MECHANICAL PROPERTIES OF MILD STEEL WIRES REINFORCED ALUMINIUM ALLOY

A DISSERTATION

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

of

MASTER OF ENGINEERING

in

MECHANICAL ENGINEERING

(With Specialization in Production and Industrial System Engineering)

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled MECHANICAL PROPERTIES OF MILD STEEL WIRES REINFORCED ALUMINIUM ALLOY", in partial fulfilment of the requirement for the award of the Degree of "Master of Engineering", submitted in the Department of Mechanical and Industrial Engineering' of the University of Roorkee is an authentic record of my own work carried out during a period oct 94-Feb95 under the supervision of Dr. (Mrs.) Vijaya Agarwal, Reader, Metallurgical Engineering Department and Shri Ajai Agarwal, Lecturer, Mechanical and Industrial Engineering Department, University of Roorkee, Roorkee.

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

(R.K. BHARTI)

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

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24/2

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SYNOPSIS

The mild steel reinforced aluminium base alloys is proposed to have a bright future in automobile Engg. Industries due to its improved mechanical properties and directional physical properties .

In this report the main effort is given on heat treatment at 500^{o} C for predetermined time i.e. 10 to 20 hrs. of aluminium alloy reinforced with m.s. wires.

The discussion is around the mechanical properties which brought about the strengthening of these types of alloys and study of micohardness of the interface growth at different temperature and different extents of times.

CONTENTS

CHAPTER 1

INTRODUCTION

The development of metal matrix composites (MMCs) has been one of the most major innovation in the material in the past 20 years. Many of the social and technological factor influencing this development has been reviewed by A. Kelly [1]. The use of metal fibre composite is gaining more importance over of aluminium alloys etc. as Engineering Material paricularly in automobile engineering industries and aerospace applications, due to its improved mechanical and phyical properties. [2-4].

In the recent year, the aluminium based composites are widely used as connecting rod, cylinder head, turbine blades and vanes etc. in engineering industries and has considered for other important areas applications due to its low density, wide alloy range and heat treatment capability, high strength to weight ratio, high corrosion resistance etc., Very recently the continuous fibre reinforced metal matrix compositíes with single orientation have attracted consideration as a result of there relatively good mechanical properties.

The early development of composite materials was hindered by the high raw material costs and the slow and expansive processing methods. However, it is now feasible that the cost of same composite can be drastically reduced. Fully automated methods have been developed for manufacturing some composite products there results in better quality control and lower cost. The impact of fibre reinforced composite material is vital to all industries [5].

The fibre in a composite are often deliberately aligned with the direction of bondings. Externally applied forces are transferred to and distributed among the fibres. The transferring and distribution of loadings are achieved through the matrix material and take place at the fibre matrix interface. The fibres are also reasonable for the stiffness of the composite. In MMC, the fibre may lower the density of composite. Fibre are generally more brittle than the matrix and the breaking of fibres at localised regions does not trigger catastrophic failure of the composite. This is due to the fact that cracks orginating in fibres are arrested by the ductile matrix [5].

The fibre matrix interface plays a rather unique role in the behaviour of composite material. The nature of the interface determines the wetting and bonding between the constitutent phase. This in turn controls the effectiveness of load transferred and the strength of composites. Transport of mass between fibres and matrix may take place across the interface.

In the present investigation, commercially pure aluminium with alloying additions like copper has been chosen to embed mild steel wires. MMC is fabricated by reinforced casting technique. The advantage of such casting is that it gives improved casting quality and low cost of production compared to that of other non conventional castings.

The specimens prepared out of these reinforced casting with different numbers of MS wires were heat treated for 20 hours at different temperatures like 425, 450, 475 and 500 degree celcius. The thickness of the reaction interface were measured.

The thickness of reaction interface is found to increase with temperature, and follows relation

$$Y = ax^2 + b x + c$$

the microhardness across the reaction interface is found to be 426 VHN. The ultimate tensile strength of the reinforced castings were found to increase with number of reinforced MS wi-res. The fractography studies were carried out under Scanning Electron Microscope (SEM).

