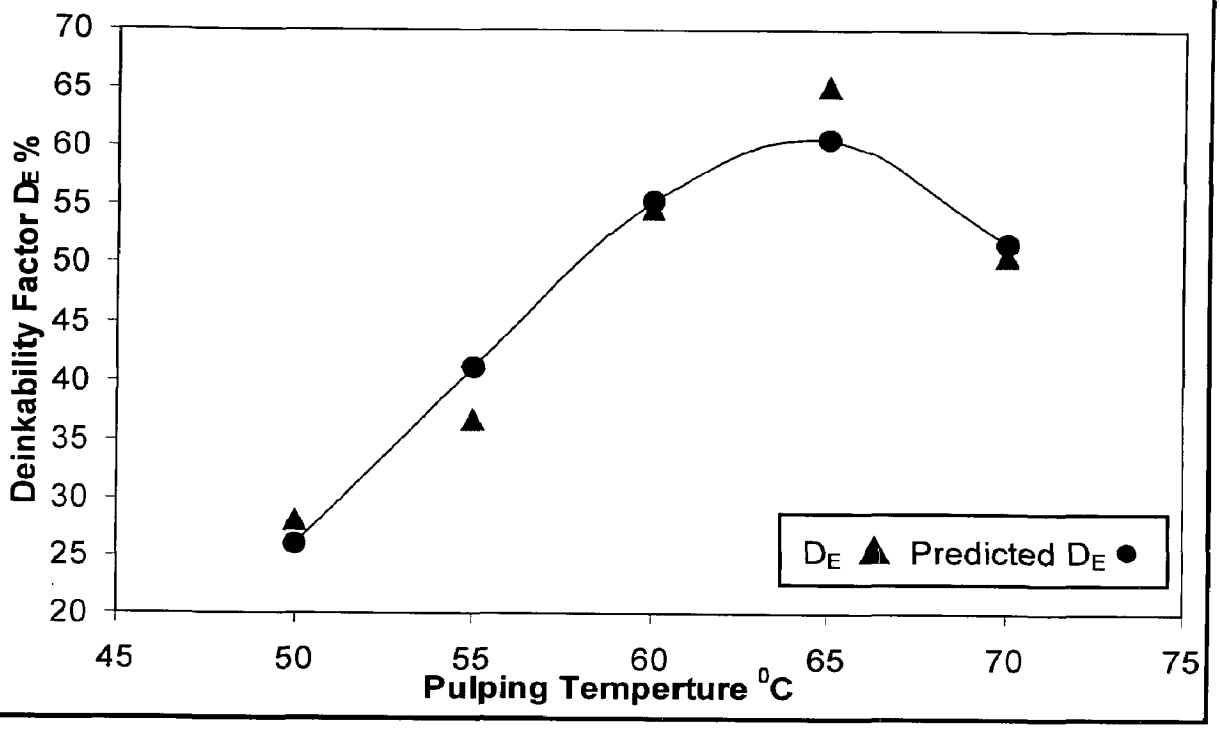


Fig. 4.24 - Pulping Temperature Vs. Deinkability Factor D_E for OMG



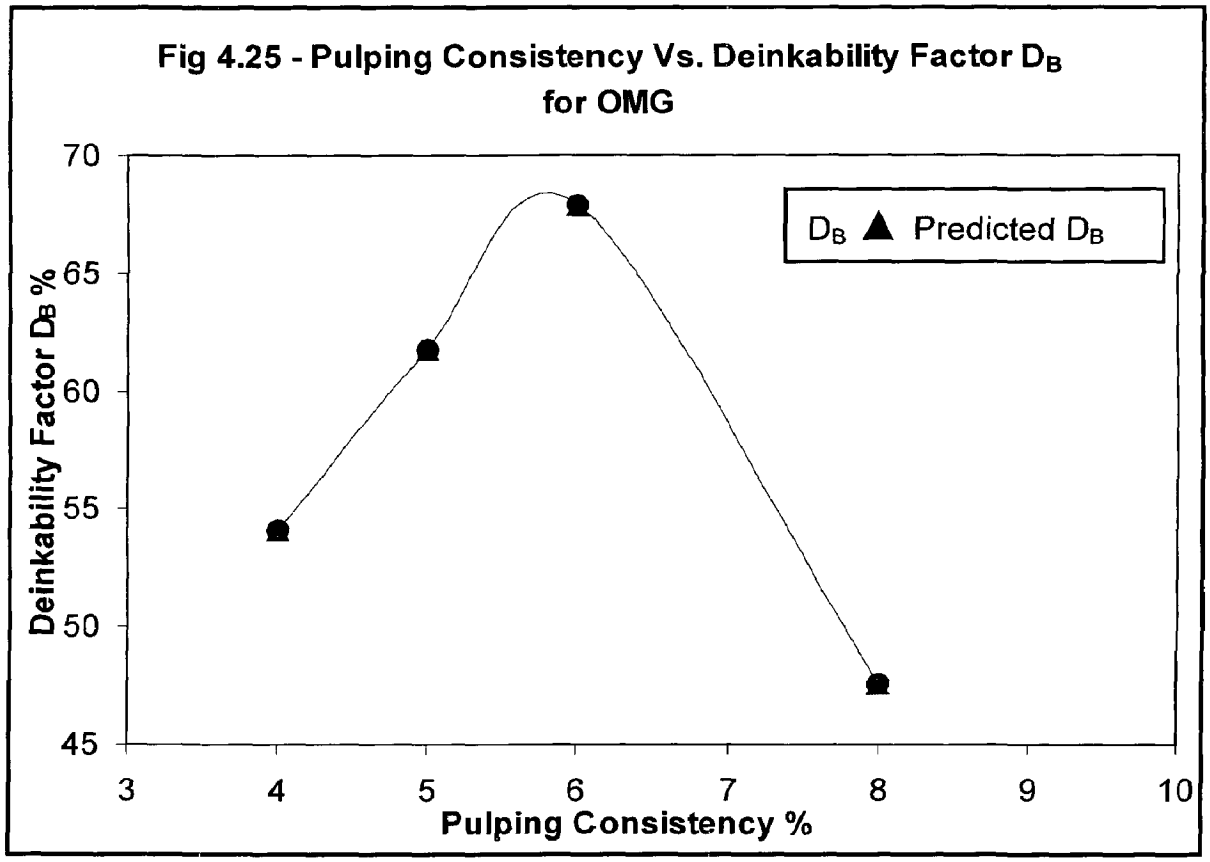


Fig 4.25 - Pulping Consistency Vs. Deinkability Factor D_B for OMG
Deinkability Factor D_B %
70
65
60
55
50
45
3
4
5
6
7
8
9
10
Pulping Consistency %
D_B
Predicted D_B

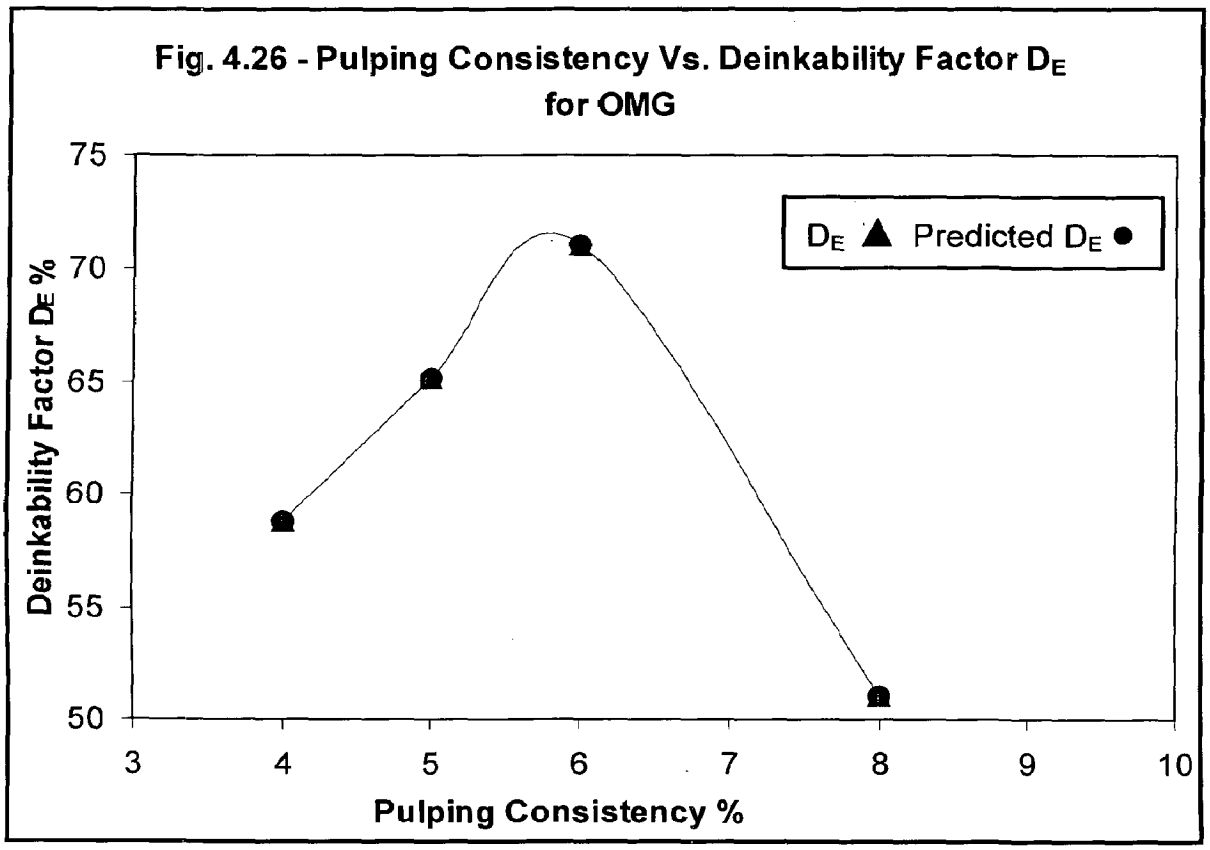


Fig. 4.26 - Pulping Consistency Vs. Deinkability Factor D_E for OMG
Deinkability Factor D_E %
75
70
65
60
55
50
3
4
5
6
7
8
9
10
Pulping Consistency %
D_E
Predicted D_E

