COMPARISON OF SAW WELDS FABRICATED BY INDIGENOUS AND GERMAN CONSUMABLES

A DISSERTATION

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

of

MASTER OF TECHNOLOGY

in

MECHANICAL ENGINEERING

(With Specialization in Welding Engineering)

By

ANUJ VERMA

DEPARTMENT OF MECHANICAL & INDUSTRIAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE
ROORKEE - 247 667 (INDIA)

FEBRUARY, 2002

CANDIDATE'S DECLARARTION

I hereby declare that the work, which is being presented in this dissertation entitled, **"COMPARISON OF SAW WELDS FABRICATED BY INDIGENOUS AND GERMAN CONSUMABLES"** in the partial fulfilment of the requirements for the award of the degree of **Master of Technology** in **Mechanical Engineering** with the specialization in **"Welding Engineering"**, submitted in the Mechanical and Industrial Engineering Department, Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period from August 2001 to February 2002 under the supervision and guidance of **Shri C.L.Raina**, Assistant Professor, Mechanical and Industrial Engineering Department, Indian Institute of Technology, Roorkee.

I have not submitted the matter embodied in this dissertation for the award of any other degree or diploma.

Place: Roorkee.

Dated: February 26, 2002.

(ANUJ VERMA)

CERTIFICATE

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

Dated: February 26, 2002

(C.L.RAINA)

Mech. & Ind. Engg. Department

Indian Institute of Technology, Roorkee.

Roorkee – 247 667 (INDIA)

ACKNOWLEDGEMENT

I am highly indebted to my guide **Shri C.L.Raina,** Mechanical and Industrial Engineering Department, Indian Institute of Technology, Roorkee for encouraging me to undertake this dissertation as well as providing me all the necessary guidance and inspirational support throughout this dissertation work, without which this dissertation would not have been in the present form.

I extend my grateful thanks to my friends and staff of the Welding Research Laboratory for their cooperation and generous support.

Last but not least, but for the Blessing and continued encouragement of my parents this thesis work would not seen the light of the day.

(ANUJ VERMA)
M. Tech (Welding Engineering)

ABSTRACT

In this present work investigations have been done to study the Mechanical and Metallurgical properties of weld fabricated by Indigenous consumables and German consumables at different values of current.

Mechanical properties like Ultimate Tensile Strength, Yield Strength, Percentage Elongation and Percentage Reduction in Area, Impact Strength and Hardness are compared. Experimental results shown that the weld fabricated by indigenous consumables have improved properties than the German consumables.

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INTRODUCTION

The feature that distinguishes SAW from other arc welding process is the granular material that covers the welding area. By common usage this material is termed as flux. Flux plays a central role in achieving the high deposition rates and good weld quality that characterize the SAW process. Reaction between the flux and molten metal influences the cleanliness, properties and sometimes the composition of the weld metal; and it influences the shape of the weld bead and its mechanical properties. Good corrosion resistance, depending on the requirement, can be obtained by proper selection of flux and wire. With correct selection of consumables, mechanical properties at least equal to those of the base metal are consistently obtained. Mechanical properties can be determined by conducting standard tests on the weld metal specimen. Mechanical properties determine the behavior of weld metal under applied loads.

There are various tests to determine the mechanical properties of the weld metal. In destructive tests, tensile test and impact tests are important. Tensile test helps in determining properties like Ultimate Tensile Strength, Yield strength, percentage Elongation, percentage reduction in area. If the values of Percentage Elongation is large indicates it is more ductile

Impact Strength is a complex characteristic which takes into account both toughness and ductility which account for both toughness and strength of a weld material.

The capacity of material to resist or absorb shock energy before it fractures is called its impact strength. Ductile material posses high Impact strength than brittle materials. Impact Strength of a material can be found by subjecting the specimen to impact loading.

LITERATURE REVIEW

2.1 HISTORICAL BACK GROUND

In 1887 the Nikalas Von Berardos and Stanislav Olezewski, in which a single carbon electrode was used, fusion being obtained by drawing an arc between the work to be welded and carbon electrode, receive a patent of arc welding. Metal was added from an auxiliary rod into the arc or molten puddle [15, 16].

Strohmenger obtained a U.S. patent in 1912 for heavy-covered electrode coated with blue asbestoses with a binder of sodium silicate or water glass. This was the first covered electrode, which produced weld metal free of impurities [11].

2.2. SUBMERGED ARC WELDING PROCESS

In submerged arc welding, the end of a continuous bare wire electrode is inserted into a mound of flux over the area of joint to be welded and the electrode is fed continuously from wire spool i.e. from welding head. An arc is initiated, causing the base metal, electrode and flux in the immediate vicinity to melt. The electrode is advanced in the direction of welding and mechanically fed from wire spool with the help of electric motor mounted on the welding head via guide roller through the nozzle into flux, which is steadily added from flux hopper through flux feed tube. The molten base metal and the filler metal flow together to form a molten weld pool in the joint, at the same time, the molten flux floats on the surface to form a protective lag cover. Remaining un-molten, non-conductive flux acts as a effective radiation shield. This gives rise to superior weld mechanical properties.

2.3 POWER SOURCE OF SUBMERGED ARC WELDING PROCESS

It can be applied in semiautomatic, automatic and mechanized welding. D.C. rectifier, generator, A.C. transformer etc may provide power. Although most of welding is carried out in range from 400 A to 1500 A., current as high as 2000 A at 45 V or as low as 150 A at 18 V can be used . It can operate on both the polarities of D.C. and A.C [8].

2.4 SUBMERGED ARC WELDING FLUXES AND THEIR PROPERTIES

2.4.1 General

Submerged Arc welding fluxes are commercialized in 1936 with fused fluxes .in 1946 can be used, basic i.e. agglomerated fluxes followed. The real key to high productivity and versatility is the flux itself, it blankets the arc, eliminates flash, spatter and smoke, controls the arc stability, and governs bead shapes (appearance) and influence weld chemistry.

These are basically a raw material of geological origin, these are based on silica, silicates, limestone, clay, oxides, fluorides and other minerals .A flux is a granulated/fused mineral usually made of predominantly oxides and fluorides, that are physically and chemically active in shielding in the metal and control the metallurgical points. Many constituents of flux do not serve to improve welding flux, but they are present, as residues will influence the physical and chemical behavior of the flux [14]

Generally flux constituents are: SiO_2, MnO, Al_2O_3, MgO, $CaCO_3$, CaF_2, CaO, K_2O,Na_2O, Zr_2O_3, FeO, Na_3AlF_6, BaO, Mo, Al, Nb, B, V, Mn, Si, etc. It contains all the above elements or some of the elements in different proportions, each element induces characteristics in welding fluxes i.e. manipulation gives the suitability of flux to meet the requirements.

2.4.2 Flux Purpose

There are various purpose of flux and their effects are listed below [4]:

A. Formation of protective slag,

B. Fluxing, de-oxidation of weld metal,

C. Alloying of weld metal,

D. Protection of the arc environment against oxidation.

E. To get metallurgical advantages.

2.4.3 Classification of Submerged Arc Welding Fluxes

According to Manufacture

A. Fused

B. Agglomerated

C. Mechanically mixed.

According to Basicity [13, 20]

The Ultimate tensile strength and Yield strength increase with the increase in B.I. while the percentage Elongation and percentage reduction of area decrease with increase in Basicity. Impact strength at all the test temperatures are found to increase with increase in Basicity.

$$\text{Basicity Index (B.I.)} = \frac{\text{Basic oxides}}{\text{Acidic Oxides}}$$

$$\text{B.I.} = \frac{CaO + MgO + CaF_2 + Na_2O + K_2O + BaO + 1/2[MnO + FeO]}{SiO_2 + 1/2[TiO_2 + ZrO_2 + Al_2O_3]}$$

When the B.I less than 1 it is acidic in nature

Neutral oxides having B.I. in the range of 1 to 1.5

When the B.I. lies in the range of 1.5 to 2.5 than it is called basic in nature.

Highly basic characterize if B.I. greater than 2.5

2.4.4 Flux Properties

- **Physical properties**

Viscosity

Viscosity of molten flux plays a major role in producing acceptable joints. A flux must remove inclusion and gases away from the weld metal by absorbing atoms or molecule into the flux at the liquid metal – slag interface. Followed diffusion of these species away from the interface. A flux low viscosity will have greater bulk diffusion rate, greater reaction rate at metal slag interface. Viscosity should be high enough to protect the weld metal from atmospheric gases . If it is too viscous, it will not absorb or transport gases at metal-slag interface resulting the surface pocking of weld bead. The viscosity also determines the position of weld joint, for example, for overhead welding needs high viscous slag to assist in reinforcements and protecting weld pool from collapsing [7,10,12].

Viscosity also welds bead morphology. A flux with a high viscosity will tend to confine the weld pool. Thus increasing the heat input for a given area and resulting in deeper penetration and derives the metallurgical advantages by slower cooling rate [7].

The higher the viscosity, the higher capacity of the flux to retain weld pool and gives rise to good bead appearance but if it is too high, leads to narrow bead.

Surface Tension

A higher surface tension between molten flux, usually associated with undercut i.e. lower the surface tension better the weld appearance and stability [2]

Bulk density

Which determines the consumption of flux in operation (gm/mm^3), lower the bulk density, higher the flux consumption [2,10].

Particles size /Grain Size

A finer flux can produce a denser and compact burden over the flux cavity, thereby reducing its volume. Evaluation and escape of gases from weld bead then becomes most difficult, results in characteristic aerated slag. Finer fluxes are also less tolerant to oil and rust because of instability of the resultant gases to escape. Larger grain size in the flux can give rise to a hamper peaky weld bead with increased penetration. Finer fluxes are used at higher current with greater welding speeds without undercutting due to arc stability and superior weld bead surface compared o coarse grains.

Melting point

The melting temperature of the flux must be lower than that of the molten metal, so that no gases are applied between the flux and metal, the Flux must remain in the molten state until after the weld has solidified so that complete fluxing action occur i.e. melting point should be about 1300°C [2,3,13].

Arc stability

The arc stability affects the initiation and maintenance of arc and the weld bead morphology i.e. constant heat input and uniform weld bead depends on flux composition Arc stability is defined as the voltage fluctuations from the given welding voltage .Larger the magnitude of the voltage fluctuations, greater the arc instability. The stability of arc mainly depends on the ionization potential of the flux constituents i.e. No. Of electron/ions present in arc plasma. Mainly, arc column consists of iron vapors and highly adulterated with other chemical vapors [7].

Flowability

It is related to the ease with which flux can be delivered to the joint ahead of the arc during welding. If it is high then it leads to arc instability, faster reaction rate and heat transfer [2].

- **Chemical Properties**

Removal of H_2, N_2 and Harmful Elements

The molten flux has harmful elements like non-metallic inclusion and dissolved gases. These should be removed from the weld. This is done by addition of elements, which have higher amount of affinity towards these elements i.e. by chemical reaction [13].

Addition of Alloying Elements

The molten flux should be able to induce some useful elements, which are lost by chemical reactions or to improve the mechanical properties of the weld metal. This is done by the addition of favorable elements like Mn, Ti, Al etc.in the fluxes and due to very complex chemical reactions in weld pool.