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

The engineering of modern composite material has had a significant impact of the technology of design and construction. By combining two or more material together , it is to be make advance composite material which are lighter, stiffer and stronger than any other structural material. The history of man made composite material can be dated back to ancient Chinese [6], Egyptians, and Israelities [7].

The definition of composites given by various workers are as, " A composite marerial is a materials system composed of a mixture or combination of two or more macroconstituents differing in form and/or material composition and that are essentially insoluable in each other " [8].

Another definition given by Berghezen stresses, " The fibre reinforced composites are only those introgeneous material which are prepared by a association and bonding in a single structure of material possesing quite different properties and when these are complimentry give a composite material possesing additional and/or superior properties to the individual components either alone or mixed together " [9].

Metal matrix composites (MMCs) are of intrest today because they offer the opportunity to tailor a material with a combination of properties unavailable in any single material, e.g., combining the very high tensile strength and modulus of elasticity of various type of fibres with the low density of a metal such as aluminum, titanium, or magnesium to obtain a composite material with a higher strength-to-density or modulus-to-density ratio than any single known alloy.

Composites are generally divided into various categories depending upon their structural constituents, viz. perticulate composites, fibre composites etc.

The fibre composite are composed of two constituents namely fibre and matrix, the interface bond is the individual fibre to the matrix. Fibres can be either metallic or non-metallic in nature. Fibre,is used as a generic term to denote four types of reinforcing agents: wires, filaments, whiskers, and indigenous phase perticle in a eutectic alloy. The most common types of wires used to reinforce MMCs are beryllium, molybdenum, steel and tungsten [8].

The mechanical and physical properties can be obtained from MMCs for the Aerospace and Automobile industries due to this the technology has advanced to the point where it is possible to design and fabricate efficient and reliable high performance structure.

The selection of the reinforcement depends on the creteria as elastic modulus, tensile strength, density, melting temperature, thermal stability, coefficient of thermal expansion, size and shape, compatibility with matrix material and cost.

The structural efficiency of the reinforced MMCs is a function of the density, elastic modulus, and tensile strength of the reinforcing phase. The chemical stability and compactability of the reinforced with the matrix material are important not only for the end application , but also during material fabrication.

In this chapter, different casting techniques used for the production of MMCs, interface study, mechanical properties etc. are discussed.

2.2 CASTING TECHNIQUES

Different casting techniques used for the production of MMC are stir casting, compo casting, rheo casting, vacuum casting, reinforced casting etc. The details are discussed in the subsequent sections.

2.2.1 Stir Casting Technique

Stir casting has been studied by various investigators. Here stiring is employed during casting the liquid metal/alloy The molten alloy is vigorously agitated for a desired period of time and then the melt is directly poured into mould and quenched the microstructure of stirred alloy is governed by certain