Fig. 4.27 - Oleic acid Dosages Vs. Deinkability Factor D_B for OMG

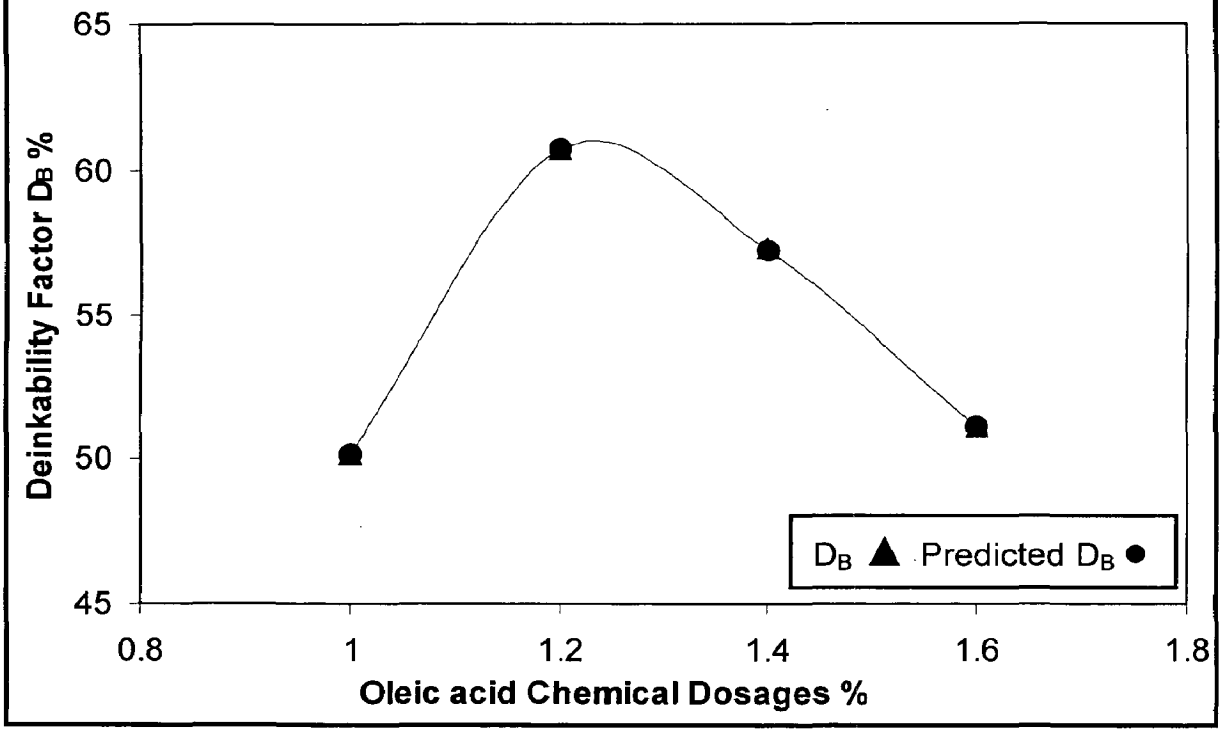


Fig. 4.28 - Oleic acid Dosages Vs. Deinkability Factor D_E for OMG

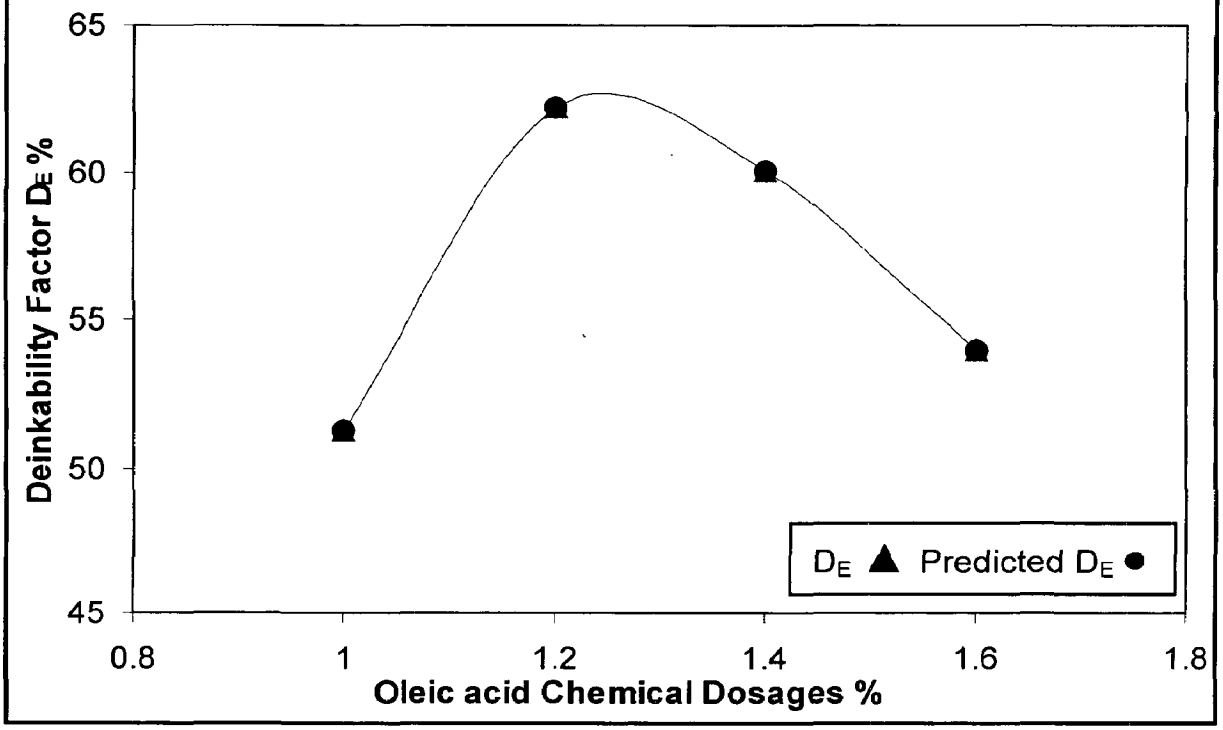


Fig. 4.29 - Palmitic acid Dosages Vs. Deinkability Factor D_B for OMG

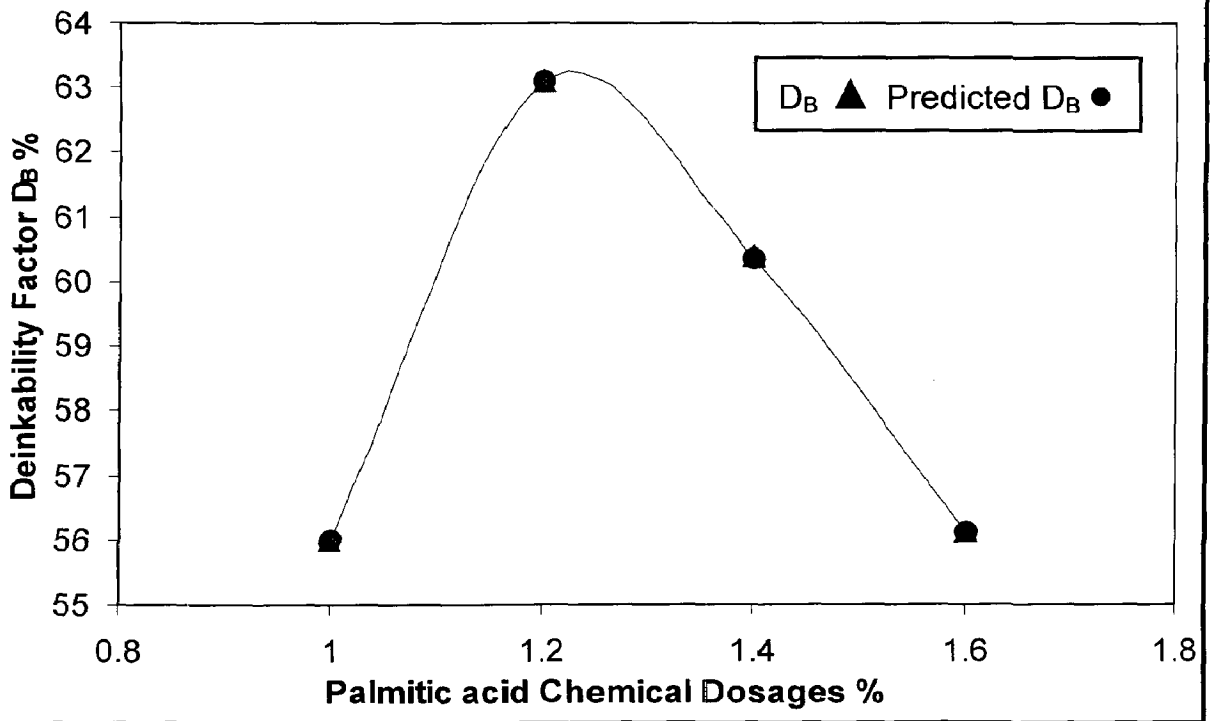


Fig. 4.30 - Palmitic acid Dosages Vs. Deinkability Factor D_E for OMG

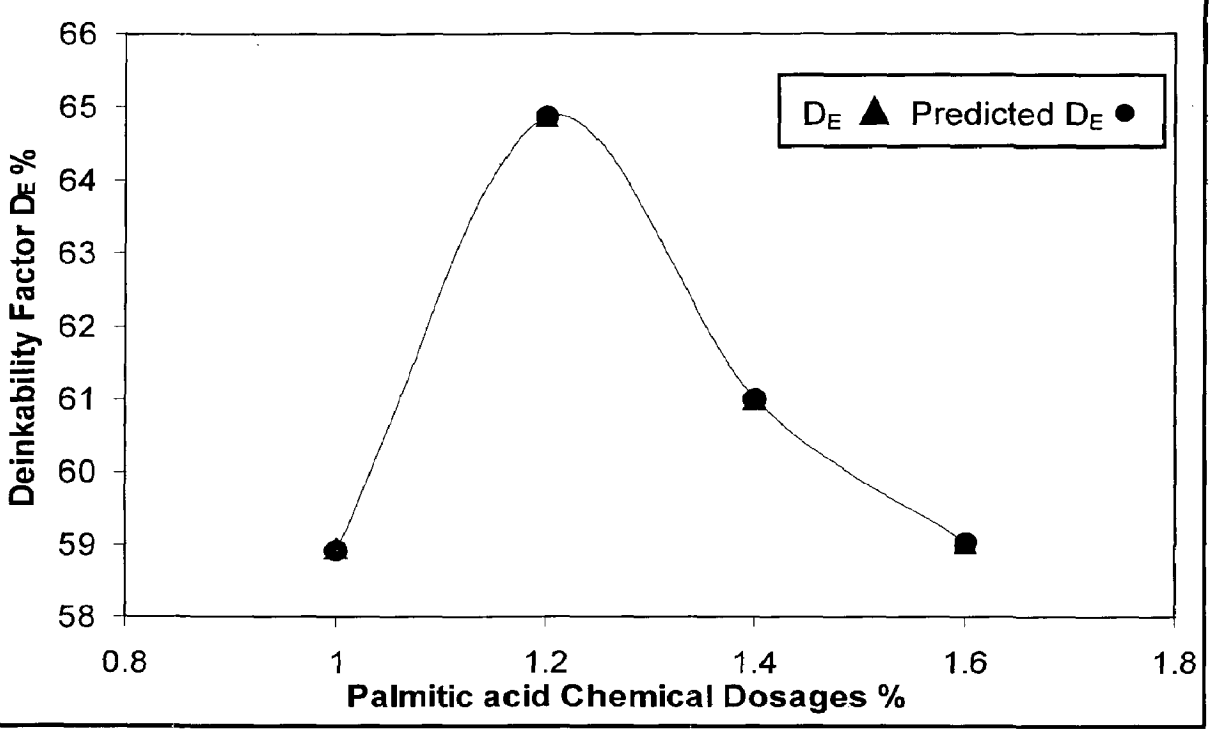


Fig 4.31- Stearic acid Dosages Vs. Deinkability Factor D_B for OMG

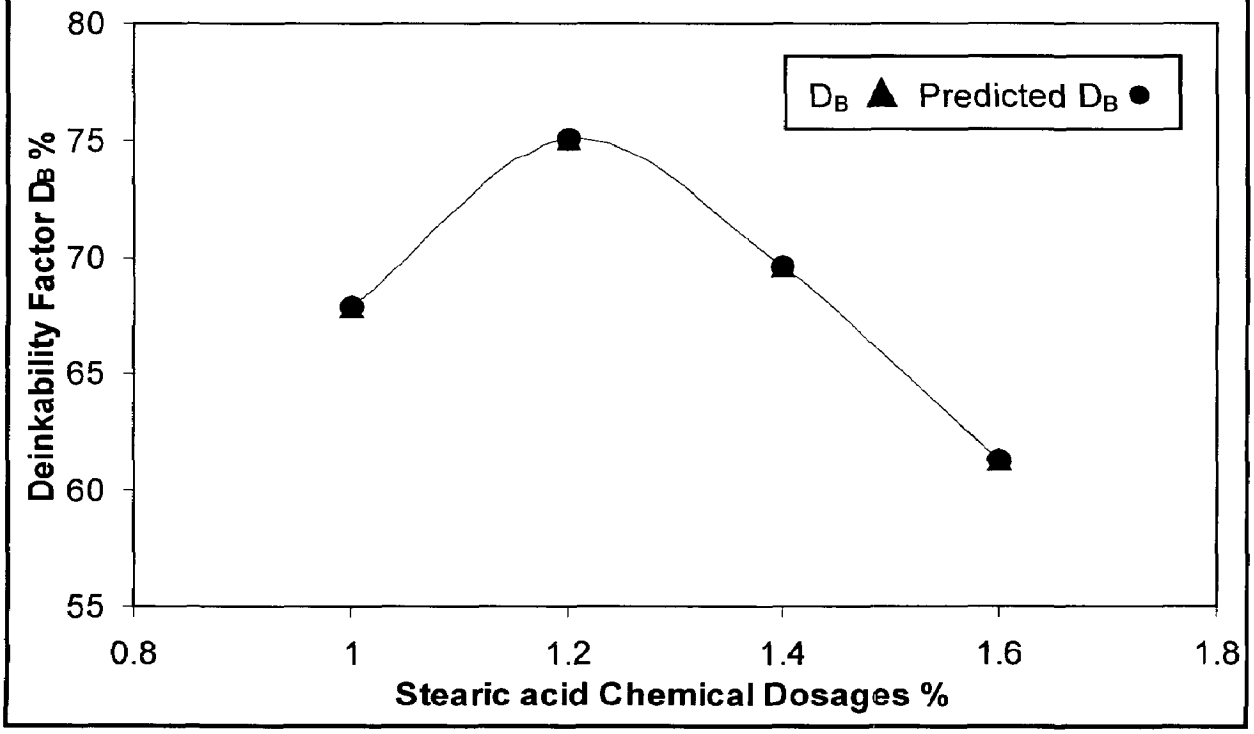