De-oxidation

The removal of dissolved molecular/atomic oxygen from base metal and filler metal to give oxygen –free weld metal, result in superior metallurgical properties. Flux must contain optimum level of de-oxidation elements i.e. the elements which have more affinity towards oxygen [5,6, 17].

2.4.5. The Main Elements in the Fluxes and Their Influences

Silica (SiO_2)

SiO_2 is acidic in chemical nature .It is the chief ingredient in all flux systems. Higher the SiO_2 content in the flux greater the viscosity and also gives good weld bead appearance. SiO_2 provides necessary viscosity and current carrying capacity. But SiO_2 in the flux leads to loss of deoxidizing agents and lead to Si diffusion in the weld metal, resulting in inferior mechanical properties specially the impact strength.

MnO

MnO is considered to be slightly acidic oxide. MnO leads alloying Mn into the weld by reduction reaction, which improves sub-zero mechanical properties. This favors higher welding speeds and deeper penetration. The most of "Mn" loss in base metal is by evaporation from weld pool. This should be compensated by addition of 'MnO' influx to improve mechanical properties. MnO increase the arc stability [2,3,5,10].

TiO_2

It is chemically neutral oxide. This gives metallurgical advantages i.e. grain refining of weld metal, when it is diffused in weld metal by reduction reaction lead to formation of acicular ferrite. TiO_2 increases arc stability and good impact properties [13].

Al_2O_3

Practically no effect but on reduction i.e. Al_2O_3 =2Al + 3[O] gives metallurgical advantage. Improve impact properties by refining the weld metal microstructure when diffused as 'Al'. This phenomena is estimate as 'Small practices of Aluminum Nitrite (AlN) are present in molten metal in sub-microscopic state which during solidification of weld restricts austenite grain growth thus promoting the acicular ferrite. Al_2O_3 decrease stability .It makes the flux sensitive to moisture. Al_2O_3 decrease the viscosity and gives medium penetration [3].

ZrO_2

Decrease the volume fraction of inclusion; improve transverse toughness ductility and hot workability. This acts mainly as 'grain refining elements' and promotes formation of acicular ferrite. This removes harmful elements like O, N,S and P etc.

CaO

This is one of the chief constituents in the flux in terms of 'Arc Stability and fluidity. 'The Alkali and Alkali earth metals posses very low ionization potential giving rise to very stable arc in operation. CaO is very stable oxide, it is basic oxide in chemical nature. This decreases the viscosity i.e. improve the fluidity; this acts as a network modifiers. Makes the flux very sensitive to the moisture, this hygroscopic character leads to porosity of weld bead.

It removes 'S' and 'P' and decrease the volume fraction of inclusion, leads to increase lead impact strength, gives very shallow penetration and increase the tendency of undercutting [3,7,10,13].

CaF_2

Increase the fluidity and leads to sprays transfer, decreases interfacial tension [1].

$CaCO_3$

Reduce the viscosity, makes the flux more basic. This avoids the absorption of moisture [6].

Deoxidizers [Al, Mn, Ti, Si]

These remove the oxygen of weld metal because these have higher affinity towards oxygen than other elements. Apart from that Al, Ti, and Mn improves mechanical properties .

2.4.6 Characteristics of Fluxes

Fused

These are usually produced in an electrical furnace using a graphite electrode fed from a transformer and graphite lined crucible to hold the melt. Passing large current through the molten bath generates heat. Typical melting and pouring temperature ranges between 1500°C-1700°C, Quenching into water solidifies the melt and then it is dried, crushed, sieved and packed.

These posses' extremely good chemical homogeneity and non-hygroscopic nature These will be giving a glassy appearance, But a drawback is losing of important chemical ingredients which posses low melting point by vaporization, secondly the segregation low melting constituents. These exhibits high degree of rust, scale and moisture tolerance.

Chief's constituents of flux are MnO and SiO_2, which are very easily reducible by alloying elements (deoxidizers). The slag produced contains high concentration of molecular oxygen, which causes oxidation of alloying elements. The products of the reaction are metallic Mn and Si and oxides of alloying elements .The former being added to weld metal and latter dissolved in slag. There will be rapid pick up of 'Si' , when SiO_2 content of flux exceeds 40%. The oxidation of alloying and also increased amount of nonmetallic inclusion of alloying and also increased amount of nonmetallic inclusion in weld metal. Higher levels of 'Si' and nonmetallic inclusion are responsible for low toughness of weld metal obtained from fused fluxes.

Agglomerated

Finely powdered ingredients are mixed and ground dry in a mixer. The mixer is steadily moistened by spraying with a solution of Alkali Silicates or Ceramic binders. The silicates solution initially fills the space between the pores of the particles. When subsequently dried the water evaporates, leaving the binder as bridge between particles, these contain relatively low amounts of SiO_2, higher contents of CaO, MnO, CaF_2. CaO and MgO are chemically stable oxides. The higher the basicity, lower the oxygen, S, P. content of weld metal and higher its notch toughness. The Basicity is limited up to 2.6

to 3.2 because of low melting temperature (less than 1300°C) these ensure efficient transfer of the alloying elements into the weld metal [3]

These give more favorable distribution of harmful elements between the slag and molten metal. The shape of flux is perfectly granular. This has lower bulk density.

According to Nature of flux

Neutral flux

These can be defined qualitatively as those fluxes, whose deposit strength is not significantly altered by amount of fluxes fused. The Basicity index varies 1 to 1.5. The main constituents areAl_2O_3 up to 50% along with TiO_2, MnO, CaO etc. This exhibits all the properties between the acidic and basic fluxes. But theoretically it explained that these increase the notch toughness due to alloying of 'Al', which promotes acicular ferrite in weld metal. These have relatively poor arc stability [3,9].

Acidic

The main ingredients of these fluxes are acidic oxides like MnO up to 40 % and MnO, CaO, Al_2O_3 etc. These are generally manufactured by using fusing techniques. These are called to be chemically 'active' fluxes. These posses, the Basicity index less than 1 [8].

These possess following characteristics

a Flux consumption is lower.

b Weld bead is smooth and good.

c These produce easily detachable slag i.e. self detachable slag

d Carry higher currents with higher welding speeds

e Poor arc stability

f Produce inferior weld, when consider mechanical properties due to higher density of inclusions and gases

g Higher viscosity suitable for all position of joints .

h Higher degree of rust and scale tolerance .

i Nature is Non-hygroscopic [7].

j. Deep penetration.

Basic fluxes

This contains mainly CaO up to 45%, CaF_2, MnO, $CaCO_3$ and others. Most of them are chemically basic in nature and highly stable oxides. These are generally prepared by agglomeration process.

The Basicity index must be between 1.5 and 3.5. These are called to be active fluxes. These ensure efficient transfer of the alloying elements because of low melting temperature and higher fluidity.

These exhibit following characteristics

a Higher flux consumption

b These result in distorted bead and poorest surface quality

c Most difficult to detach the slag.

d Posses lower viscosity i.e. higher fluidity used

e Good arc stability due to low ionization potential ingredients.

f Gives good mechanical properties , these are brought by less inclusion of non-Metallic and distribution of elements.

g Very hygroscopic in nature , lead to porosity

h These are less tolerant to rut and scaling.

2.5 OXYGEN ACTIVITY IN SUBMERGED ARC WELDS

The metals show higher solubility of oxygen in molten state, but as the temperature decrease the solubility of 'O' in metal decreases and leads to entrapment of molecular /atomic oxygen, if the cooling is very fast in the weld metal. This lead to inferior mechanical properties especially the sub-zero impact properties i.e. lowering toughness and loss of valuable alloying elements (C, Cr, Mn etc.) from weld metal.

Oxygen activity is one of main factors which governs the use of fluxes .As, we know, that Basicity increases the amount 'O' in the weld metal decreases.

The source of Oxygen in Weld Metal

1 Entrapment of molten flux particles by weld metal droplet.

2 Decomposition of flux components in the arc column.

3 Air entrapment with the porous flux particles.

4 Slag –metal reactions.

Chief sources of oxygen in weld Metal

1 Decomposition of flux components in arc column.

2 Slag metal reactions.

The extent of entrapment will be depending on the relative stability of the arc. The de-oxidation process is done by addition of high affinity ingredients e.g.Al, Si, Mn, Ti etc. For instance 'Al' posses very high affinity towards oxygen than other elements. This lead to "Oxidation and reduction reaction "which plays critical role in addition of alloying elements to weld metal According to decomposition of elements, which contribute to the increase in 'oxygen' level in weld metal, chemical stability in decreasing

SiO_2, MnO, MgO, Al_2O_3, TiO_2, Na_2O, K_2O, CaO, CaF_2 reduce the amount of oxygen as in case of basic fluxes [5,6].

2.6 MICROSTRUCTURE

For given composition, one of the important factor governing Mechanical Properties is the ferrite grain size. The term "grain size " is used here in a general sense and refers to characteristics dimension for the structure in question . It may be said that in general the yield strength of the weld metals increase and impact transition temperature falls a grain size is reduced .The ferrite grain size is large determined by the size of prior austenite grains and this, as pointed out, is the function of weld thermal cycle. High heat input rate processes in SAW generate a relatively coarse grained weld metal [19].

EXPERIMENTAL SETUP

3.1 EXPERIMENTAL MACHINES

Figure 3.1 shows the submerged arc machine on which welding work was prepared. Straight polarity (D.C.$^+$) was used during welding. The diagram of the equipment used for welding purpose is shown in figure 3.2.

3.2 PREPARATION OF ASSEMBLY

The procedure of preparing the assembly and testing them are described in many well-recognized standards. The coupon dimensions are taken as per the standard specified in ISO 2560-1973 [18].

Fig 3.3 shows the joint Design. Two 20 mm thick steel plates are butt welded with a V–groove. A backing plate 10 mm thick is provided on the underside. Root gap dimension between the two plates is 16mm. Base metal dilution is minimized by deposited weld metal on the beveled edges of the base plate & backing plate. The test specimens are so prepared that the sections which are subjected to the test consist of pure, undiluted weld-metal. All weld metal impact test specimen were taken out from the coupon shown in Fig. 3.3.

Two consumables have been used, one is indigenous consumables and the other is a German consumable. Indigenous consumables chosen are Automelt Grade IV with grade C wire and German consumable chosen is OP121TT with S_3 wire

A number of passes are deposited to fill the entire welding groove current specified. The consumable can be used with both AC and DC. Welding is done in the flat position, with each pass not more than 16mm wide. The direction of deposition of each layer alternates from each end of the plate. The reinforcement of the weld is not allowed to exceed 3mm.

3.2.1 Number of Assembly

Six weld assembles have been welded – three for Indigenous consumables and other three assemblies for German consumables. Each assembly is welded with different current using different consumables. The assembly is as per ISO-2560 and is shown in Fig. 3.3

3.3 SELECTION OF CONSUMABLES AND PROPERTIES

Automelt grade IV flux (Manufacturer : Advani – Oerlikon Ltd)

Agglomerated Flux Fully in basic nature have Basicity Index 3.0.