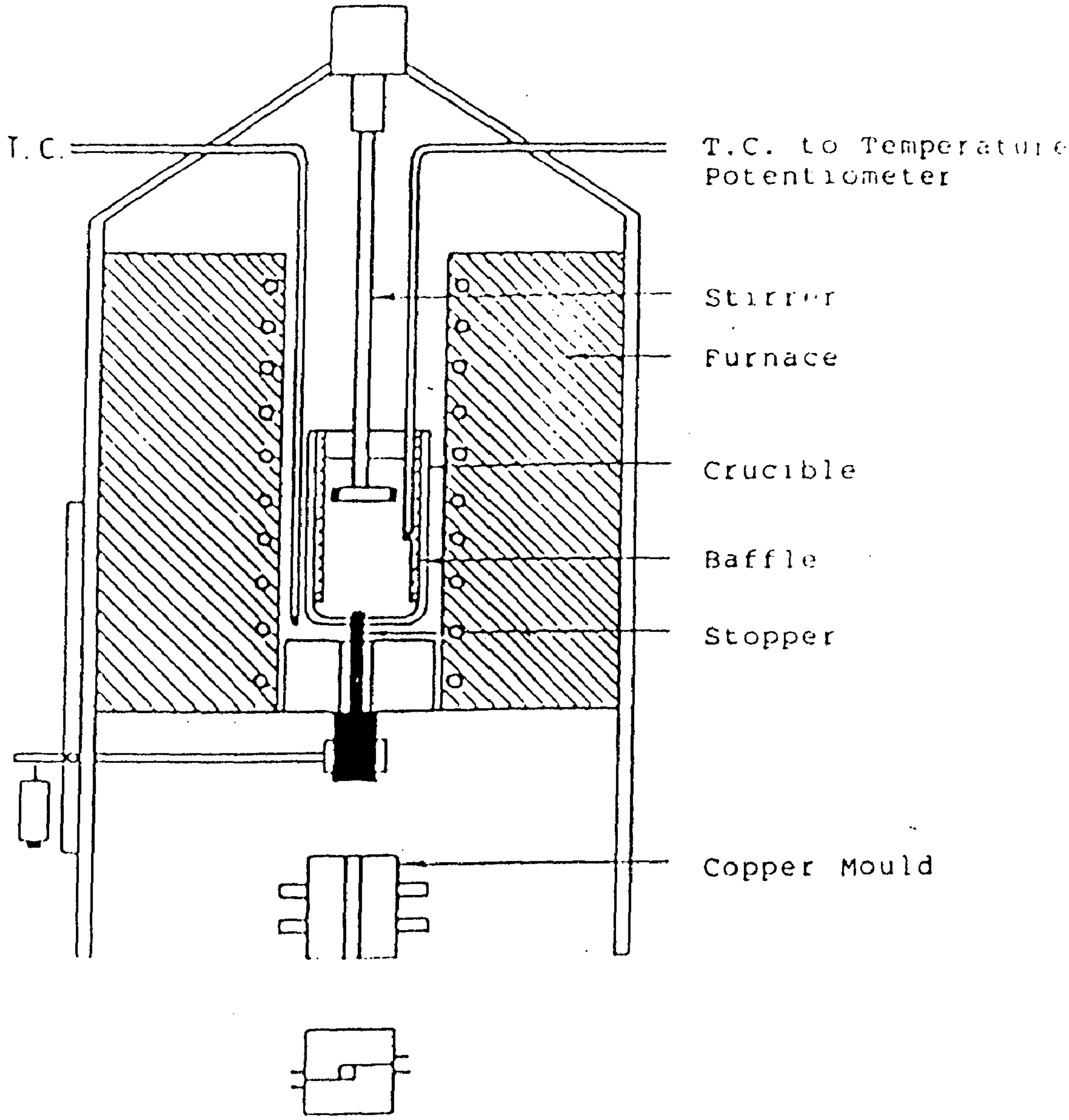


Fig. 2.1 Schematic experimental set up.

process variables such as agitator or stirrer speed, stirrer shape, stirring time, pouring temperature and cooling rate. The morphology of stir cast alloy is quite different from conventionally cast alloy [10]. The experimental setup used, is shown in Fig. 2.1.

The production of Al-Pb alloy by stir casting is done by agitating the melt containing two immissible liquid .The stirring is done by agitator at the desired temperature and then the processing temperature is reached the alloy is cast into mould. As a result of vigorous stirring, liquid-liquid mixing occurs and to maintain this distribution of two phases in microstructure at room temperature, faster cooling is applied by quenching the methilin water, oil, ice brine solution in order to quech the material quickly bottom pouring technique is used.

In Stir casting vigorous agitation is employed in the liquid rigion and from the region melt is directly cast into the mould, while continuing agitation. Micro structure of Stir cast alloy generally consists of a matrix of primary constituent while second phase particles are distributed all over the matrix [10].

2.2.2 Compo Casting Technique

The process has the potential of producing a wide variety particulate and fibrous materials for improved wear resistance, improved strength, high corrosion resistance.