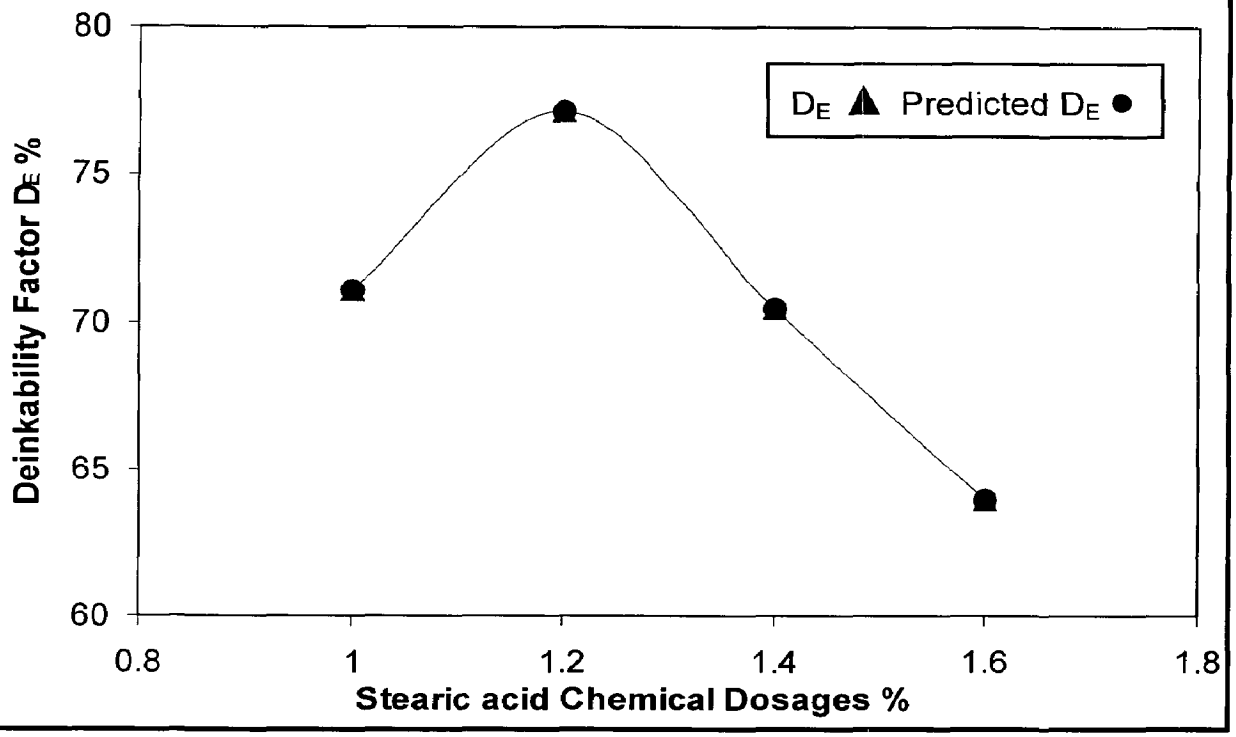


Fig. 4.32 - Stearic acid Dosages Vs. Deinkability Factor D_E for OMG



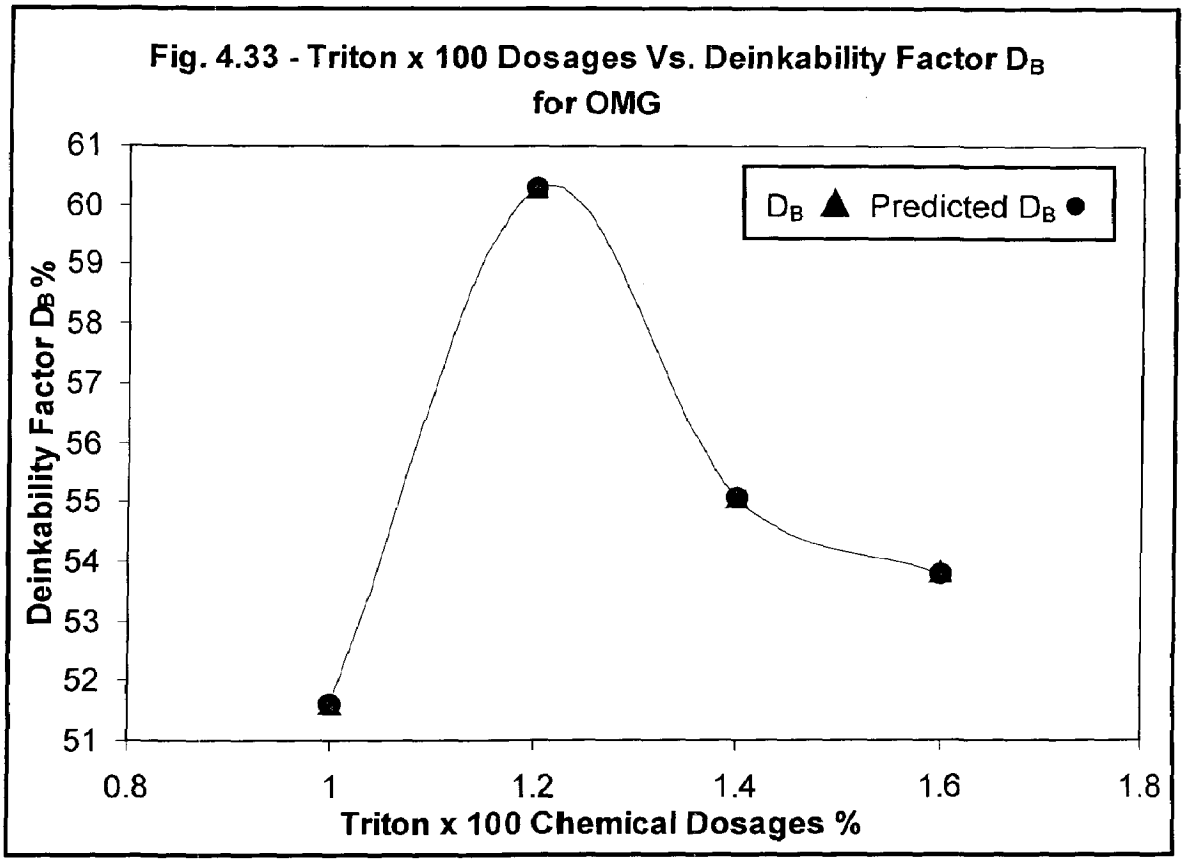


Fig. 4.33 - Triton x 100 Dosages Vs. Deinkability Factor D_B for OMG
Deinkability Factor D_B %
61
60
59
58
57
56
55
54
53
52
51
D_B ▲ Predicted D_B ●
0.8
1
1.2
1.4
1.6
1.8
Triton x 100 Chemical Dosages %

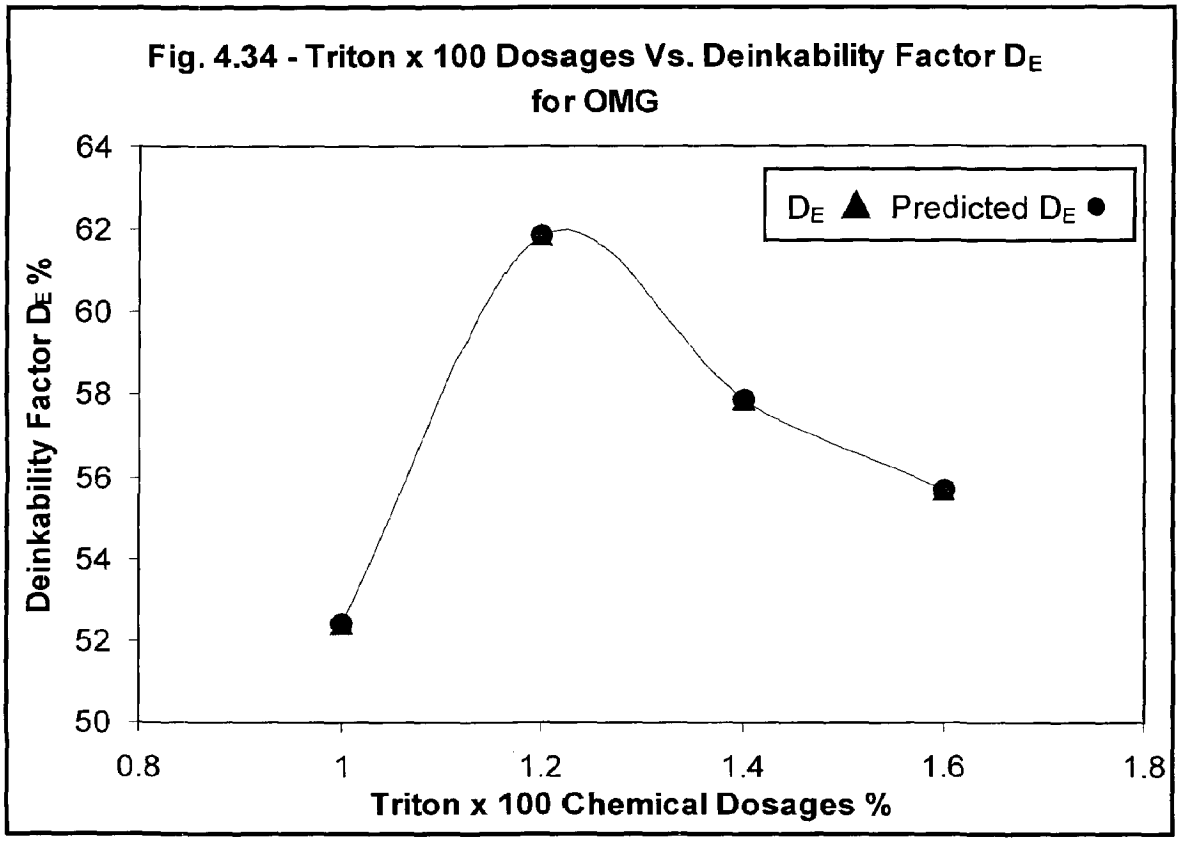


Fig. 4.34 - Triton x 100 Dosages Vs. Deinkability Factor D_E for OMG
Deinkability Factor D_E %
64
62
60
58
56
54
52
50
D_E ▲ Predicted D_E ●
0.8
1
1.2
1.4
1.6
1.8
Triton x 100 Chemical Dosages %