CaO + MgO	**SiO_2**	**CaF_2**	**Al_2O_3 + MnO**
30%	10%	35%	20%

Chemical Composition of the Filler Wire

Grade C wire

C	**Mn**	**Si**	**Cu**	**S**	**P**
0.1 %	1.84 %	0.094 %	0.13 %	0.023 %	0.016 %

OP121TT Flux (Manufacturer : German)

SiO_2 + TiO_2	**MgO + CaO**	**CaF_2**	**Al_2O_3 + MnO**
10%	25%	30%	20%

The diameter of both wire S_3 and Grade C wire is 4 mm .It must be same otherwise the weld metal properties and other antecedent aspects of the weld get affected.

3.4 SELECTION OF WELDING PARAMETERS

Serial no.	Current(Amp)	Voltage (V)	Speed (30 cm/min)
1.	550	30	30
2.	650	30	30
3.	750	30	30

3.5 ALL WELD-METAL TESTS

Yield point, tensile, elongation, impact and other values of the weld-metal deposited by a welding consumable determined by a welding consumable. All-weld-metal-means deposit which is undiluted by the base metal. In these tests, the test specimens are so prepared that the sections which are subjected to the test consist of the pure, undiluted weld-metal. The dimension of all weld metal tensile test are specified as per ISO-2560 and is shown in Fig 3.4. The formulas for finding the ultimate tensile strength, yield strength, percentage elongation and percentage reduction in area are given below:

$$\text{Ultimate Tensile Strength} = \frac{\text{Ultimate Tensile Load}}{\text{Original Cross - section Area Of Specimen}}$$

$$\text{Yield Strength} = \frac{\text{Yield Strength}}{\text{Original Cross - section Area Of Specimen}}$$

$$\% \text{Elongation} = \frac{\text{Final Gauge Length} - \text{Original Gauge Length}}{\text{Original Gauge Length}} \times 100$$

$$\% \text{Reduction in Area} = \frac{\text{Original Cross section Area} - \text{Final Cross section Area}}{\text{Original Cross - section Area}} \times 100$$

3.6 IMPACT TESTS

The impact test piece is of the Charpy-V-notch type. Six test pieces have to be taken from the test assembly. Their longitudinal axes have to be transverse to the weld and the upper surface 5mm from the upper surface of the plate. The notch must be positioned in the centre of the weld cut in the face of the test piece, perpendicular to the surface of the plate. All dimensions have to be in accordance with the instructions given in Fig. 3.5.

Impact machine specification:

Pendulum velocity	:	5.4	m/sec
Range	:	300	Joules
Least count	:	2	Joules

3.7 HARDNESS TESTS

Hardness of welds specimen was determined by Vickers Methods. A load of 100 gm was applied on specimen and a pyramid shaped indenter was allowed into the test piece. After the completion of the test, impression of the indenter pyramidically was measured and the corresponding VHN hardness values were taken from standard chart. Three values of hardness were taken within the weld section of etched specimen and average value of hardness is taken