The basic process involves addition of the non-metals partially solidified, vigorously agitated slurries of alloys. Initially the high effective viscousity of metal slurry prevents particles from settling, floating or agglomerating, with increasing mixing times, after addition intracting between the particles and the liquid matrix promotes bonding. Particles and fibres of a variety of materials, including sic,Al203, Mgo, Boron, Mica and glass beeds have been incorporated into the aluminium and magnisium alloys by this technique. Sizes have ranged from submicron to 100 or more microns. The composites, thus prepared are then cast either when the alloy is partially solid or after reheating to above the liquidus temperature of the alloy. The experimental set used for the batch type production of Al(Mg), Al203 particulate composite is shown in fig.2.2

2.2.3 Rheo Casting Technique

Stir casting of semi solid melt is widely known as rheocasting. In this technique the alloy is cooled down to semi solid region from liquid state while agitating vigorously. Vigorous agitation of the melt eliminates the region under constitutional super cooling and dendritic growth is disfavoured unlike that of unconventionally cast alloy. The solid forming in the form of spherical particle remain suspended in the liquid melt resulting in the slurry. The amount of these suspended solid particles depends upon the pouring temperature between the liquidus and solidus at which the slurry is cast. Because of the

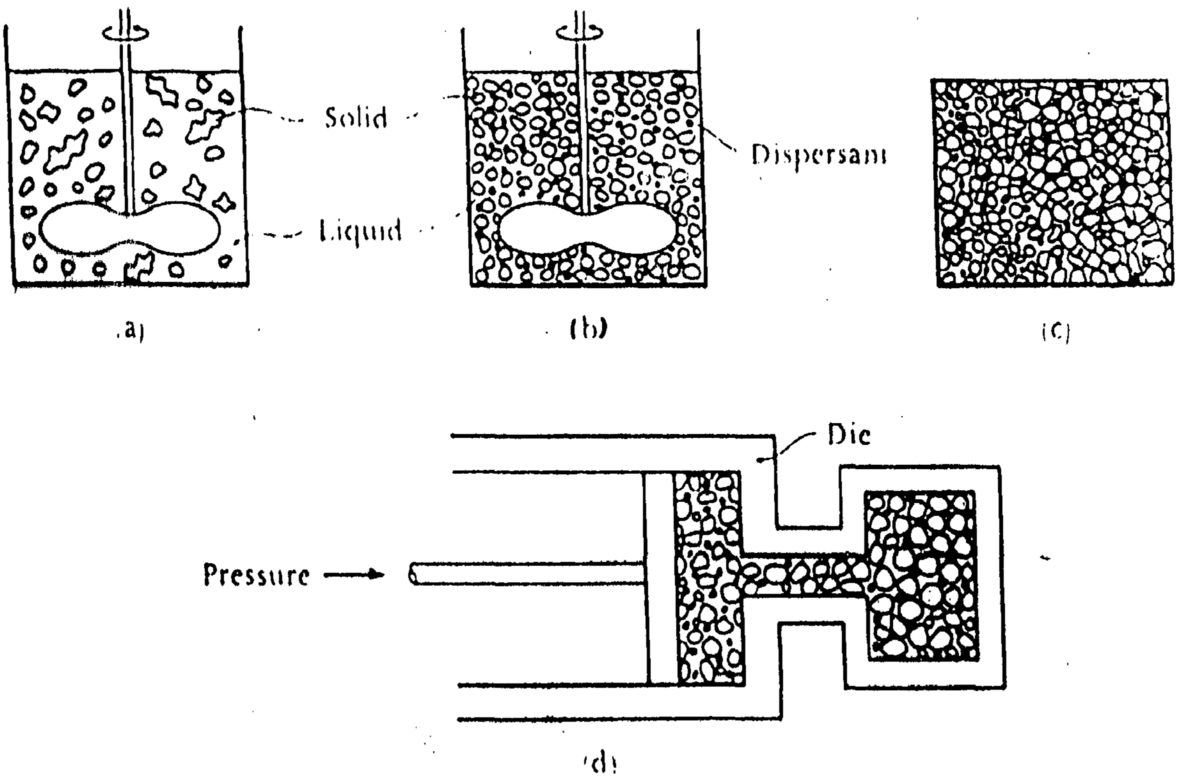


Fig. 2.2 Compo casting (a) a solidifing alloy is stirred to breakup the dendritic network (b) a reinforcement is introduce into the slurry (c) in absence of force, the solid liquid does not flow and (d) high pressure cause the solid liquid mixture to flow into a die.

lower pouring temperature in the semi solid state as compared to that of a casting from the fully liquid alloy. The microstructures obtained are quite different from conventionally cast alloy.