Fig. 4.35 - Brij 35 Dosages Vs. Deinkability Factor D_B for OMG

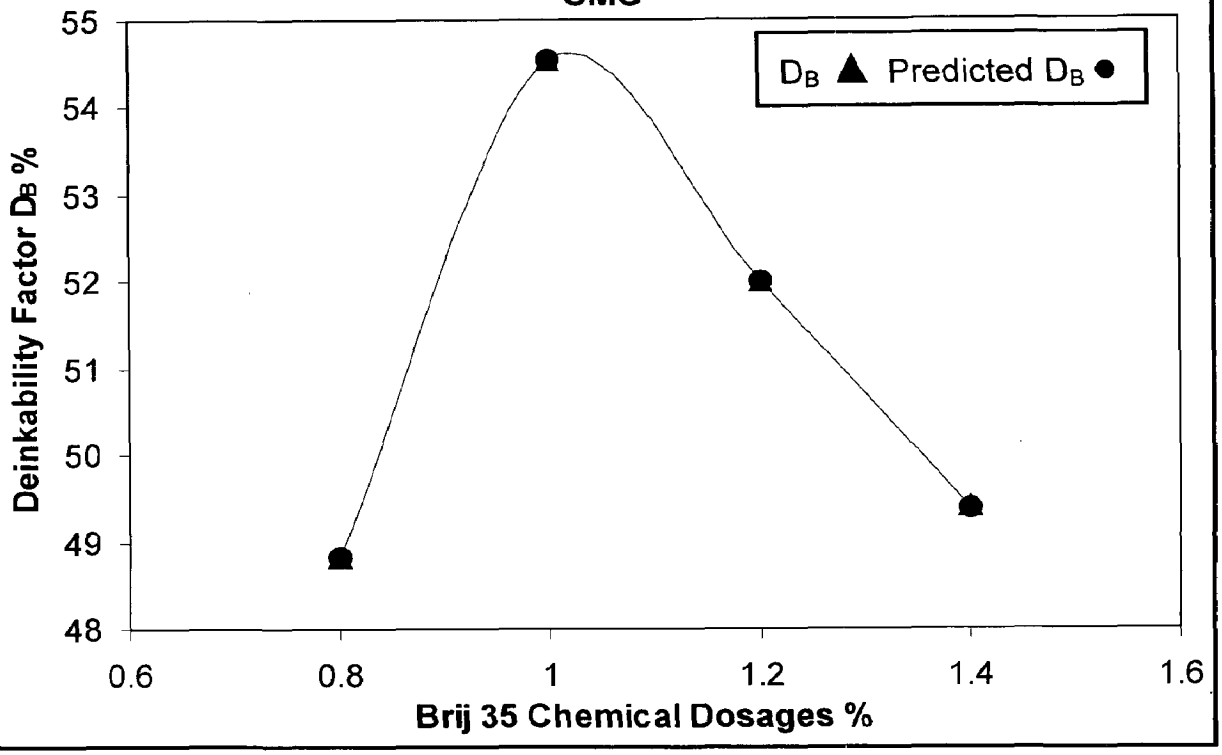


Fig. 4.36 - Brij 35 Dosages Vs. Deinkability Factor D_E for OMG

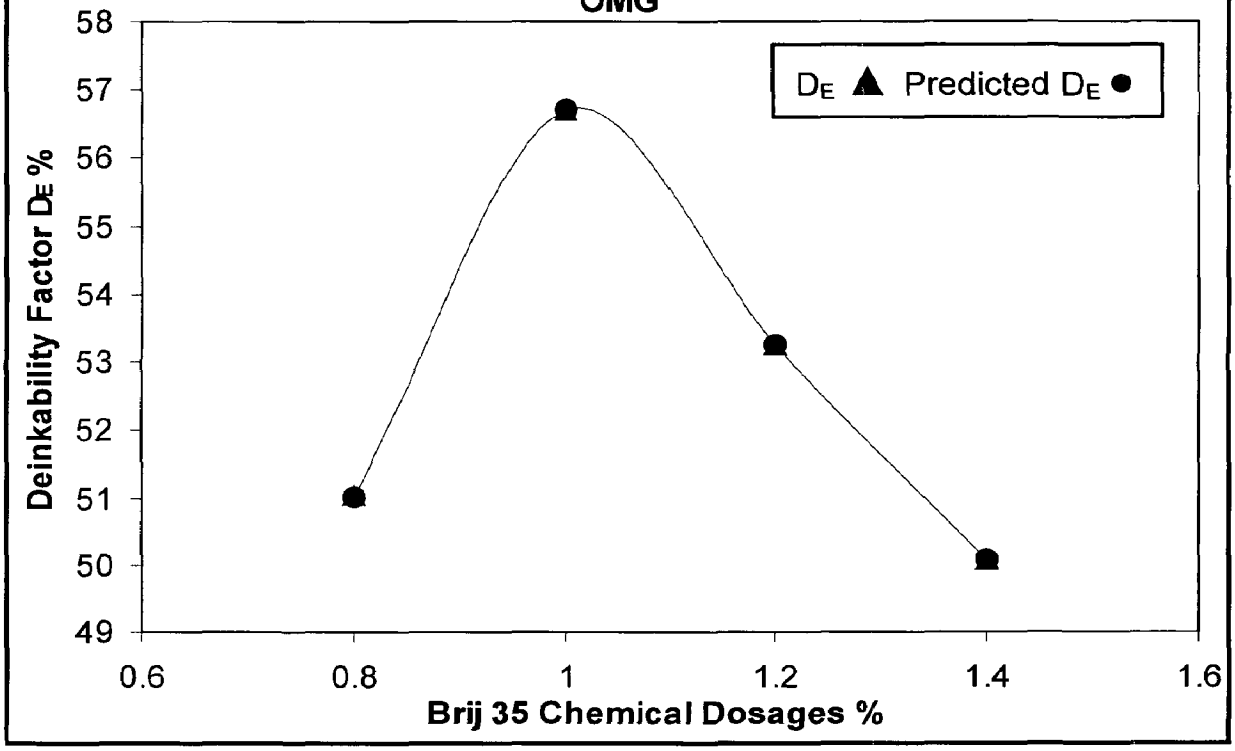


Fig. 4.37- Stearic acid Dosages Vs. Deinkability factor D_B for Coated OMG

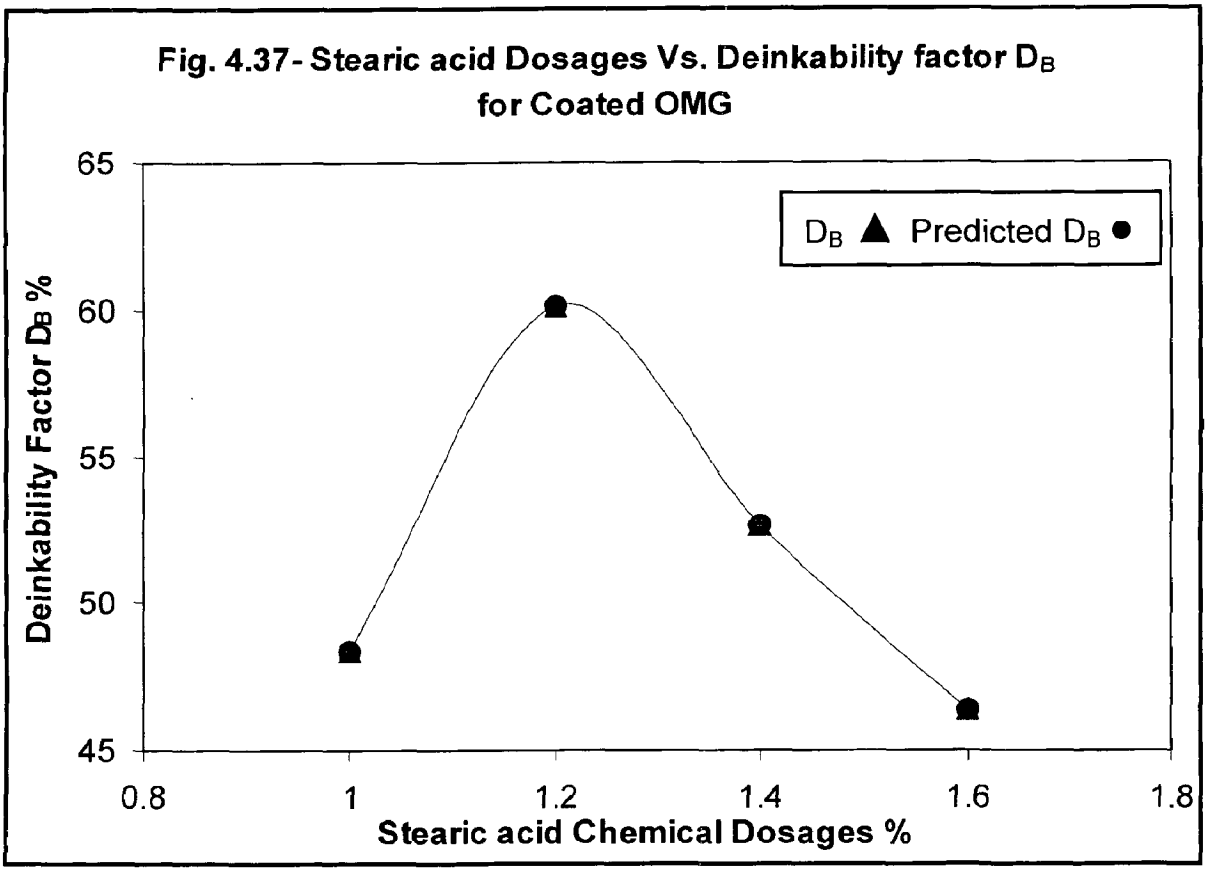


Fig. 4.38 - Stearic acid Dosages Vs. Deinkability factor D_E for Coated OMG

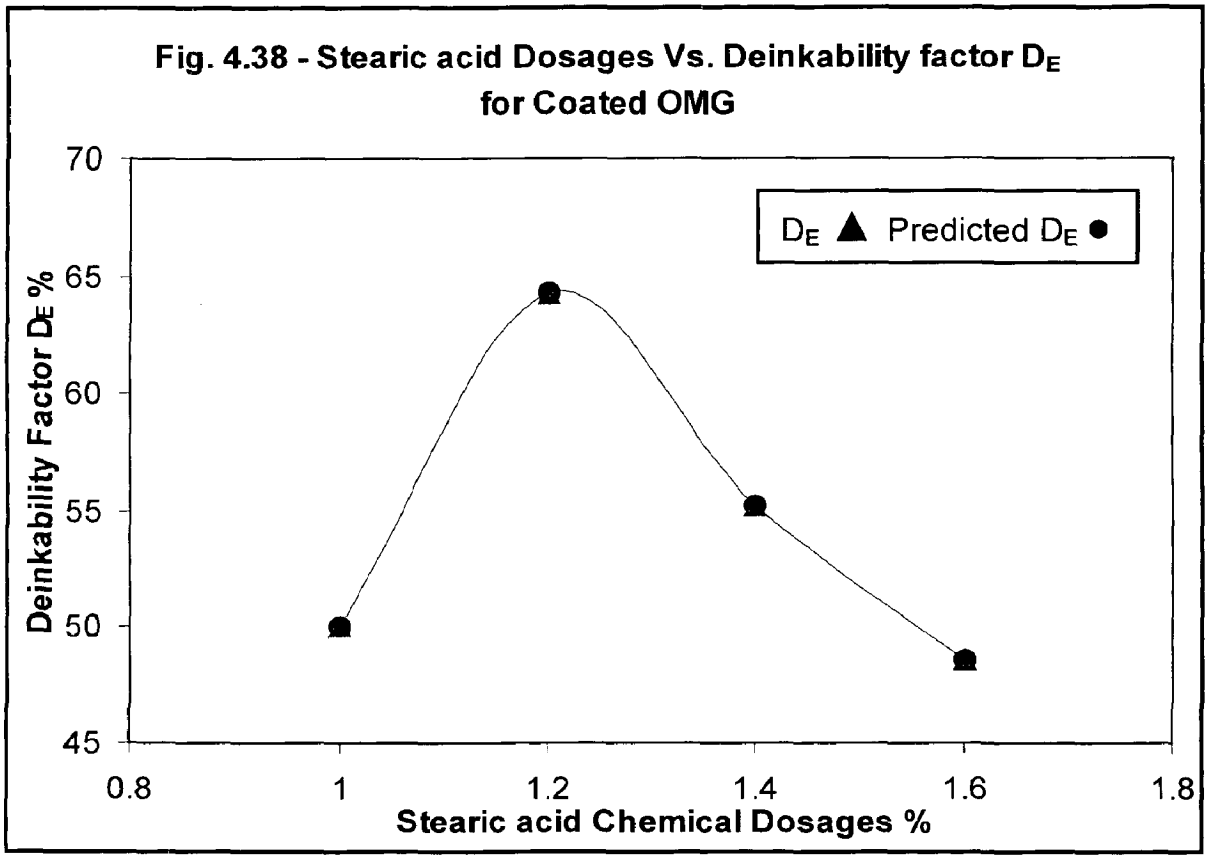


Fig. 4.39 - ONP/OMG Furnish Ratio Vs. Deinkability Factor