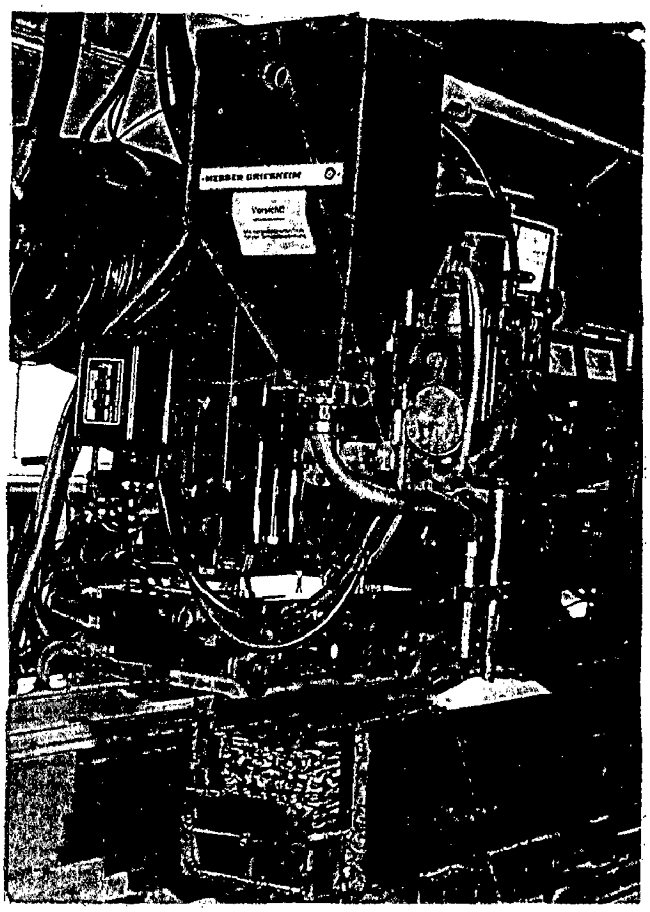

Fig 3.1 Photograph of Experimental Set up

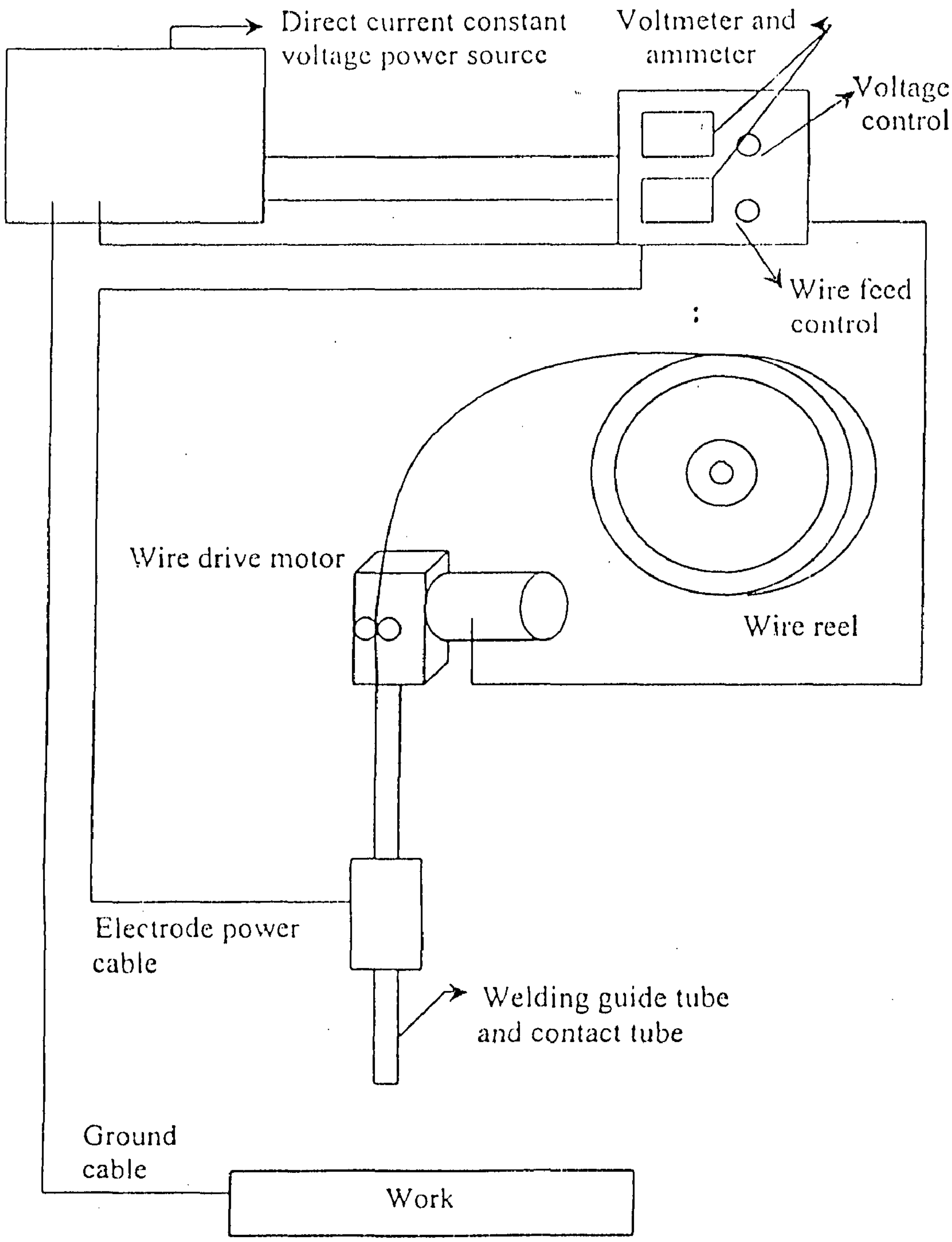

Fig 3.2 Circuit Diagram of Experimental Set up

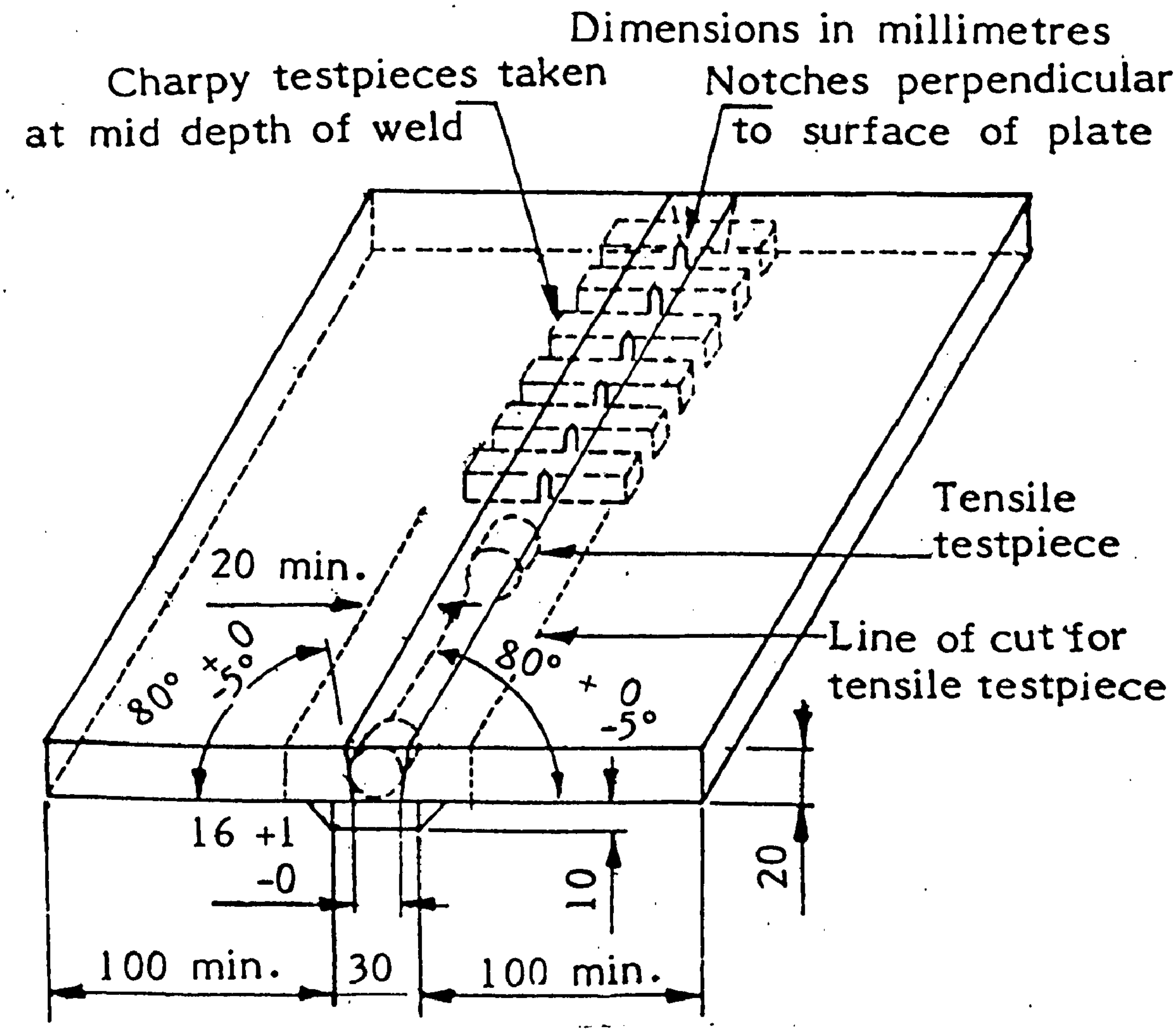

Fig 3.3 Test Assembly as per ISO 2560

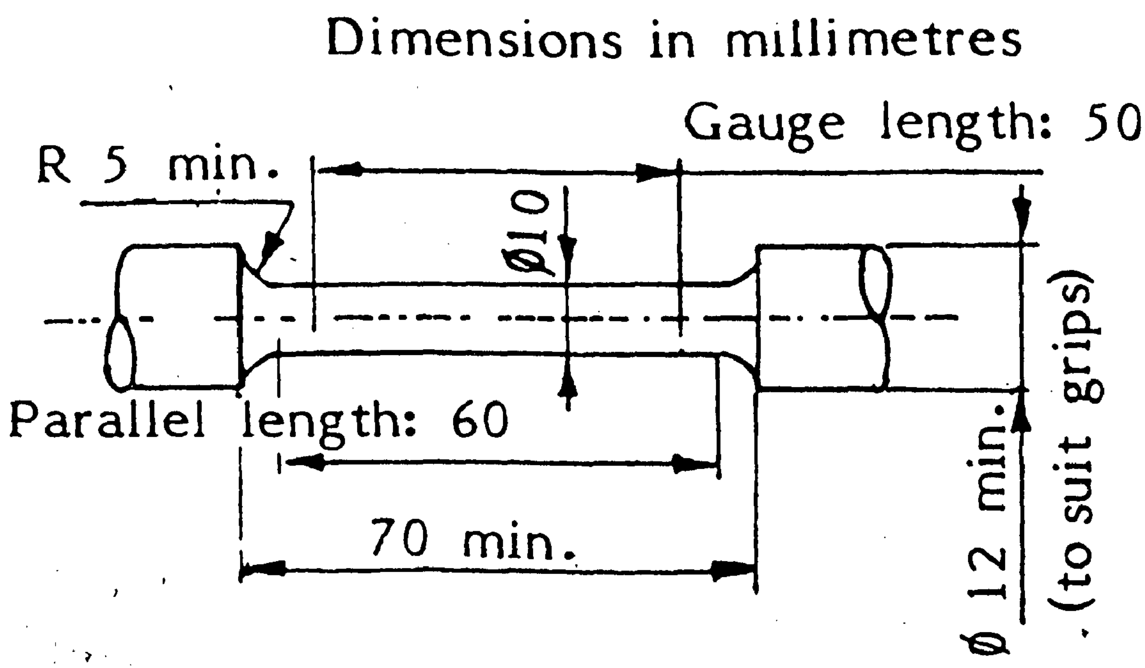

Fig 3.4 Tensile Test Piece as per ISO 2560

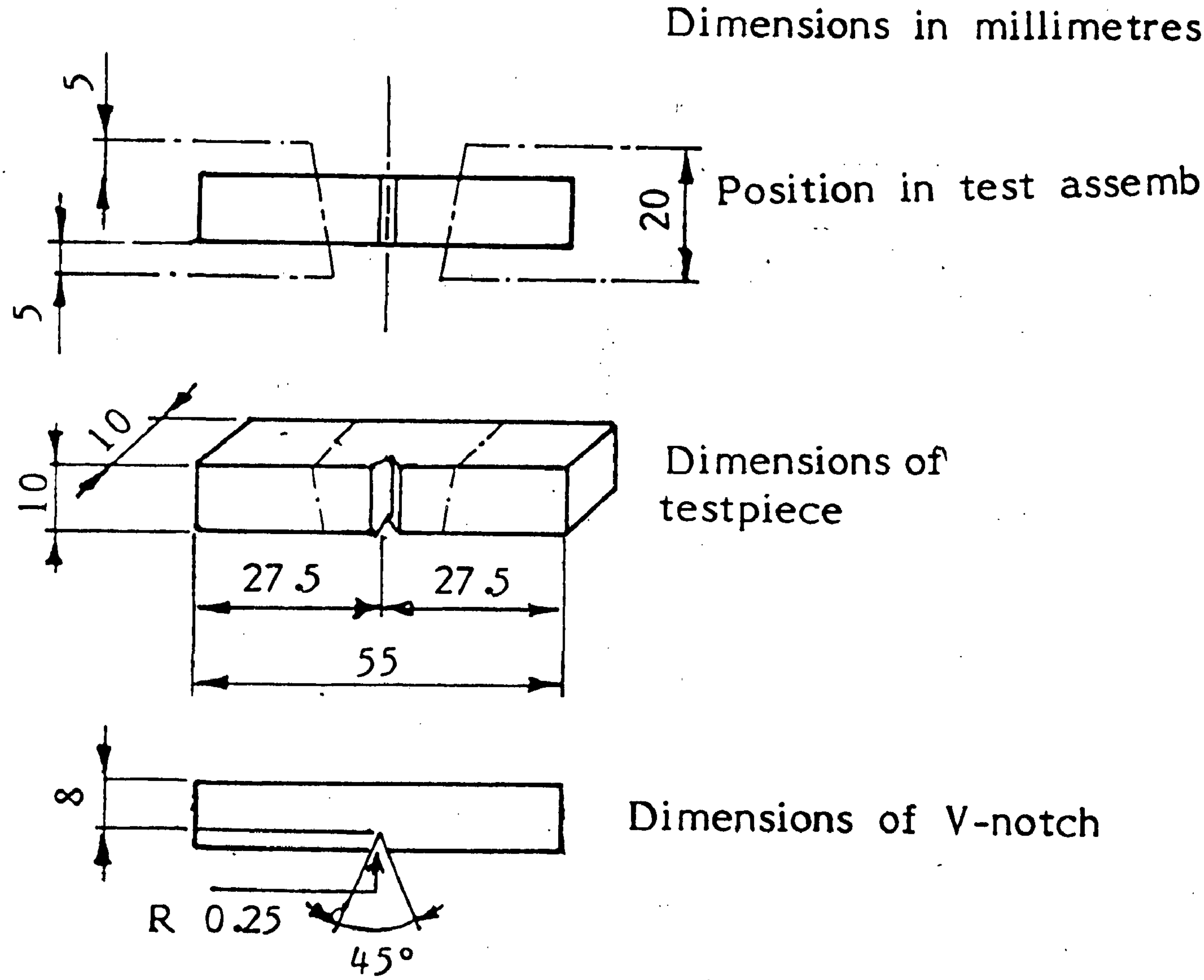

Fig 3.5 Impact Test Piece as per ISO 2560.

RESULTS AND DISCUSSIONS

4.1 COMPARISON OF VARIOUS MECHANICAL PROPERTIES, IMPACT AND HARDNESS PROPERTIES OF WELD METAL FABRICATED BY INDIGENOUS AND GERMAN CONSUMABLES.

The effect of different consumables on to Mechanical and Impact properties, Hardness of weld metal have been described under this article .The response curves are graphical representation of changes in the values of the performance characteristics (Yield Strength, Ultimate Tensile Strength, percentage Elongation, percentage Reduction in area, Toughness, Hardness) with different consumables.

4.1.1. Comparison of Yield Strength, Ultimate Tensile Strength, Percentage Elongation and Percentage Reduction in Area Using Different Consumables

The Mechanical properties of the welds deposited by Indigenous & German consumables were determined experimentally. The welds were fabricated with three different current intensities viz 550A, 650A and 750A keeping voltage, welding speed constant at 30 V and 30 cm/min respectively. The results of the Mechanical tests viz Yield Strength, Ultimate Tensile Strength, percentage Elongation and percentage Reduction in area are shown in Tables 4.1 & 4.2.

Fig 4.1 & 4.3 shows the trend of the Ultimate Tensile Strength & Yield Strength of weld respectively deposited by German consumables and Fig 4.2 & 4.4 shows the pattern of the Ultimate Tensile Strength & Yield strength of weld respectively deposited by Indigenous consumables. This decreasing trend is attributable to coarse grain structure as is evident from microstructures shown in Fig 4.13, 4.14, 4.15, 4.16, 4.17, and 4.18. As the current increases, heat input to the weld increases and the grain structure becomes coarse which is clearly supported by the photographs.

Further, the Ultimate Tensile Strength & Yield Strength of weld deposited by Indigenous consumables is comparatively higher than the welds deposited by German consumables. The higher values of the Ultimate Tensile Strength & Yield Strength are because of relatively finer grain size found in weld deposited by Indigenous consumables than the weld deposited by German consumables.

Figure 4.5 and 4.7 shows the trend of the Percentage Elongation & Percentage Reduction in area of weld respectively deposited by German consumables and Fig 4.6 & 4.8 shows the pattern of the Percentage Elongation & Percentage Reduction in area of weld respectively deposited by Indigenous consumables. As the current increases from 550A to 750A, both Percentage Elongation and Percentage Reduction in area increases. This increasing trend is attributable to the decrease in strength as discussed previously.

Further, the Percentage Elongation & Percentage Reduction in area deposited by indigenous consumables is comparatively lower than the weld metal deposited by German consumables. These lower values of the Percentage Elongation & Percentage reduction in area are because of the strength of weld deposited by Indigenous consumables is comparatively higher than the welds deposited by German consumables

4.1.2. Comparison of Impact Properties using Different Consumables

In order to compare the impact properties of weld metal, specimens were taken from the coupon shown in fig 3.3 in the orientation as shown. The experimental results of Charpy Impact test are given in Tables 4.3 and 4.4 at temperatures -30 °C, 0 °C, and room temperature deposited by German consumable and Indigenous consumables respectively

Figure 4.9 and 4.10 shows that the Energy absorbed by weld metal deposited by Indigenous consumables is lesser than the weld metal deposited by German consumables. This is due to the higher strength of the weld metal deposited by Indigenous consumables as discussed previously

Further, as the temperature decreases from room temperature to sub-zero temperature, the values of the impact strength decreases significantly. This decrease is attributable to the fact that the material gets embrittled.

4.1.3 Comparison of Hardness Using Different Consumables

In order to compare the Hardness of different weld metals, experiments were conducted. The experimental results are given in Tables 4.5 and 4.6 deposited by German consumables and Indigenous consumables respectively.

Figure 4.11 and 4.12 shows that the Hardness of weld metal deposited by Indigenous consumables is comparatively higher than the weld metal fabricated with German consumables at different currents.