In rheo casting the alloy is partially solidified in the crucible while agitating vigoruously to obtain a fluid like behaviour of the slurry. Hence during casting the liquid alloy at temperature, Tp is cooled down to semi solid reason between the liquidus TL and solidus TS temperature The stirring is employed from the liquidus temperature TL to the holding Temperature TR. After holding the alloy in semi solid region at TR for certain time. Say t. The slurry is poured into the mould where it is cooled down to room temperature at different quenching rates.

Schematic representation of rheo casting in a binary liquibrium diagram is shown in Fig.2.3.

The rheo casting can be a continuous or a batch type process. In the batch type process the semi solid melt is hold in the crusible at the desired temperature and stirring is carried out by the stirrer with blades of different shapes and material as shown in Fig. 2.4(a), Batch type, and Fig. 2.4 (b), continuous type.

Ichikawa produced the rheocast Al-Pb alloy by melting Al-Pb alloy in vacuum and stirring it at the work speed of 70 sec^{-1} to

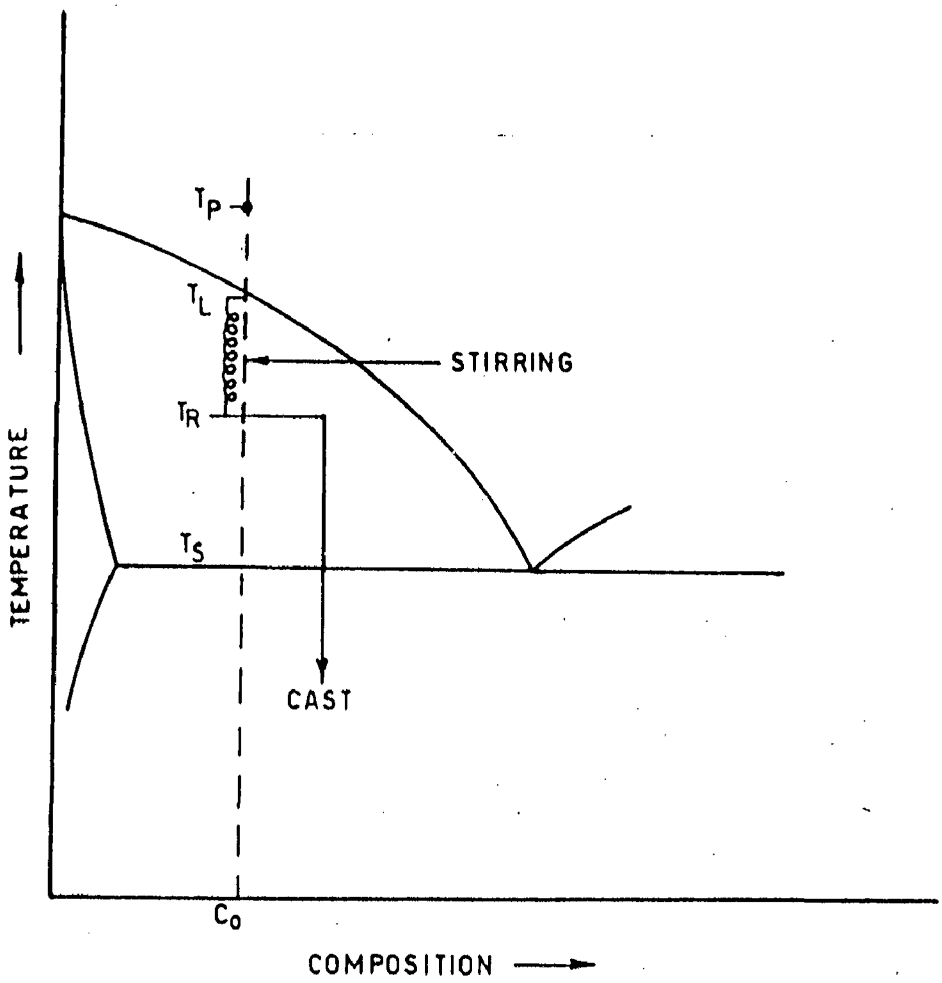


Fig. 2.3 Schematic representation of Rheo casting in a binary equilibrium diagram.