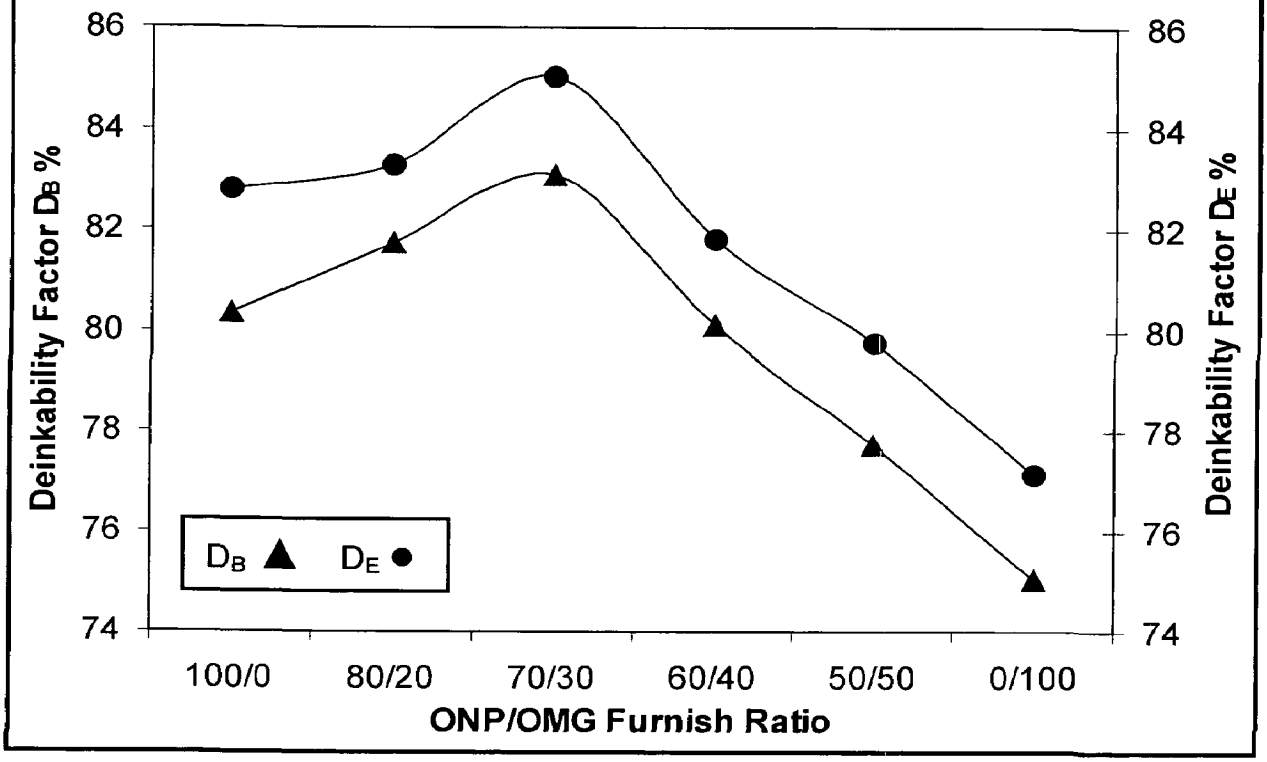
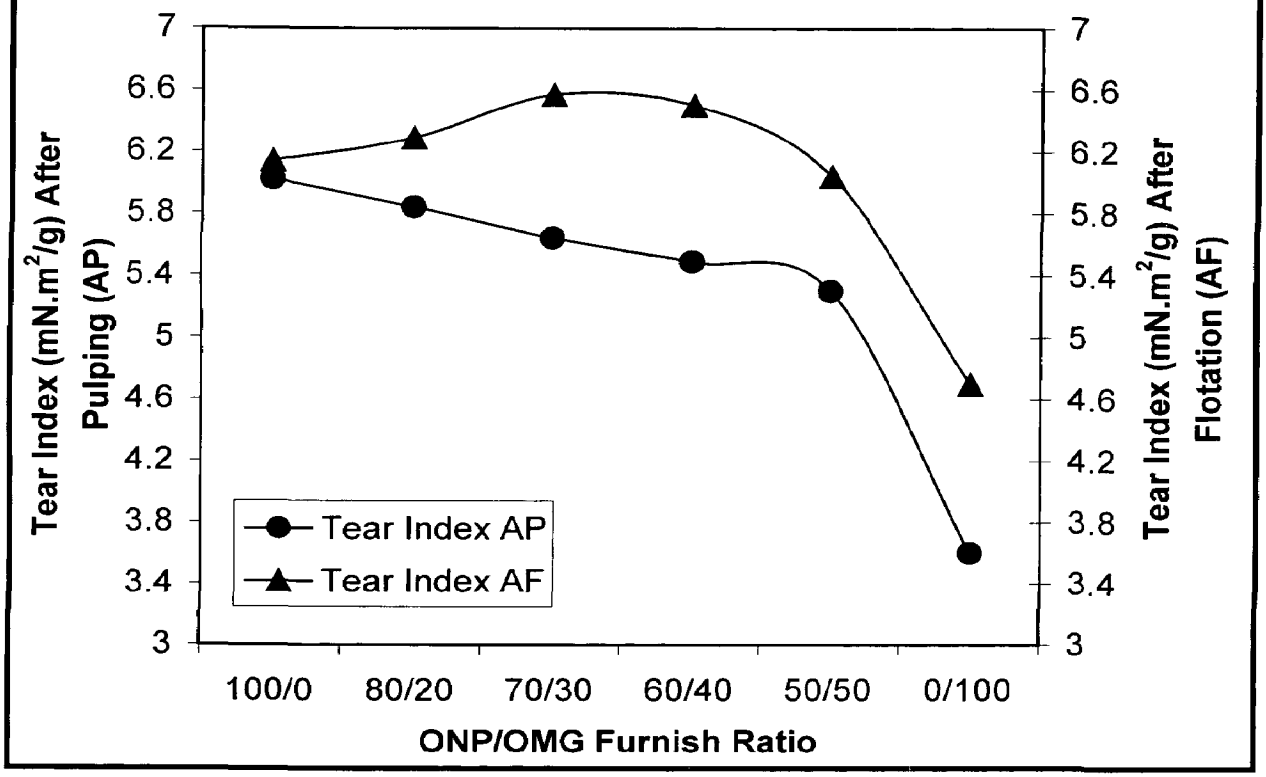


Fig. 4.40 - ONP/OMG Furnish Ratio Vs. Deinkability Factor



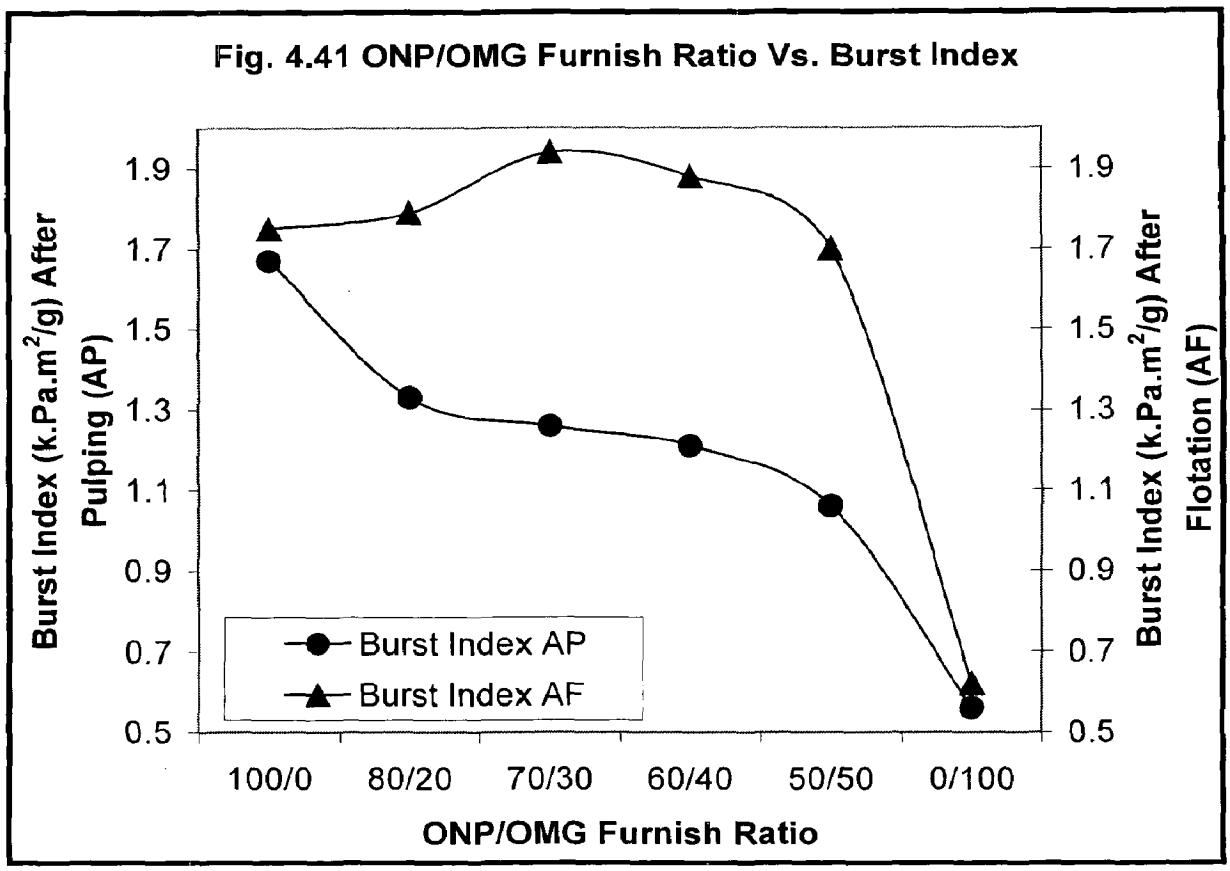


Fig. 4.41 ONP/OMG Furnish Ratio Vs. Burst Index
Burst Index (k.Pa.m²/g) After Pulping (AP)
Burst Index (k.Pa.m²/g) After Flotation (AF)
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
Burst Index AP
Burst Index AF
100/0
80/20
70/30
60/40
50/50
0/100
ONP/OMG Furnish Ratio