It is observed that as the current intensity increases from 550A to 750A, the hardness decreases in the welds deposited by both the consumables as shown in Tables 4.5 & 4.6. This is because of the fact that at lower current values, the heat input to the weld is less and consequently the structure is fine grain. At the higher current intensity the heat input to the weld is comparatively higher resulting in coarse grain structure and consequent decrease in the hardness. This is attributable to the fact that Ultimate Tensile Strength and Yield strength of welds deposited by Indigenous consumables is higher than the weld deposited by German consumables.

4.1.4 Comparison of Chemical of Element Using Different Composition

The chemical composition of the welds deposited by Indigenous and German consumables are shown in Tables 4.7 and 4.8. The Si content of the weld metal deposited by Indigenous consumables is higher than the Si content of weld metal deposited by German consumables. This leads to comparatively higher ultimate tensile strength and yield strength values of the welds deposited by Indigenous consumables

Serial no.	Current (Amp)	Uts (MN/m^2)	Yp (MN/m^2)	% Elongation	% Reduction in area
1.	550	477.1	342.1	30.1	71.2
2.	650	461.2	323.2	33.1	73.4
3.	750	447.3	312.4	35.2	77.5

Table : 4.1 Experimental Results of Various Mechanical Properties of All Weld –Metal Test Using German Flux OP121TT and S_3 Wire at variable current .

Serial no.	Current (Amp)	Uts (MN/m^2)	Yp (MN/m^2)	% Elongation	% Reduction in area
1.	550	560.6	428.8	26.1	69.8
2.	650	515.4	365.6	29.4	72.8
3.	750	493.1	336.5	32.3	75.5

Table : 4.2 Experimental Results of Various Mechanical Properties Of All Weld –Metal Test Using Automelt grade IV flux and C-wire at variable current .

S. No.	Current (Amp.)	Temperature		
		-30^0C Energy absorb (Joule)	0^0C Energy absorb (Joule)	22^0C (room temp.) Energy absorb (Joule)
1.	550	83	135	173
2.	650	91	141	183
3.	750	120	155	200

Table 4.3: Experiment results of energy absorption using German Flux OP121TT and S_3 Wire at variable current

S. No.	Current (Amp.)	Temperature		
		-30^0CEnergy absorb (Joule)	0^0C Energy absorb (Joule)	22^0C (room temp.) Energy absorb (Joule)
1.	550	48	83	123
2.	650	56	110	137
3.	750	70	135	180

Table 4.4: Experiment results of energy absorption using Automelt grade IV and Grade C wire at variable current

S. No.	Current	Hardness (VHN)
1.	550	254
2.	650	238
3.	750	223

Table 4.5: Experimental results of Hardness (VHN) German Flux OP121TT and S_3 Wire at variable current

S. No.	Current (Amp)	Hardness (VHN)
1.	550	281
2.	650	268
3.	750	237

Table 4.6: Experimental results of Hardness (VHN) Automelt Grade IV with Grade C wire at variable current .

Serial No.	Current(Amp)	Elements				
		C %	Mn %	Si %	S %	P%
1.	550	0.068	0.560	0.122	0.027	0.010
2.	650	0.072	0.597	0.148	0.018	0.007
3.	750	0.062	0.472	0.135	0.013	0.008

Table 4.7 Percentage composition of various elements in weld metal at different current fabricated by German Flux OP121TT with S_3 wire .

Serial No.	Current(Amp)	Elements				
		C %	Mn %	Si %	S %	P%
1.	550	0.063	0.403	0.47	0.023	0.040
2.	650	0.074	0.600	0.38	0.025	0.047
3.	750	0.071	0.428	0.43	0.027	0.036

Table 4.8 Percentage composition of various elements in weld metal at different current fabricated Automelt Grade IV Flux with Grade C wire..

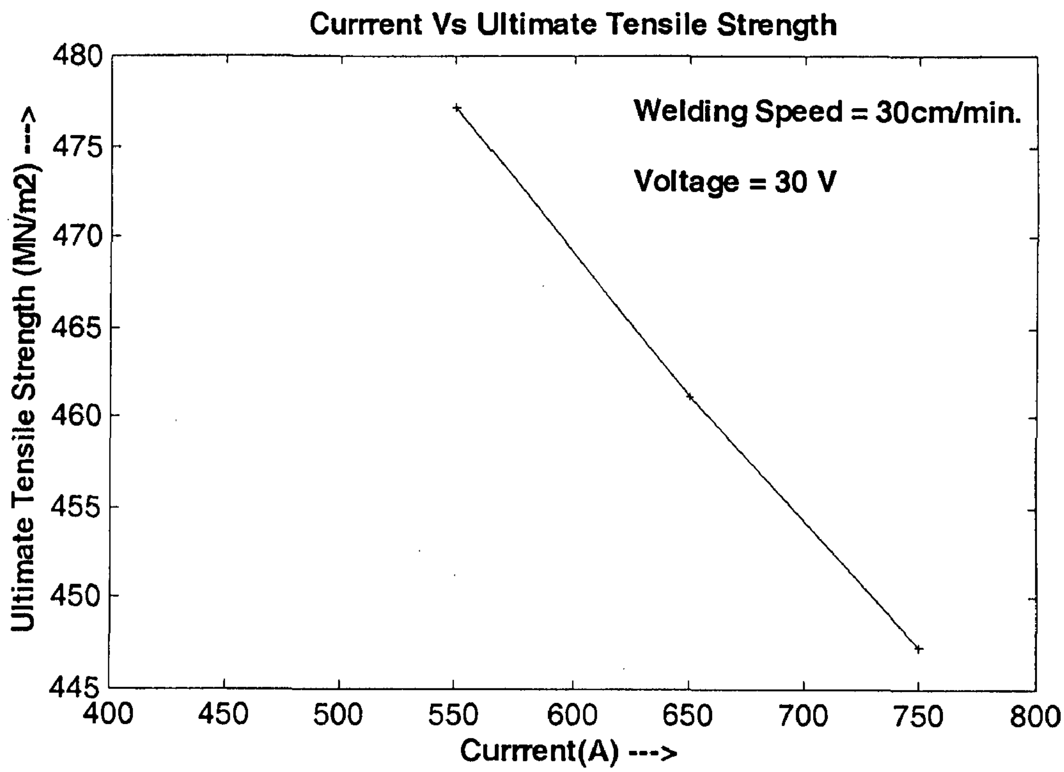

Fig 4.1 Effect of Current on the Ultimate Tensile Strength Using German Flux OP 121TT with S_3 Wire

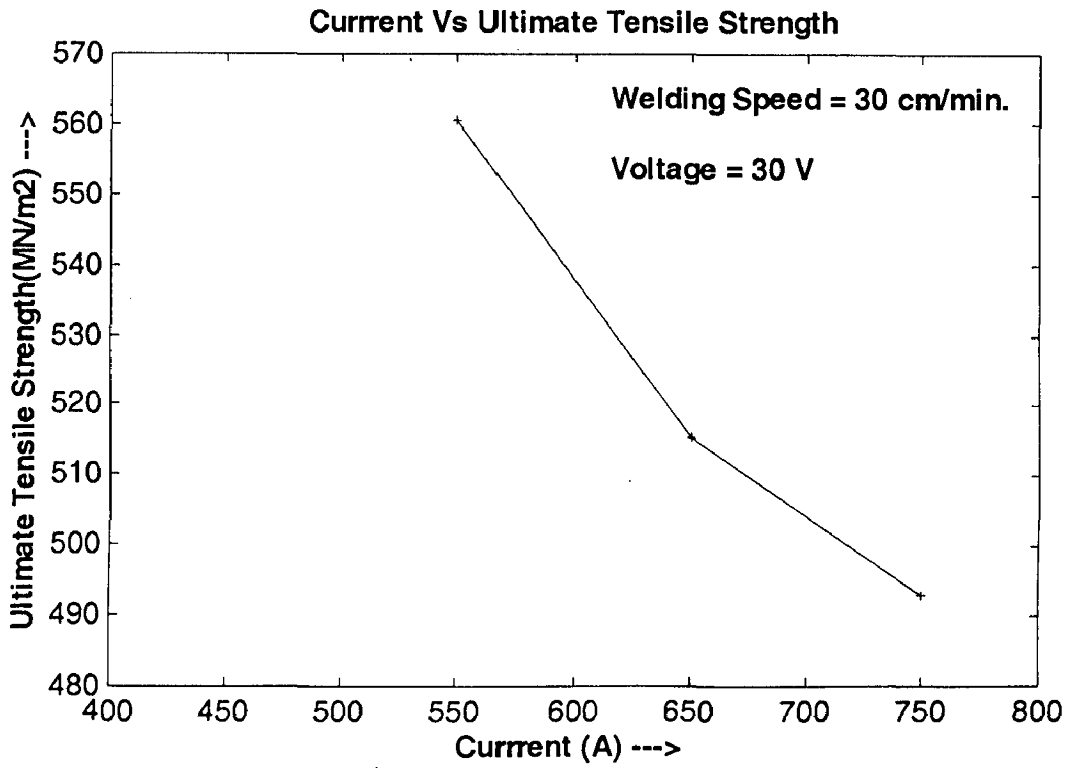

Fig 4.2 Effect of Current on the Ultimate Tensile Strength Using Automelt Grade IV Flux with Grade C Wire

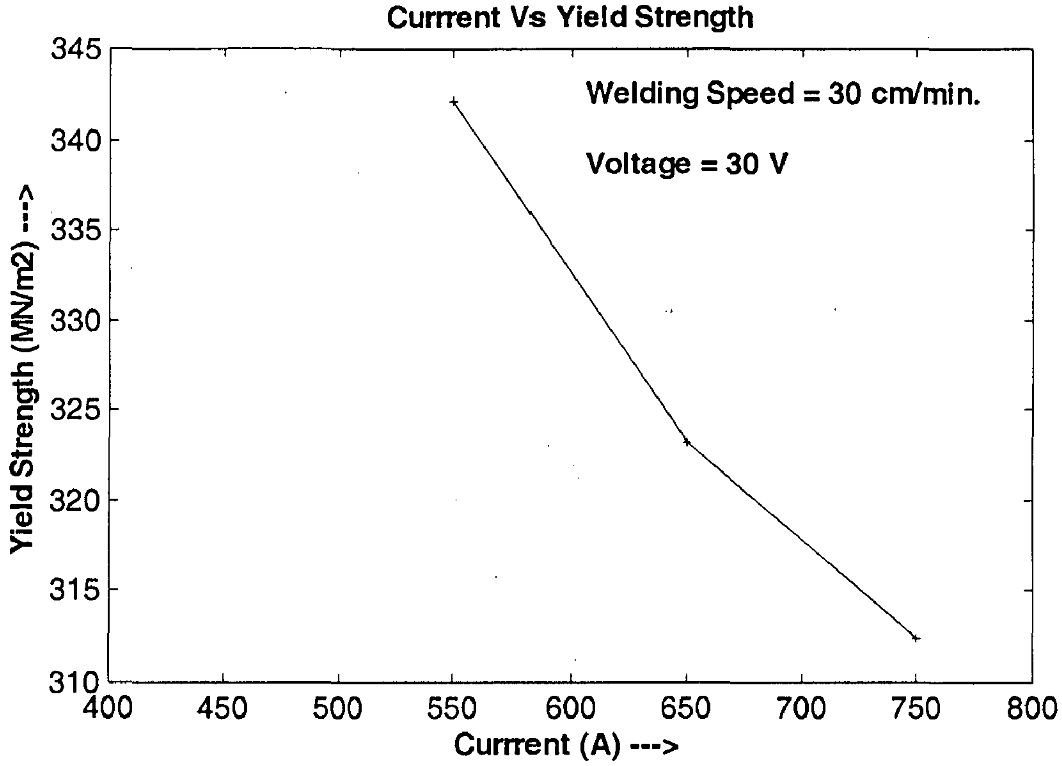

Fig 4.3 Effect of Current on the Yield Strength Using German Flux OP 121TT with S_3 Wire