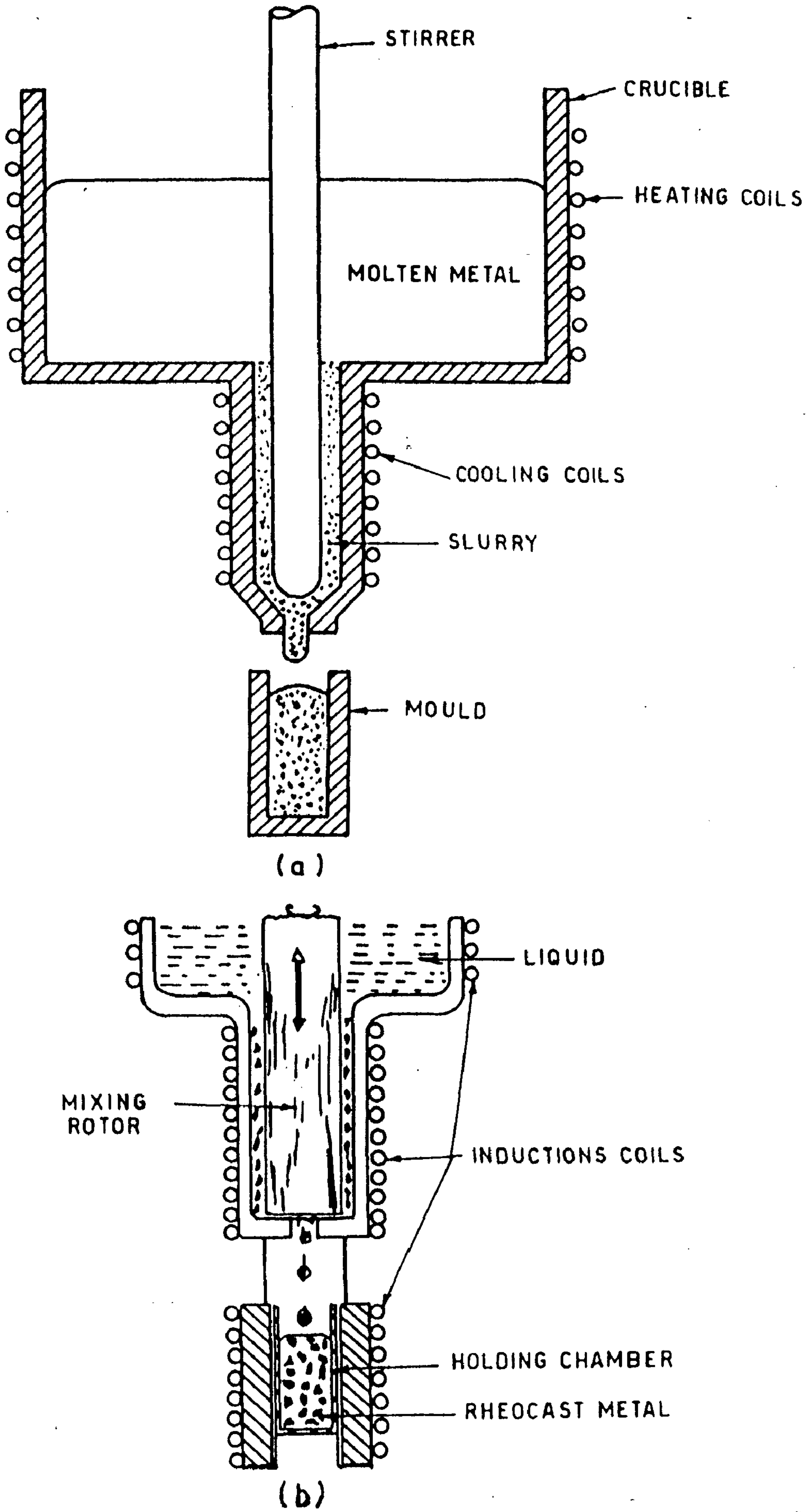


Fig. 2.4 Rheocasting units (a) Batch type (b) Continuous type.

prevent gravity segregation by distributing lead uniformly in semi solid alloy [11].