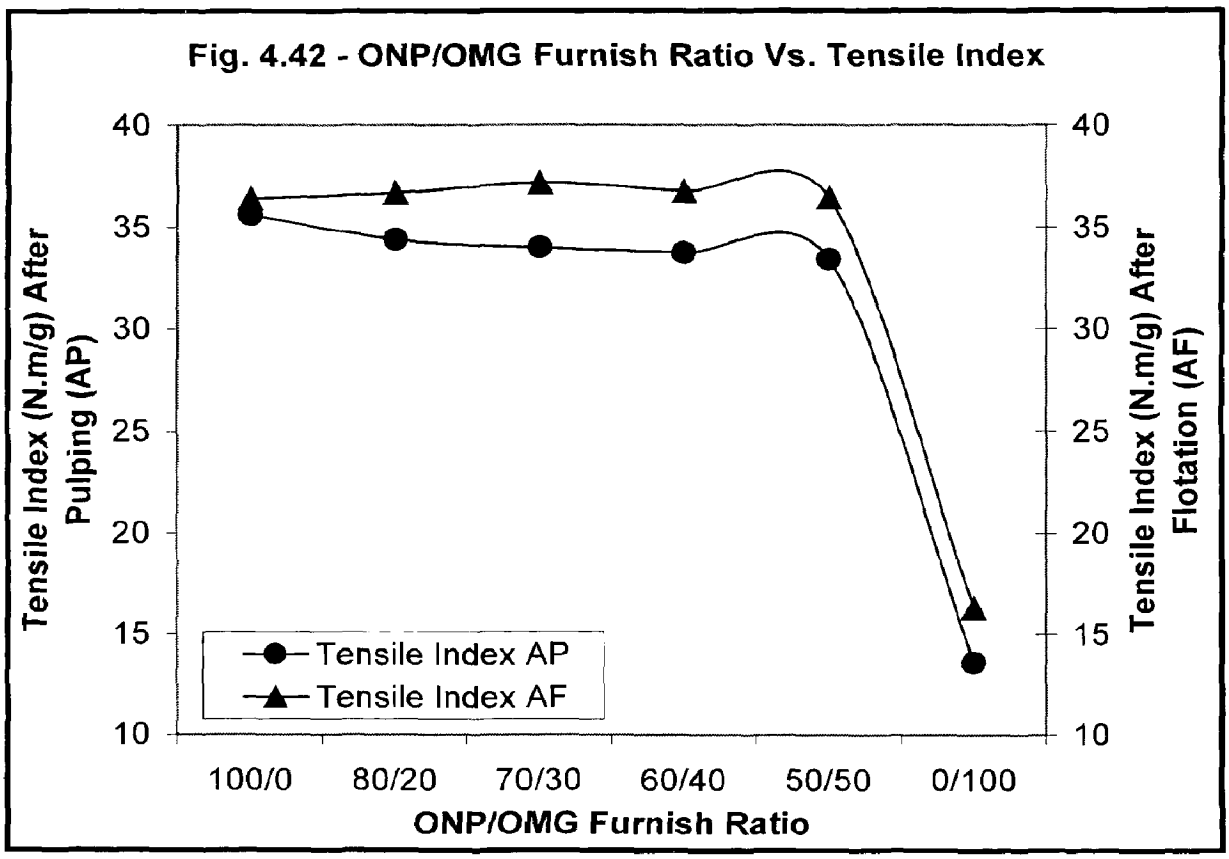


Fig. 4.42 - ONP/OMG Furnish Ratio Vs. Tensile Index
Tensile Index (N.m/g) After Pulping (AP)
Tensile Index (N.m/g) After Flotation (AF)
40
35
30
25
20
15
10
Tensile Index AP
Tensile Index AF
100/0
80/20
70/30
60/40
50/50
0/100
ONP/OMG Furnish Ratio

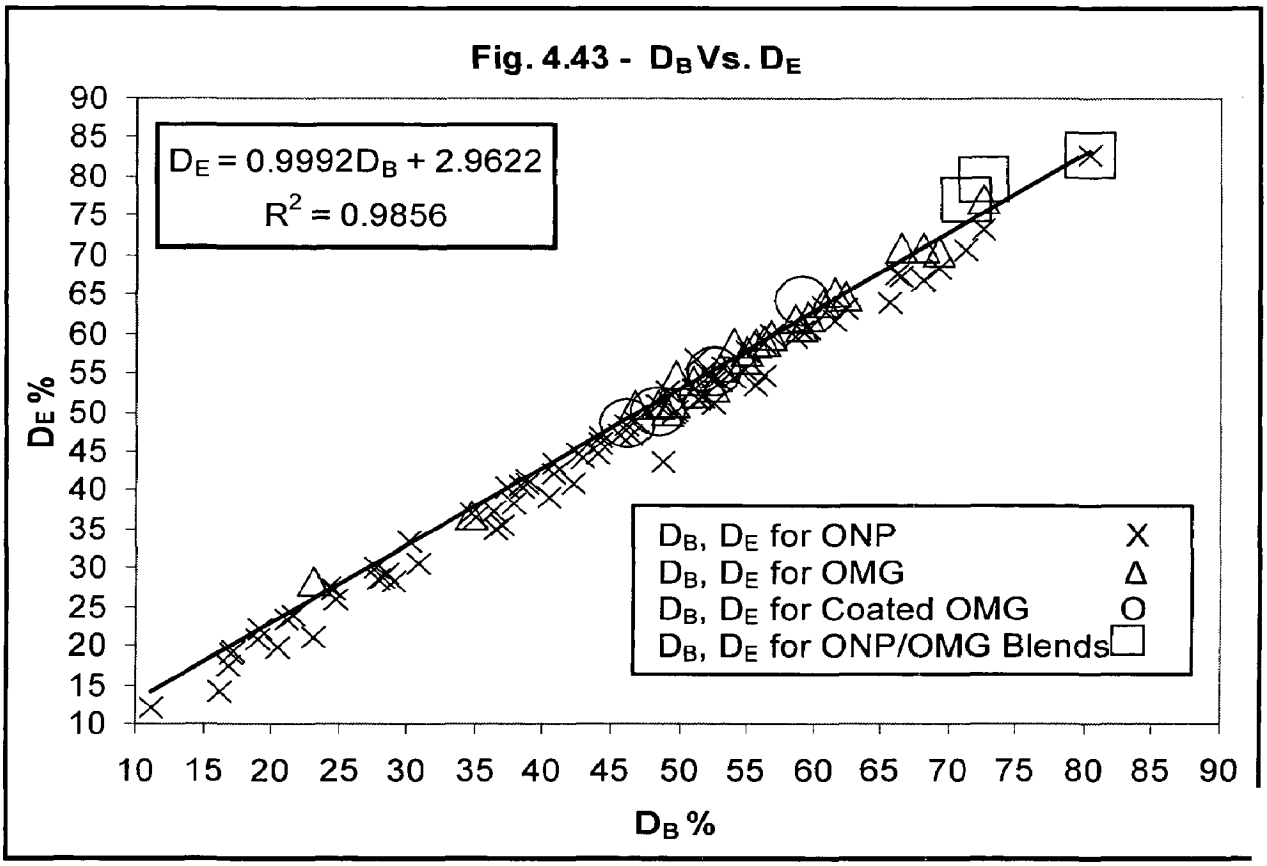


Fig. 4.43 - D_B Vs. D_E
$D_E = 0.9992D_B + 2.9622$
$R^2 = 0.9856$
D_B, D_E for ONP X
D_B, D_E for OMG Δ
D_B, D_E for Coated OMG O
D_B, D_E for ONP/OMG Blends □
D_E %
D_B %
10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

chemical dosage, the ink agglomerate size increases. Initially, for small dosages, the size of the agglomerate is small (<50 μm), which negatively affects the brightness. With the increase of chemical dosages, size of the ink agglomerate increases (>50 μm) up to an optimum size. These large agglomerates are more easily removed by flotation. The deinkability factor is highest at this condition. Finally, beyond the optimum chemical dosage, the agglomerate size increases to a limit where the ink agglomerates remain back in the system, leading to lower deinkability factor. Thus it is observed that the collector dosage is critical to the deinking operation. This may be due to the conversion of hydrophobic material into hydrophilic material because of overdose. Due to the scatter of these large agglomerates, the brightness probably continues to increase. Stearic acid gives best results in comparison to all other active deinking chemicals for all the furnishes.

6. From the above conclusion, it is evident that the used fatty acid / surfactants can be classified in the following two categories:
    a. Stearic, Palmitic, Oleic Acid and Triton x 100, Brij – 35, show a behavior where the ink goes on accumulating on the fixed size air bubbles with the increase in surfactant dosage and reaches to an optimum dosage of surfactant. Beyond this point, the ink agglomerate size is more and is not sustainable on the air bubble. This large size ink agglomerate goes back in the system leading to lower Deinkability Factors with increased dosages.
    b. Tween 80 and Anmol DI surfactants show a behavior where perhaps the surfactant is not only helping the ink agglomeration but also forming intermediate size agglomerate with dust or fines. The

size of agglomerate with dust, fines or ink is such that it goes out on the air bubbles forming foam and leads to relatively cleaner pulp resulting in continuously increasing Deinkability Factor. It has been observed that the loss of fines is relatively more with these surfactants in comparison to Triton x 100, Brij – 35, and fatty acids, which is probably possible with the above reasoning.

7. Flotation deinking models of ONP and OMG show a reasonable fit to all the experimental runs, to predict the deinkability factors under different operating conditions for different process variables, in the present experimental range. Mathematical Polynomial Regression Analysis program is used to calculate the coefficients and a comparison is carried out between the experimental and predicted deinkability factors to show the suitability of the proposed deinkability model. The general n^{th} order polynomial equation for the predication of D_B and D_E. is as below:

$$\ln D_B = a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4 + a_5x^5 + a_6x^6 + \ldots\ldots\ldots\ldots a_nx^n \quad [5.1]$$

$$\ln D_E = a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4 + a_5x^5 + a_6x^6 + \ldots\ldots\ldots\ldots a_nx^n \quad [5.2]$$

Where

D_B = Deinkability Factor based on ISO Brightness

D_E = Deinkability Factor based on ERIC values

a_0, a_1.... a_n are empirical coefficients from the corresponding equation.

x = Dimensionless process variables such as Temperature, Consistency, Pulping/ Flotation Time, Active Deinking Chemical Concentration as used in the respective equation.

8. Polynomial equations with least regression error were obtained to estimate the deinkability factors. The values of n varied between 5 to 6 in different cases. The proposed deinking model is thus predicting the deinkability factors

based on ISO brightness and ERIC values within acceptable limits for the present experiments carried out for ONP and OMG.

9. Wastepaper is a changing furnish because printing inks and printing processes as well as finishing products in papermaking are under continuous development. Although it is tried to work with a 'typical wastepaper furnish' the conclusions drawn from the results might have to be reconsidered by a particular mill with its own typical wastepaper furnish.

10. Effect of operating variables and active deinking chemicals on the blending of ONP was studied with mixture of OMG for 100/0, 80/20, 70/30, 60/40, 50/50 and 0/100. Addition of 70% ONP with 30% OMG was found to be optimum among the four furnishes of ONP/OMG and their blends.

11. The blends of the mixed ONP and OMG were also examined to investigate the change in proportion of mechanical and chemical fibers, fillers, fines, and ink during flotation. After the pulping stage, filler and fiber components from magazines influenced the trends in strength properties. After the flotation stage, enhancement in all strength properties occurred probably due to the loss of most filler and fines during flotation.

12. For all the 124 experimental runs, a relationship is found between D_B and D_E as **y = mx+c** and is as given below:

$$\boxed{D_E = 0.9992D_B + 2.9622 \text{ or approximately } D_E = D_B + 3 \quad \text{.....(5.3)}}$$

$$\boxed{R^2 = 0.9856}$$

The correlation coefficient R^2 gives a good fit of all the experimental data and thus the equation no. 5.3 can be used to predict the other value, if one of the two i.e. either D_B or D_E is known.

13. Yield is lowest at the optimum conditions for ONP, OMG and their blends, may be due to some loss of fibers with ink foam going out from the flotation cell.

5.2 RECOMMENDATIONS

1. More work is needed with proper measurement of size, distribution and flow rate of air bubbles.
2. Further work should be carried out with higher pulp consistency system in hydrapulper, as in the present case we could not perform experiments beyond 8% consistency.
3. More work is needed to explicitly analyze the effect of coated and uncoated OMG and their blends with ONP.
4. More work is needed with different type of Ink and the disposal of the foam generated from environmental consideration.
5. More work is also needed to couple biodeinking with deinking by chemicals only for analyzing the suitability of biotechnology application in deinking process.