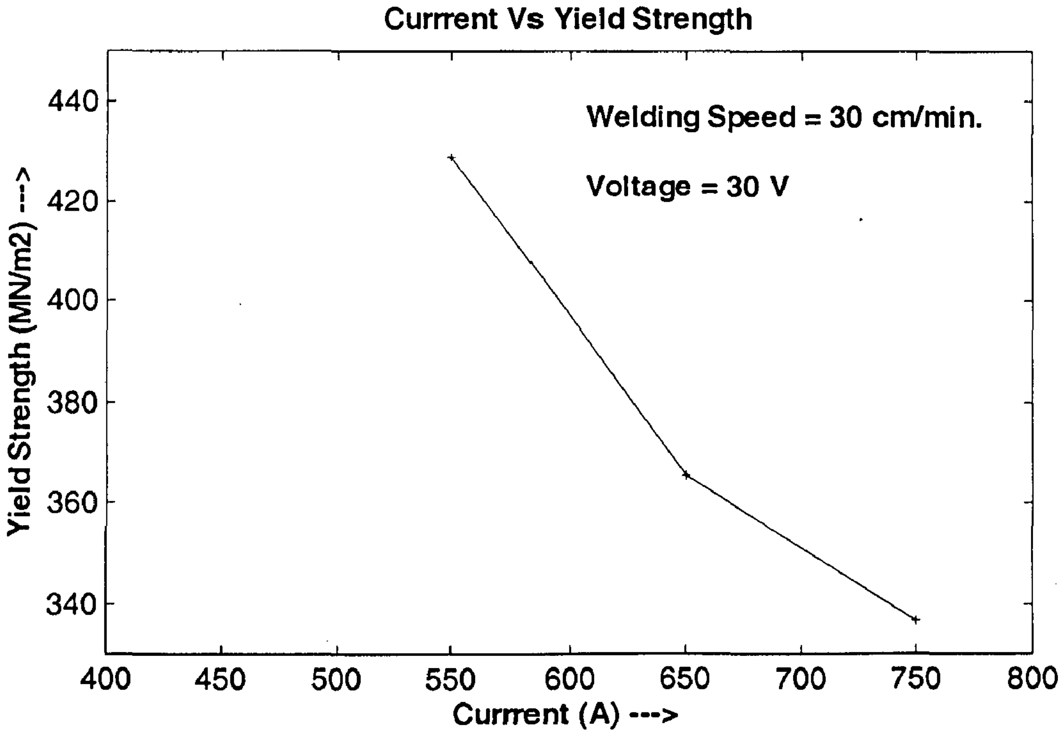

Fig 4.4 Effect of Current on the Yield Strength Using Automelt Grade IV Flux with Grade C Wire

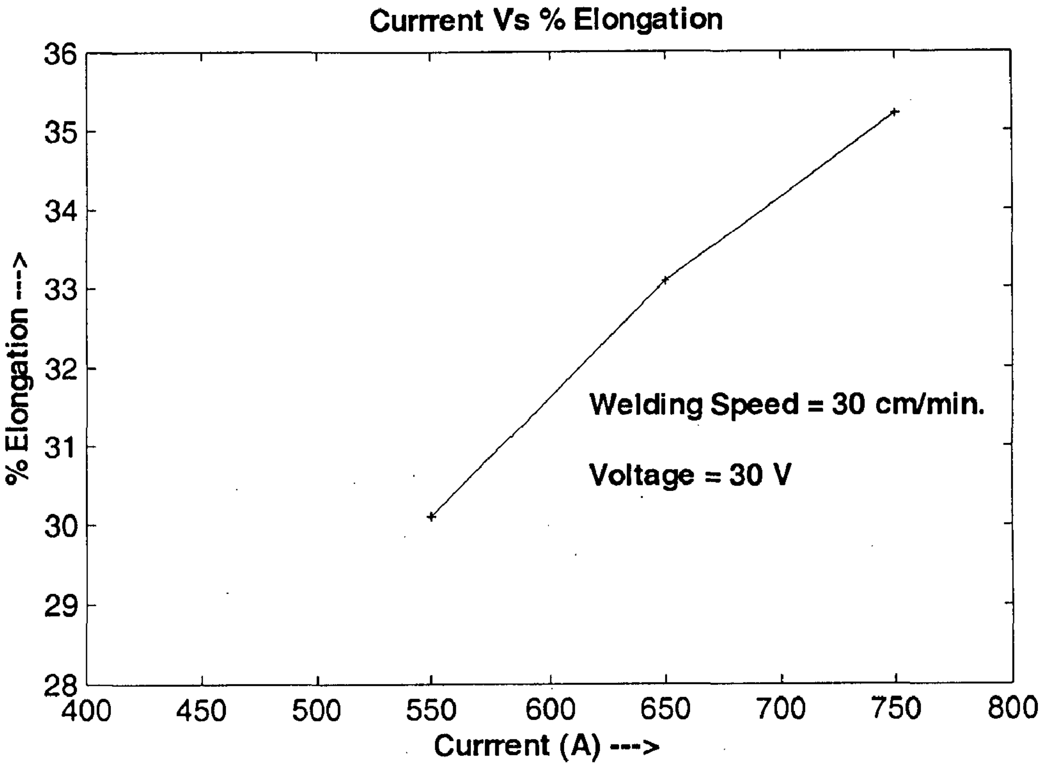

Fig 4.5 Effect of Current on the Percentage Elongation Using German Flux OP121TT with S_3 Wire

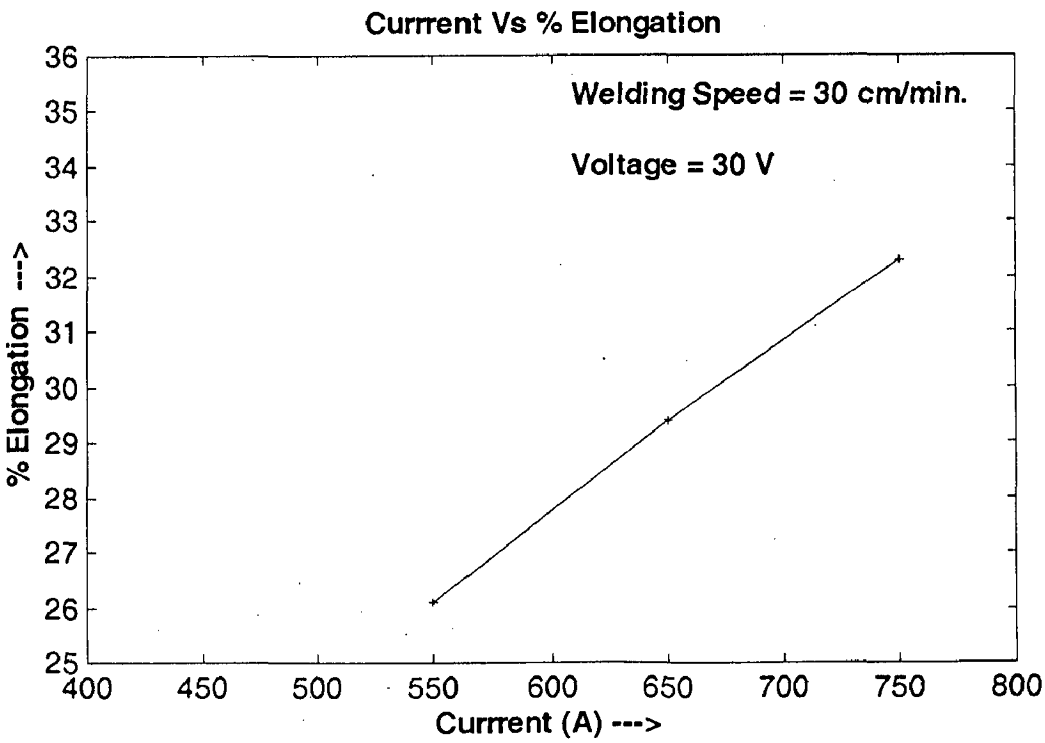

Fig 4.6 Effect of Current on the Percentage Elongation Using Automelt Grade IV Flux with Grade C Wire

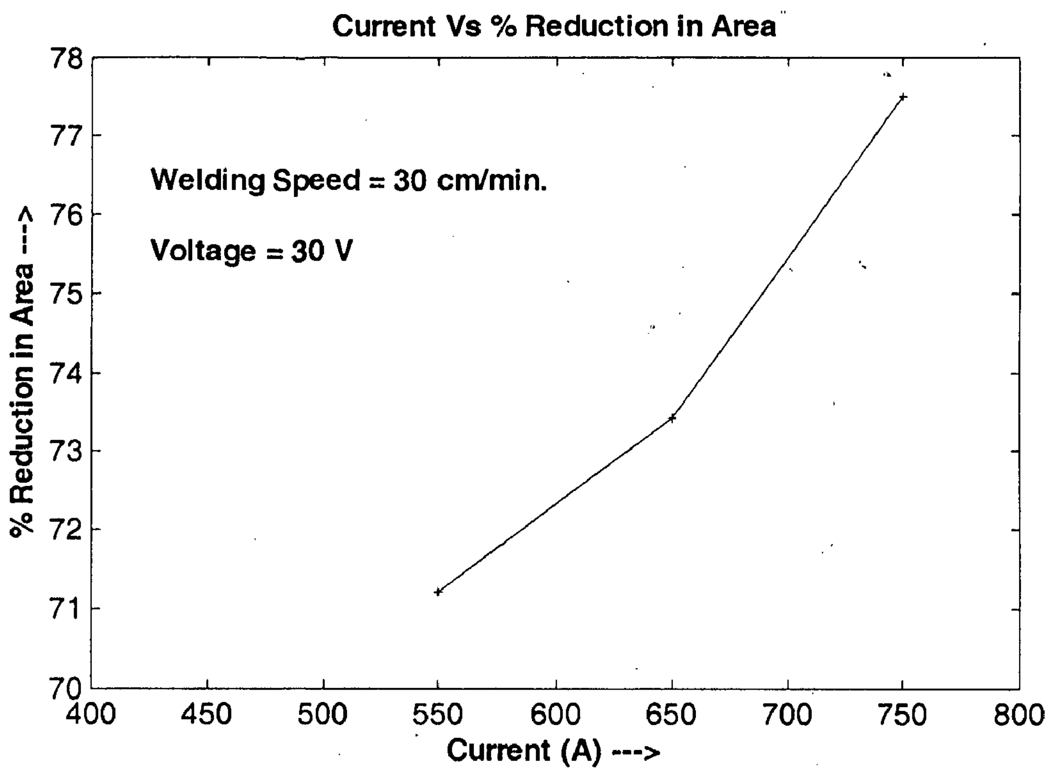

Fig 4.7 Effect of Current on the Percentage Reduction in Area Using German Flux OP121TT with S_3 Wire