Mehrabian also produced rheo cast Al-Pb alloy by despersing 6 to 10 weight percentage lead [12].

2.2.4. Vacuum Casting Technique

The vacuum process is a process of making moulds using dry sand, plastic film and vacuum. This process is significantly different from conventional process of making moulds by squeezing and jolting. In vacuum process compacting of dry sand is achieved through a pressure differential . This pressure differential is maintained till the pouring and solidification of the casting. The vacuum process in aluminium is a sensible alternative in situation where one demands surface finish and dimensional accuracy approaching that of die casting but production requirement do not justify die casting and tooling cost. The basic sequence of operations of vacuum process are shown in Fig. 2.5.

The following variables that may affect the quality of casting produced by vacuum process have been identified.

1. Plastic film based variables,
2. Moulding sand based variables,
3. Vacuum suction levels, and
4. Metal based variables,

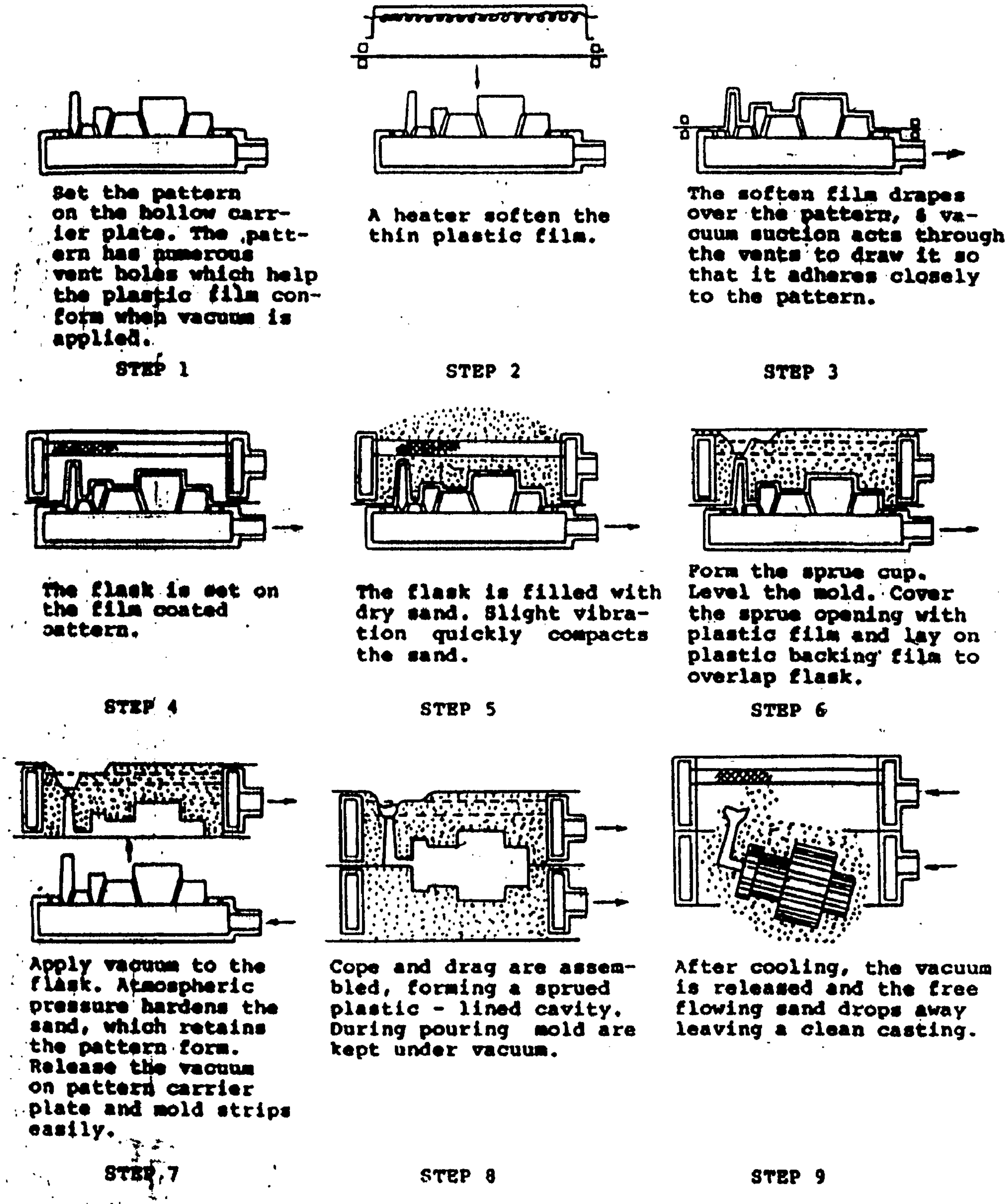


Fig. 2.5 Elemintary sequences in producing vacuum process moulds.

This technique was invented by Hoshimase Kubo, Kunu Nakata and Masao Nondo of Kabushiki Kaisha, foundry of Nagano, Japan in 1971, [13].

2.2.5 Reinforced Casting

Metallic matrix of fibre reinforced composites is selected according to its application eg. aluminium for low temperature application, titanium for intermediate temperature, and Ni. based super alloy for high temperature applications.

Glass fibre reinforced plastics manufactured in a variety of plastic base matrices is the most widely used composites in common structure and in consumer products. The advanced fibre composites developed particularly for aero - space hardware such as boron and graphite fibre with Al. matrix and unidirectional solidified boron aluminium composites.

Polymer matrix composites reinforced with carbon aramid and boron fibre are established aero-space material. The technology has advanced to the point where it is possible to design and fabricate efficient and reliable high performance structures. Durability of production components has been at least as good as their metals counterpart and that maintenance cost may actually be lower [14-15].

The fabrication of matrix and fibers into composites with useful properties is one of the most difficult task in developing refractory wire reinforced superalloy.