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APPENDIX

EXPERIMENTAL DATA ON RECYCLING AND FLOTATION DEINKING OF ONP, OMG AND THEIR BLENDS

Table 1. Experimental data for fiber analysis of the raw material (ONP&OMG)

Sr. No.	Hardwood Chemical fiber %	Hardwood Mechanical fiber %	Softwood Chemical fiber %	Softwood Mechanical fiber %	Chemical pulp %	Mechanical pulp %
A	For ONP (*The Indian Express, Hindustan Times and The Times of India)*					
1	19	18.50	11.29	51.19	30.29	69.69
2	21.23	22.73	7.23	48.79	28.73	71.52
3	24.69	22.77	5.42	47.10	30.11	69.87
B	For coated OMG *(India Today, Business Today)*					
4	15.96	24.60	8.84	50.20	24.80	74.80
5	17.17	22.10	7.90	52.80	25.07	74.90
C	For uncoated OMG (*IPPTA Journal)*				100	0

Table 2 Pulping Conditions of Time variations in pulper for ONP

Sr. No.	Pulping Time (Min)	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	5	45.07	937.89	46.84	839.30
2	8	45.19	872.91	47.92	729.18
3	10	45.52	802.61	50.01	610.42
4	12	46.27	789.06	52.48	516.99
5	14	47.03	771.23	54.37	417.12
6	15	47.31	759.67	55.73	367.39
7	16	47.18	783.69	54.51	426.80
8	18	46.61	819.23	52.43	546.37

PARAMETERS: Temperature 60 ^{0}C, Consistency 5%, Flotation time10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid –1%)

Table 3. Pulping Conditions of Time variations in pulper on Deinkability factor for ONP

Sr. No.	Pulping Time (Min)	X	D_B %	Predict D_B %	D_E %	Predict D_E %
1	5	0.40	11.11	11.11	12.09	12.06
2	8	0.65	17.26	17.31	19.16	19.41
3	10	0.81	29.00	28.52	28.27	27.60
4	12	0.97	42.15	42.92	40.84	41.46
5	14	1.14	52.54	52.33	54.62	55.94
6	**15**	**1.22**	**61.50**	**56.67**	**61.61**	**58.46**
7	16	1.30	53.03	55.57	54.01	55.59
8	18	1.46	40.44	40.26	39.19	39.08

PARAMETERS: Temperature 60 ^{0}C, Consistency 5%, Flotation time 10 Minutes, (Blank Run: ERIC 123 ppm, ISO Brightness 61) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%)
x = Dimensionless Pulping time, Deinkability factor D_B %, D_E % experimentally and Predicted ln D_B%, ln D_E% from equations

Table 4 Pulping Conditions of Temperature variations in pulper for ONP

Sr. No.	Temperature ^{0}C	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	40	45.15	1197.03	47.82	1008.96
2	45	45.57	1093.67	48.91	861.89
3	50	46.61	989.31	51.87	685.54
4	55	47.19	878.46	53.96	480.39
5	60	47.31	759.67	55.73	367.39
6	65	48.01	668.35	56.53	319.26
7	70	46.22	796.09	53.89	423.17
8	75	46.17	937.33	51.73	608.57

PARAMETERS: Pulping Time 15 Minutes, Consistency 5%, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%)

Table 5 Pulping Conditions of Temperature variations in pulper on Deinkability factor for ONP

Sr. No.	Temperature ^0C	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	40	0.947	16.84	14.99	17.51	16.00
2	45	0.962	21.64	24.99	23.87	25.99
3	50	0.977	36.55	37.53	35.06	38.32
4	55	0.992	49.02	50.18	52.59	50.74
5	60	1.007	61.50	59.00	61.61	59.63
6	**65**	**1.022**	**65.58**	**60.21**	**64.01**	**61.46**
7	70	1.037	51.89	52.57	55.40	54.83
8	75	1.052	37.34	38.69	40.37	41.78

PARAMETERS: Consistency 5%, Pulping Time 15 Minutes Flotation time 10 Minutes, (Blank Run: ERIC 123 ppm, ISO Brightness 61) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%) x = Dimensionless Temperature, Deinkability factor D_B %, D_E% experimentally and Predicted In D_B %, In D_E % from equations

Table 6 Pulping Conditions of Consistency variations in pulper for ONP

Sr. No.	Consistency %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	2	44.89	1162.21	48.62	943.19
2	3	45.95	1027.04	51.71	659.27
3	4	46.16	944.16	53.76	476.43
4	5	48.01	668.35	56.53	319.26
5	6	48.12	616.47	56.89	286.79
6	8	48.33	583.09	53.13	407.17

PARAMETERS: Temperature 65 ^0C, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%)

Table 7 Pulping Conditions of Consistency variations in pulper on Deinkability factor for ONP

Sr. No.	Consistency %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	2	0.43	23.15	23.16	21.07	21.04
2	3	0.65	38.27	38.14	40.68	40.81
3	4	0.86	51.21	51.51	56.75	56.50
4	5	1.08	65.58	65.25	64.01	64.17
5	**6**	**1.30**	**68.09**	**68.21**	**66.80**	**66.75**
6	8	1.73	37.88	37.87	38.23	38.23

PARAMETERS: Temperature 65 ^{0}C, Pulping Time 15 Minutes Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%) x = Dimensionless Consistency, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 8 Flotation Conditions of Time variations in flotation cell for ONP

Sr. No.	TIME (Min)	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	2	48.12	616.47	50.47	513.37
2	4	48.12	616.47	51.69	467.64
3	6	48.12	616.47	53.38	407.96
4	8	48.12	616.47	55.29	352.13
5	10	48.12	616.47	56.89	286.79
6	12	48.12	616.47	57.03	278.43
7	14	48.12	616.47	57.29	267.78

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping time 15 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid – 1%)

Table 9 Flotation Conditions of Time variations in flotation cell on Deinkability factor for ONP

Sr. No.	TIME (Min)	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	2	0.25	18.93	18.92	20.89	20.86
2	4	0.50	27.71	27.78	30.15	30.36
3	6	0.75	40.83	40.56	42.25	41.53
4	8	1	55.66	56.14	53.56	54.74
5	**10**	**1.25**	**68.09**	**67.66**	**66.80**	**65.75**
6	12	1.50	69.17	69.33	68.50	68.91
7	14	1.75	71.19	71.16	70.66	70.59

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, (Blank Run: ERIC 123 ppm, ISO Brightness 61) Chemicals (NaOH – 2.0 %, Na_2SiO_3 - 2.5 %, DTPA - 0.5 %, H_2O_2 - 1 %, Stearic acid – 1 %) x = Dimensionless Flotation time, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 10 Pulping Conditions of Oleic acid dosages variations *in pulper for* ONP

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	0.2	44.17	1123.38	46.89	981.21
2	0.4	45.28	970.31	49.13	738.57
3	0.6	46.12	892.19	51.63	619.49
4	0.8	48.06	774.43	53.97	467.98
5	1.0	48.69	720.67	55.23	387.39
6	1.2	50.01	662.15	56.86	321.62
7	1.4	52.18	553.82	57.14	317.37
8	1.6	53.76	419.25	57.29	289.52

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%)

Table 11 Pulping Conditions of Oleic acid dosages variations in pulper on Deinkability factor for ONP

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	0.2	0.22	16.16	16.09	14.21	14.26
2	0.4	0.44	24.49	24.97	27.35	26.83
3	0.6	0.66	37.02	35.72	35.45	35.79
4	0.8	0.88	45.67	46.39	47.04	45.21
5	1.0	1.11	53.12	54.85	55.76	56.87
6	**1.2**	**1.33**	**62.32**	**59.27**	**63.16**	**63.06**
7	1.4	1.55	56.23	57.79	54.88	54.73
8	1.6	1.77	48.75	48.48	43.79	43.82

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes (Blank Run: ERIC 123 ppm, ISO Brightness 61) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 12 Pulping Conditions of Palmitic acid dosages variations in pulper for ONP

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	0.2	45.81	1189.13	48.73	952.56
2	0.4	46.13	1000.49	50.37	743.24
3	0.6	47.08	965.61	52.47	617.31
4	0.8	47.56	842.20	54.63	453.11
5	1.0	48.13	670.27	55.79	337.65
6	1.2	49.01	616.05	56.97	284.37
7	1.4	51.87	461.68	57.06	259.05
8	1.6	52.98	347.22	57.19	232.49

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%)

Table 13 Pulping Conditions of Palmitic acid dosages variations in pulper on Deinkability factor for ONP

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	0.2	0.22	19.22	19.21	22.18	22.16
2	0.4	0.44	28.51	28.52	29.31	29.40
3	0.6	0.66	38.72	39.02	41.33	41.13
4	0.8	0.88	52.60	51.20	54.10	53.71
5	1.0	1.11	59.51	61.87	60.77	62.56
6	**1.2**	**1.33**	**66.38**	**64.44**	**67.27**	**64.99**
7	1.4	1.55	56.84	57.50	59.82	60.91
8	1.6	1.77	52.49	52.39	51.16	50.97

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes (Blank Run: ERIC 123 ppm, ISO Brightness 61) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 14 Pulping Conditions of Stearic acid dosages variations in pulper for ONP

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	0.2	46.31	1069.54	49.98	809.46
2	0.4	46.71	927.62	51.66	630.51
3	0.6	47.32	819.19	53.63	483.24
4	0.8	48.06	764.67	55.17	394.11
5	1.0	48.12	616.47	56.89	286.79
6	1.2	49.61	580.95	58.76	201.62
7	1.4	53.43	383.18	58.92	192.43
8	1.6	55.36	304.59	59.09	181.72

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%)

Table 15 Pulping Conditions of Stearic acid dosages variations in pulper on Deinkability factor for ONP

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	0.2	0.22	24.27	24.15	27.47	23.87
2	0.4	0.44	34.63	35.39	36.92	36.93
3	0.6	0.66	46.12	44.49	48.25	46.02
4	0.8	0.88	54.94	55.86	57.74	56.28
5	1.0	1.11	68.09	69.48	66.80	68.78
6	**1.2**	**1.33**	**80.33**	**77.88**	**82.83**	**77.07**
7	1.4	1.55	72.52	73.66	73.31	73.57
8	1.6	1.77	66.13	65.94	67.66	66.04

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes,(Blank Run: ERIC 123 ppm, ISO Brightness 61) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted ln D_B %, ln D_E % from equations

Table 16 Pulping Conditions of Triton x 100 dosages variations in pulper for ONP

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	0.2	44.21	1289.41	47.08	1067.26
2	0.4	45.02	1176.29	49.84	824.62
3	0.6	46.17	1019.34	51.93	652.08
4	0.8	47.00	974.60	53.19	583.11
5	1.0	47.72	861.77	54.30	494.02
6	1.2	48.07	747.59	55.36	380.43
7	1.4	50.61	543.23	55.78	332.10
8	1.6	51.68	467.69	56.01	305.41

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA – 0.5%, H_2O_2 - 1%)

Table 17 Pulping Conditions of Triton x 100 dosages variations in pulper on Deinkability factor for ONP

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	0.2	0.22	17.09	17.04	19.04	18.97
2	0.4	0.44	30.16	30.56	33.38	33.85
3	0.6	0.66	38.84	38.10	40.97	40.31
4	0.8	0.88	44.21	44.17	45.97	45.36
5	1.0	1.11	49.54	51.01	49.77	52.23
6	**1.2**	**1.33**	**56.38**	**54.59**	**58.78**	**56.08**
7	1.4	1.55	49.75	50.48	50.24	51.28
8	1.6	1.77	46.45	46.32	47.07	46.90

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, (Blank Run: ERIC 123 ppm, ISO Brightness 61) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted ln D_B %, ln D_E % from equations

Table 18 Pulping Conditions of Brij 35 dosages variations in pulper for ONP

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	0.2	43.11	1523.04	46.78	1245.56
2	0.4	44.23	1481.14	48.89	1092.64
3	0.6	45.07	1297.37	50.64	867.29
4	0.8	46.55	1083.71	52.70	652.82
5	1.0	47.01	957.30	54.16	516.02
6	1.2	48.93	778.50	54.27	471.26
7	1.4	50.21	699.46	54.83	443.89
8	1.6	51.48	534.57	55.14	368.11

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA – 0.5%, H_2O_2 - 1%)

Table 19 Pulping Conditions of Brij 35 dosages variations in pulper on Deinkability factor for ONP

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	0.2	0.22	20.51	20.54	19.81	19.81
2	0.4	0.44	27.78	27.54	28.60	28.48
3	0.6	0.66	34.96	35.31	36.62	36.88
4	0.8	0.88	42.56	43.27	44.85	45.27
5	**1.0**	**1.11**	**51.10**	**48.25**	**52.89**	**50.67**
6	1.2	1.33	44.24	47.09	46.87	49.36
7	1.4	1.55	42.81	41.49	44.33	43.11
8	1.6	1.77	38.44	38.67	40.44	40.67

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes,(Blank Run: ERIC 123 ppm, ISO Brightness 61) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 20 Pulping Conditions of Tween 80 dosages variations in pulper for ONP

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	0.2	46.68	1471.59	50.23	1121.82
2	0.4	47.32	1266.47	51.52	917.05
3	0.6	47.60	1000.61	53.06	620.35
4	0.8	48.05	910.22	54.11	526.64
5	1.0	48.39	869.03	54.91	481.51
6	1.2	48.83	815.11	55.96	402.94
7	1.4	49.19	768.93	56.17	379.26
8	1.6	49.88	682.14	56.64	327.52