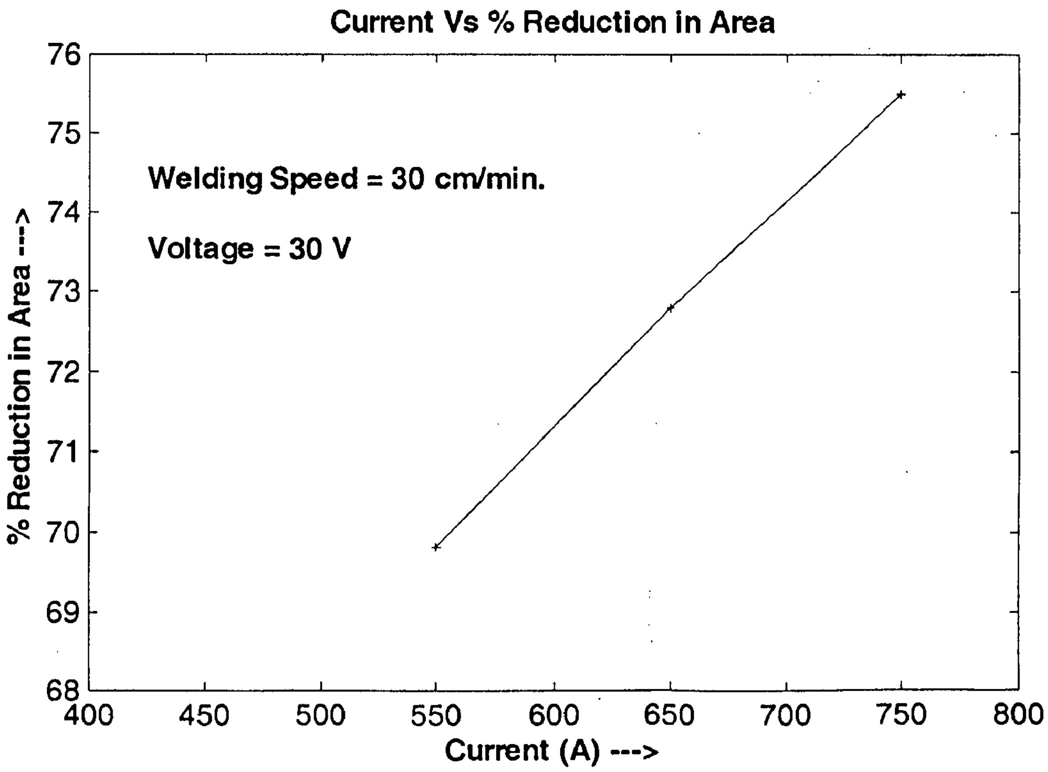

Fig 4.8 Effect of Current on the Percentage Reduction in Area Using Automelt Grade IV Flux with Grade C Wire

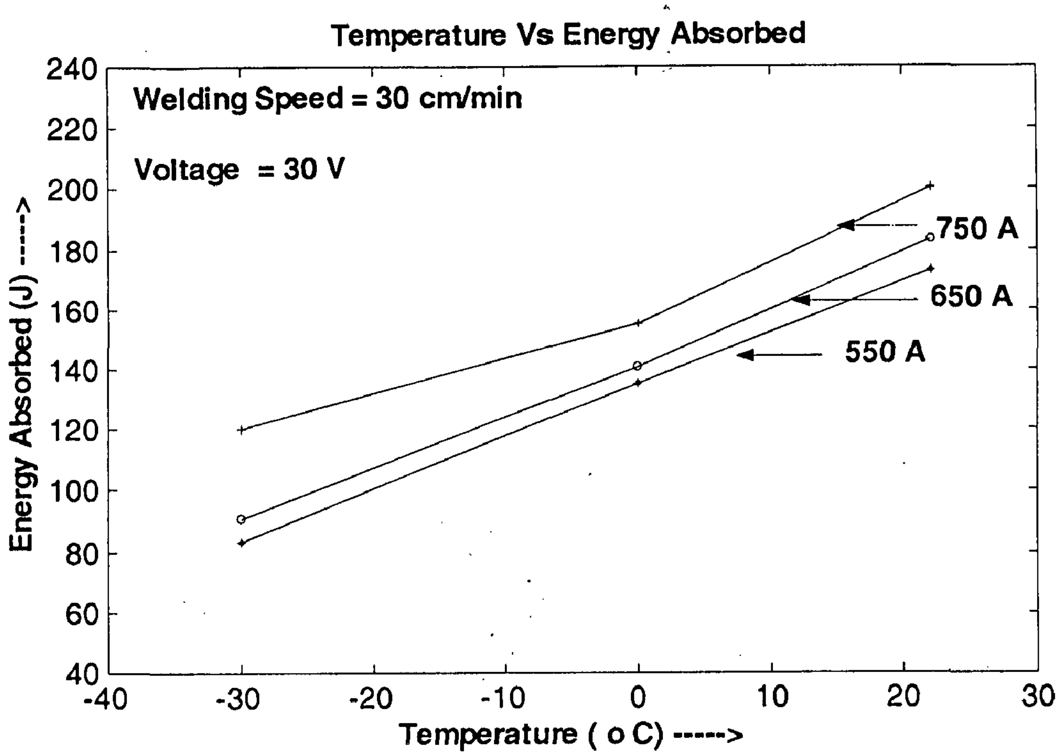

Fig. 4.9 Energy Absorbed by Weld Metal at Various Temperatures Fabricated by German Flux OP121TT with S_3 Wire at Different Currents

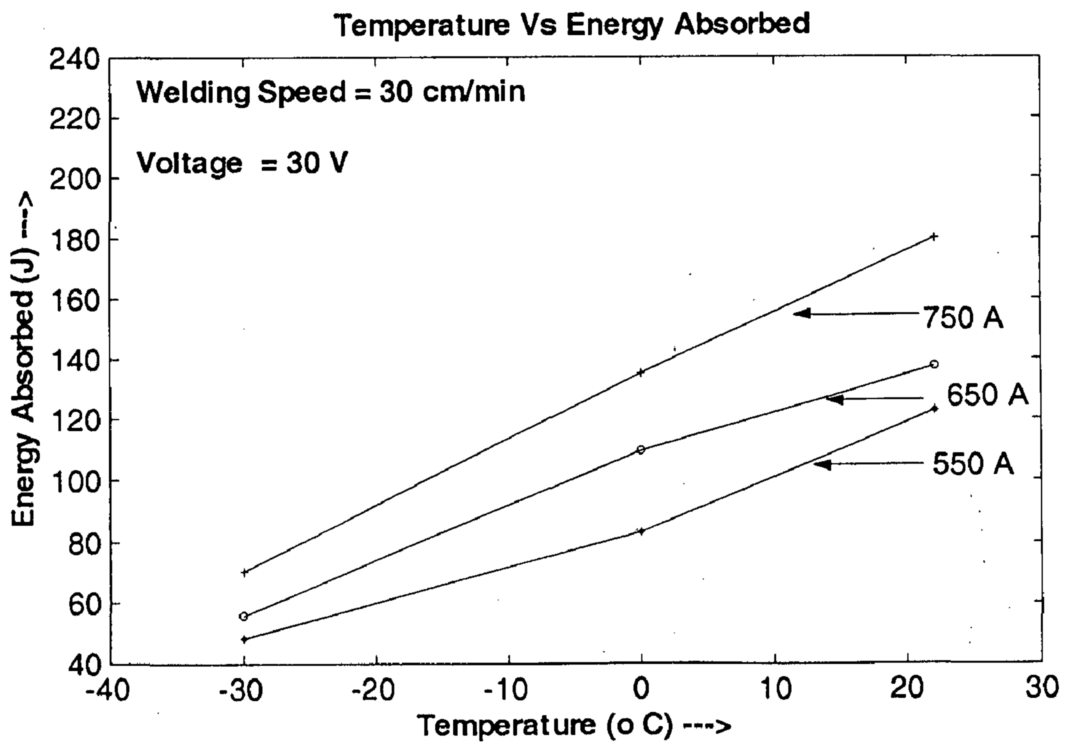

Fig. 4.10 Energy Absorbed by Weld Metal at Various Temperatures Fabricated by Automelt Grade IV Flux with Grade C Wire at Different Currents

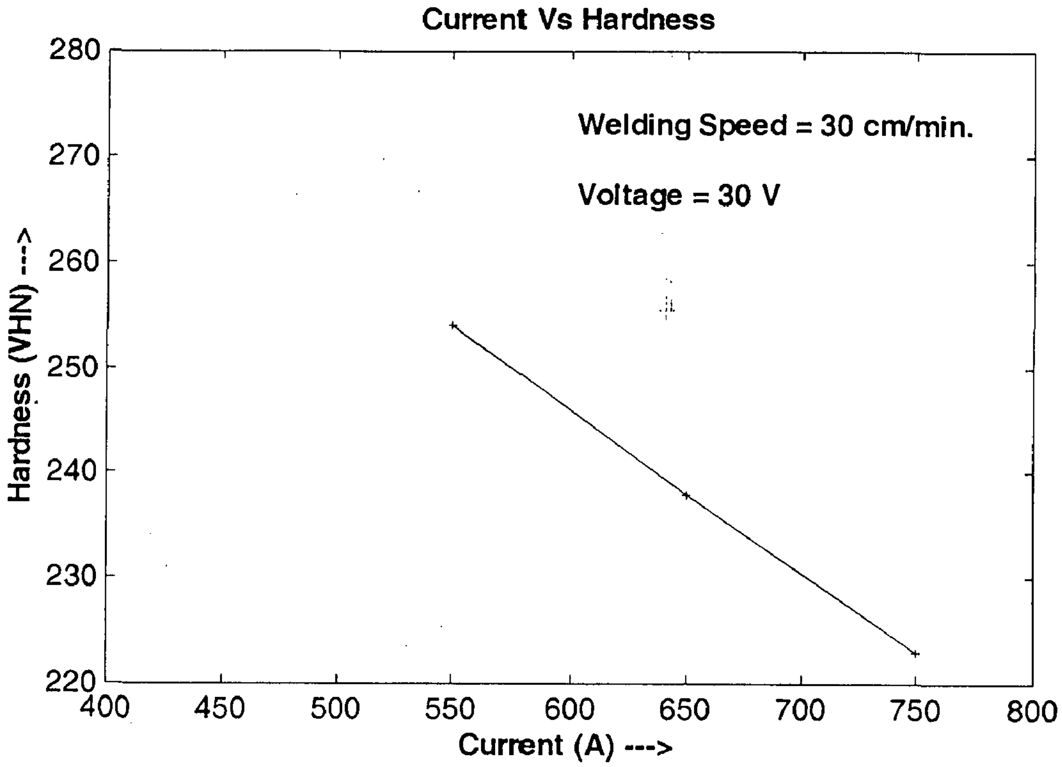

Fig 4.11 Hardness of Weld Metal Fabricated by German Flux OP121TT with S_3 Wire at Different Currents

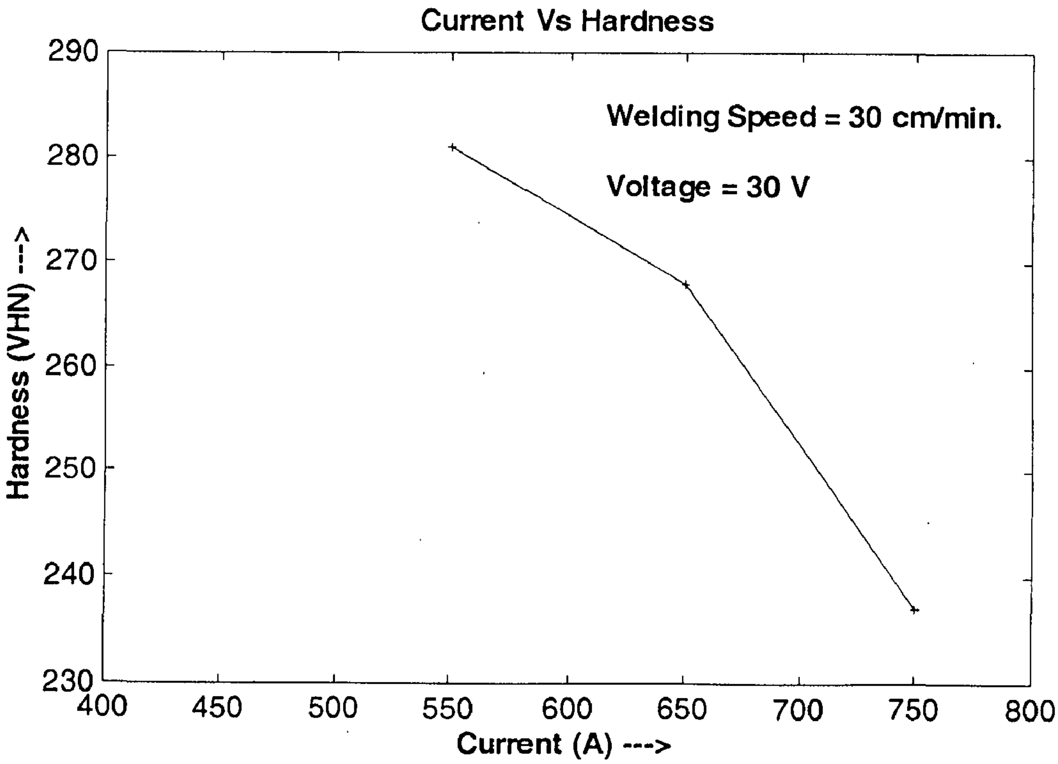

Fig 4.12 Hardness of Weld Metal Fabricated by Automelt Grade IV Flux with Grade C Wire at Different Currents

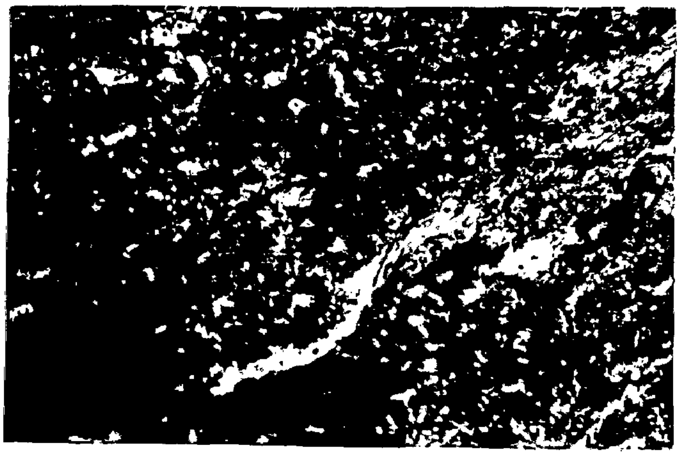

Figure 4.13 Micro Structure of Weld Metal Fabricated by German Flux OP121TT with S_3 Wire at 550 A

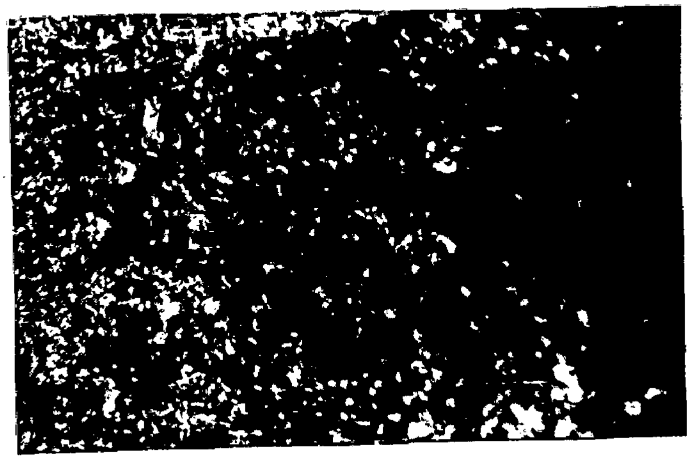

Figure 4.14 Micro Structure of Weld Metal Fabricated by Automelt Grade IV Flux with Grade C Wire at 550 A

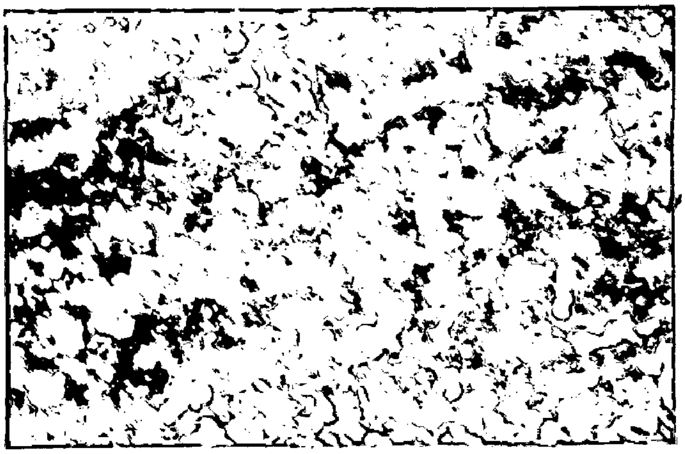

Figure 4.15 Micro Structure of Weld Metal Fabricated by German Flux OP121TT with S_3 Wire at 650 A

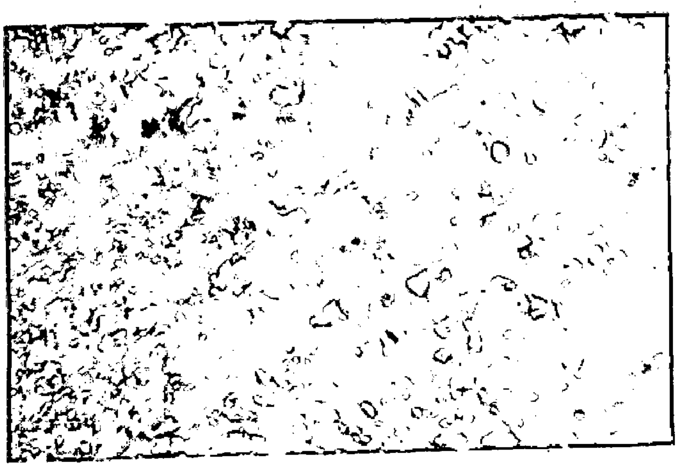

Figure 4.16 Micro Structure of Weld Metal Fabricated by Automelt Grade IV Flux with Grade C Wire at 650 A

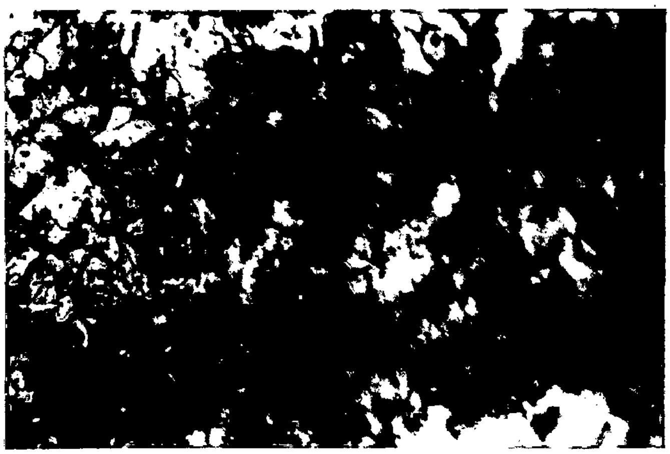

Figure 4.17 Micro Structure of Weld Metal Fabricated by German Flux OP121TT with S_3 Wire at 750 A

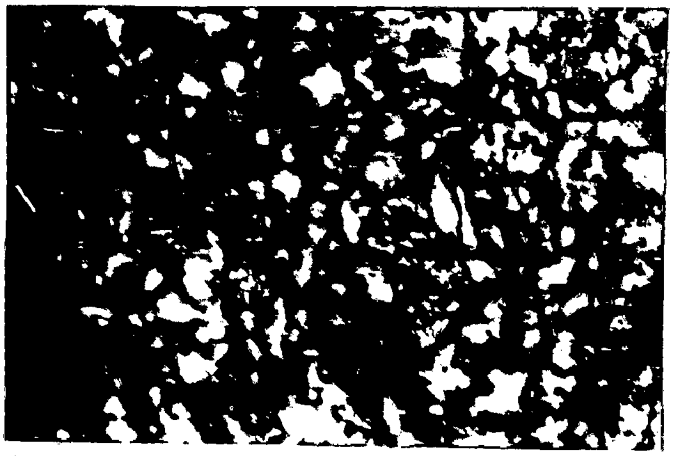

Figure 4.18 Micro Structure of Weld Metal Fabricated by Automelt Grade IV Flux with Grade C Wire at 750 A

CONCLUSIONS

On the basis of the investigations conducted, the following conclusions can be made.

- The yield strength and Ultimate Tensile Strength of weld metal fabricated by Indigenous consumables is higher than the weld metal deposited by German consumables.
- As the current increases from 550A to 750A, the Ultimate Tensile Strength and Yield Strength decreases in the case of both consumables.
- The Percentage Elongation and Percentage Reduction in Area of weld metal fabricated by Indigenous consumables are lower than the weld metal fabricated by German consumables.
- As the current increases from 550A to 750A, the Percentage Elongation and Percentage Reduction in area of weld metal fabricated by both consumables increases.
- The Impact strength of weld metal fabricated by Indigenous consumables is lower than the German consumables at the same temperatures and currents.

- As the current increases from 550A to 750A, the Impact Strength of weld metal deposited by both types of consumables increases at all temperature investigated.
- Hardness of weld metal fabricated by Indigenous consumables is higher than the German consumables.
- As the current increases from 550A to 750A, the Hardness of weld metal deposited by both types of consumables decreases.

CHAPTER 6

SCOPE FOR FUTURE WORK

The present investigation could be extended by changing the voltage and welding speed . These two parameter also affect the heat input, though welding current is the most important parameter. The role of which is investigated in present investigation.

Further the investigation could be carried out by choosing other feed wire combination like C- Mo wire with Automelt Grade IV flux .Similarly in the case of German consumables investigation could be carried out by OP121TT with S_2 wire .By trying such flux wire combination the scope of the work could be extended.

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