PARAMETERS: Temperature 65 ^{0}C, Consistency 6 %, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%)

Table 21 Pulping Conditions of Tween 80 dosages variations in pulper on Deinkability factor for ONP

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	0.2	0.22	24.79	24.75	25.93	25.92
2	0.4	0.44	30.70	30.99	30.55	30.82
3	0.6	0.66	40.74	39.84	43.32	41.97
4	0.8	0.88	46.79	47.50	48.72	50.16
5	1.0	1.11	51.70	52.60	51.94	53.12
6	1.2	1.33	58.58	56.53	59.55	56.10
7	1.4	1.55	59.10	60.40	60.32	62.74
8	1.6	1.77	60.79	60.50	63.42	62.85

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes,(Blank Run: ERIC 123 ppm, ISO Brightness 61) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted ln D_B %, ln D_E % from equations

Table 22 Pulping Conditions of Anmol Flotation DI dosages variations in pulper for ONP

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	0.2	46.24	1352.49	49.62	1066.07
2	0.4	47.11	1261.96	51.02	934.32
3	0.6	47.85	1183.54	52.63	788.18
4	0.8	48.05	1010.68	53.76	614.23
5	1.0	48.70	906.44	54.66	507.81
6	1.2	49.13	812.05	55.23	456.11
7	1.4	50.08	709.37	55.97	389.20
8	1.6	51.01	563.19	56.49	318.49

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA – 0.5%, H_2O_2 - 1%)

Table 23 Pulping Conditions of Anmol Flotation DI dosages variations in pulper on Deinkability factor for ONP

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	0.2	0.22	21.13	21.14	23.29	23.29
2	0.4	0.44	28.14	28.06	28.76	28.73
3	0.6	0.66	36.34	36.53	37.27	37.19
4	0.8	0.88	44.09	43.87	44.66	45.15
5	1.0	1.11	48.45	48.55	50.88	50.01
6	1.2	1.33	51.39	51.38	51.65	52.33
7	1.4	1.55	53.93	53.92	54.60	54.32
8	1.6	1.77	54.85	54.85	55.58	55.62

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes,(Blank Run: ERIC 123 ppm, ISO Brightness 61) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 24 Pulping Conditions of Temperature variations in pulper for OMG

Sr. No.	Temperature ^{0}C	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	50	49.78	632.17	55.67	485.19
2	55	51.02	482.84	58.94	345.95
3	60	59.64	432.72	67.41	256.33
4	65	62.17	407.20	70.09	213.47
5	70	63.80	391.63	69.23	248.53

PARAMETERS: Pulping Time 15 Minutes, Consistency 5%, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic Acid – 1%)

Table 25 Pulping Conditions of Temperature variations in pulper for OMG

Sr. No.	Temperature ^0C	x	D_B %,	Predict D_B %,	D_E %	Predict D_E %
1	50	0.96	23.35	21.65	28.14	26.05
2	55	0.98	33.02	36.64	36.71	41.20
3	60	1	50.58	51.65	54.65	55.36
4	**65**	**1.01**	**61.73**	**57.93**	**65.18**	**60.68**
5	70	1.03	48.48	49.10	50.81	51.85

PARAMETERS: Consistency 5%, Pulping Time 15 Minutes, Flotation time 10 Minutes, (Blank Run: ERIC 110 ppm, ISO Brightness 75) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic Acid – 1%) x = Dimensionless Temperature, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 26 Pulping Conditions of Consistency variations in pulper for OMG

Sr. No.	Consistency %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	4	58.41	482.73	67.39	263.54
2	5	62.17	407.20	70.09	205.47
3	6	65.22	377.19	71.86	187.29
4	8	63.02	332.68	68.72	219.06

PARAMETERS: Temperature 65 ^0C,Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic Acid – 1%)

Table 27 Pulping Conditions of Consistency variations in pulper for OMG

Sr. No.	Consistency %	x	D_B %,	Predict D_B %,	D_E %	Predict D_E %
1	4	0.69	54.12	54.11	58.80	58.79
2	5	0.86	61.73	61.73	65.18	65.18
3	**6**	**1.04**	**67.89**	**67.88**	**71.07**	**71.06**
4	8	1.39	47.57	47.57	51.02	51.02

PARAMETERS: Temperature 65 ^0C, Pulping Time 15 Minutes, Flotation time 10 Minutes, (Blank Run: ERIC 110 ppm, ISO Brightness 75) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic Acid – 1%) x = Dimensionless Consistency, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 28 Pulping Conditions of Oleic acid dosages variations in pulper for OMG

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	1.0	58.63	685.24	66.84	390.40
2	1.2	61.14	631.94	69.56	307.13
3	1.4	63.78	579.06	70.21	297.44
4	1.6	66.47	486.88	70.83	283.35

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%)

Table 29 Pulping Conditions of Oleic acid dosages variations in pulper on Deinkability factor for OMG

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	1.0	0.76	50.15	50.14	51.25	51.25
2	**1.2**	**0.92**	**60.75**	**60.75**	**62.23**	**62.22**
3	1.4	1.07	57.30	57.29	60.03	60.03
4	1.6	1.23	51.11	51.11	54.00	53.99

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes (Blank Run: ERIC 110 ppm, ISO Brightness 75) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 30 Pulping Conditions of Palmitic acid dosages variations in pulper for OMG

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	1.0	59.23	621.42	68.06	319.97
2	1.2	62.72	589.27	70.47	278.34
3	1.4	65.38	442.18	71.19	239.55
4	1.6	67.41	364.88	71.67	214.38

PARAMETERS: Temperature 65 ^{0}C, Consistency 6 %, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%)

Table 31 Pulping Conditions of Palmitic acid dosages variations in pulper on Deinkability factor for OMG

Sr. No.	Chemical Dosage%	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	1.0	0.76	55.99	55.98	58.94	58.93
2	**1.2**	**0.92**	**63.11**	**63.11**	**64.87**	**64.87**
3	1.4	1.07	60.39	60.38	61.00	60.99
4	1.6	1.23	56.12	56.12	59.04	59.04

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, (Blank Run: ERIC 110 ppm, ISO Brightness 75) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 32 Pulping Conditions of Stearic acid dosages variations in pulper for OMG

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	1.0	65.22	377.19	71.86	187.29
2	1.2	66.10	339.43	72.78	162.52
3	1.4	68.39	268.66	72.99	156.89
4	1.6	69.86	219.27	73.01	149.37

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%)

Table 33 Pulping Conditions of Stearic acid dosages variations in pulper on Deinkability factor for OMG

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	1.0	0.76	67.89	67.88	71.07	71.06
2	**1.2**	**0.92**	**75.05**	**75.06**	**77.10**	**77.11**
3	1.4	1.07	69.59	69.58	70.44	70.43
4	1.6	1.23	61.28	61.28	63.96	63.96

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, (Blank Run: ERIC 110 ppm, ISO Brightness 75) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 34 Pulping Conditions of Triton x 100 dosages variations in pulper for OMG

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	1.0	58.03	743.51	66.79	411.32
2	1.2	59.43	685.08	68.82	329.25
3	1.4	61.17	566.37	69.34	302.10
4	1.6	64.28	457.14	70.05	263.77

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%)

Table 35 Pulping Conditions of Triton x 100 dosages variations in pulper on Deinkability factor for OMG

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	1.0	0.76	51.62	51.62	52.43	52.43
2	**1.2**	**0.92**	**60.30**	**60.29**	**61.87**	**61.86**
3	1.4	1.07	55.09	55.09	57.90	57.90
4	1.6	1.23	53.82	53.81	55.70	55.69

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, (Blank Run: ERIC 110 ppm, ISO Brightness 75) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted ln D_B %, ln D_E % from equations

Table 36 Pulping Conditions of Brij 35 dosages variations in pulper for OMG

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	0.8	53.76	973.22	64.13	532.61
2	1.0	55.24	729.54	66.02	378.15
3	1.2	58.39	602.31	67.03	339.98
4	1.4	61.58	486.67	68.21	298.01

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%)

Table 37 Pulping Conditions of Brij 35 dosages variations in pulper on Deinkability factor for ONP

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	0.8	0.72	48.82	48.82	51.04	51.03
2	**1.0**	**0.90**	**54.55**	**54.54**	**56.71**	**56.71**
3	1.2	1.09	52.01	52.01	53.28	53.28
4	1.4	1.27	49.40	49.39	50.08	50.08

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, (Blank Run: ERIC 110 ppm, ISO Brightness 75) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA -0.5%, H_2O_2 - 1%) x = *Dimensionless Chemical dosage, Deinkability factor* D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 38 Pulping Conditions of Stearic acid dosages variations in pulper for Coated OMG

Sr. No.	Chemical Dosage %	AFTER PULPING		AFTER FLOTATION	
		ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	1.0	53.42	509.53	60.47	314.05
2	1.2	54.23	472.37	62.51	245.29
3	1.4	57.38	342.75	62.98	219.11
4	1.6	58.86	271.92	63.10	197.66

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%)

Table 39 Pulping Conditions of Stearic acid dosages variations in pulper on Deinkability factor for Coated OMG

Sr. No.	Chemical Dosage %	x	D_B %	Predict D_B %	D_E %	Predict D_E %
1	1.0	0.76	48.35	48.34	50.05	50.04
2	**1.2**	**0.92**	**60.13**	**60.13**	**64.26**	**64.26**
3	1.4	1.07	52.63	52.62	55.25	55.24
4	1.6	1.23	46.38	46.38	48.56	48.56

PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, (Blank Run: ERIC 119 ppm, ISO Brightness 68) Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%) x = Dimensionless Chemical dosage, Deinkability factor D_B %, D_E % experimentally and Predicted In D_B %, In D_E % from equations

Table 40 ONP/OMG Blends variations in Flotation deinking

Sr. No.	Furnish ratio %	AFTER PULPING		AFTER FLOTATION	
	ONP: OMG Blends	ISO Brightness %	ERIC (ppm)	ISO Brightness %	ERIC (ppm)
1	100 : 0	49.61	580.95	58.76	201.62
2	80 : 20	51.03	564.75	61.63	194.23
3	70 : 30	52.18	476.39	62.83	172.40
4	60 : 40	50.42	404.51	63.70	170.12
5	50 : 50	51.62	368.55	64.35	167.11
6	0 : 100	66.10	339.43	72.78	162.52
PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA – 0.5%, H_2O_2 - 1%, Stearic acid 1.2%)					

Table 41 ONP/OMG Blends variations in Flotation deinking on Deinkability factor

Sr. No.	Furnish ratio %	Blank Run		D_B %	D_E %
	ONP:OMG Blends	ISO Brightness %	ERIC (ppm)		
1	100 : 0	61	123	80.33	82.83
2	80 : 20	64	120	81.72	83.30
3	**70 : 30**	**65**	**119**	**83.07**	**85.05**
4	60 : 40	67	118	80.09	81.80
5	50 : 50	68	116	77.71	79.76
6	0 : 100	75	110	75.05	77.10
PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid 1.2%)					

Table 42 ONP/OMG Blends variations in Flotation deinking on strength properties

Sr. No.	Furnish ratio %	AFTER PULPING			AFTER FLOTATION		
	ONP: OMG Blends	Tear Index ($mN.m^2/g$)	Burst Index ($k.Pa.m^2/g$)	Tensile Index (N. m/g)	Tear Index ($mN.m^2/g$)	Burst Index ($kPa.m^2/g$)	Tensile Index (N. m/g)
1	100 : 0	6.02	1.67	35.61	6.14	1.75	36.43
2	80 : 20	5.84	1.33	34.40	6.29	1.79	36.69
3	**70 : 30**	**5.64**	**1.26**	**34.01**	**6.57**	**1.94**	**37.18**
4	60 : 40	5.49	1.21	33.77	6.50	1.88	36.79
5	50 : 50	5.30	1.06	33.43	6.04	1.70	36.46
6	0 : 100	3.6	0.56	13.6	4.7	0.62	16.3
PARAMETERS: Temperature 65 ^{0}C, Consistency 6%, Pulping Time 15 Minutes, Flotation time 10 Minutes, Chemicals (NaOH – 2.0%, Na_2SiO_3 - 2.5%, DTPA - 0.5%, H_2O_2 - 1%, Stearic acid 1.2%)							