Fabrication method can be classied as either solid phase or liquid phase depeding upon the condition of the matrix phase during its penetration into a fibrous bundles.

Liquid phase method consists of casting the molten matrix so that matrix infiltrates the bundles of fibres in the form of parallel stacks or mats. The molten metal must wet the fibres, form a chemical bond and yet be controlled so as not to degrade the fibres by dissolution, reaction or recrystallization. Larger fibre diameter have been used to increase the size of unreacted wire core and matrix alloy composition have been selected to reduce solute diffusion into the fibers.

Liquid phase methods are particularly suited to the preparation of fibre reinforced super alloy for automobile engineering industries and for gas turbine applications because casting is the basic fabrication technique presently used for these applications. The use of fibers having a diameter less than 0.75 cm in composites prepared by liquid metal ifiltration leads to displacement of the wires. An alternate means of using liquid state technology is to coat the wire with matrix by passing it as single strand through a molten bath of matrix. The coated wires could then be diffusion bounded in closed dies to form the composite component [16].

The most important reason for most of the work on refractory fibre super alloy composites has been to produce a material capable of operation as highly stressed component such as turbine blades in advanced air craft and industrial gas turbine engine.

The development of these novel high temperature structural composites is certainly promising for structural application at elevate temerature yet additional development work is needed for future improving their mechanical properties.

2.3 FABRICATION METHODS

For the preperation of the fibre reinforced composites various method have been adopted by various worker, some of them are as :

2.3.1 Powder Metallurgy Technique

By this technique stainless steel fibres reinforced aluminium composites can be prepared with good static, dynamic and elevated temperature property. This technique involves cold pressing and hot pressing. Cold pressing is more difficult because high pressure needed to press the powder to the required density can break the fibre. Powder is vibrated into stacked fibres mates, after induction pressure is applied gradually when final temperature is reached. [8].

In the case of powder metallurgy,the matrix alloy powder is blended with particles of the reinforceent to achieve a

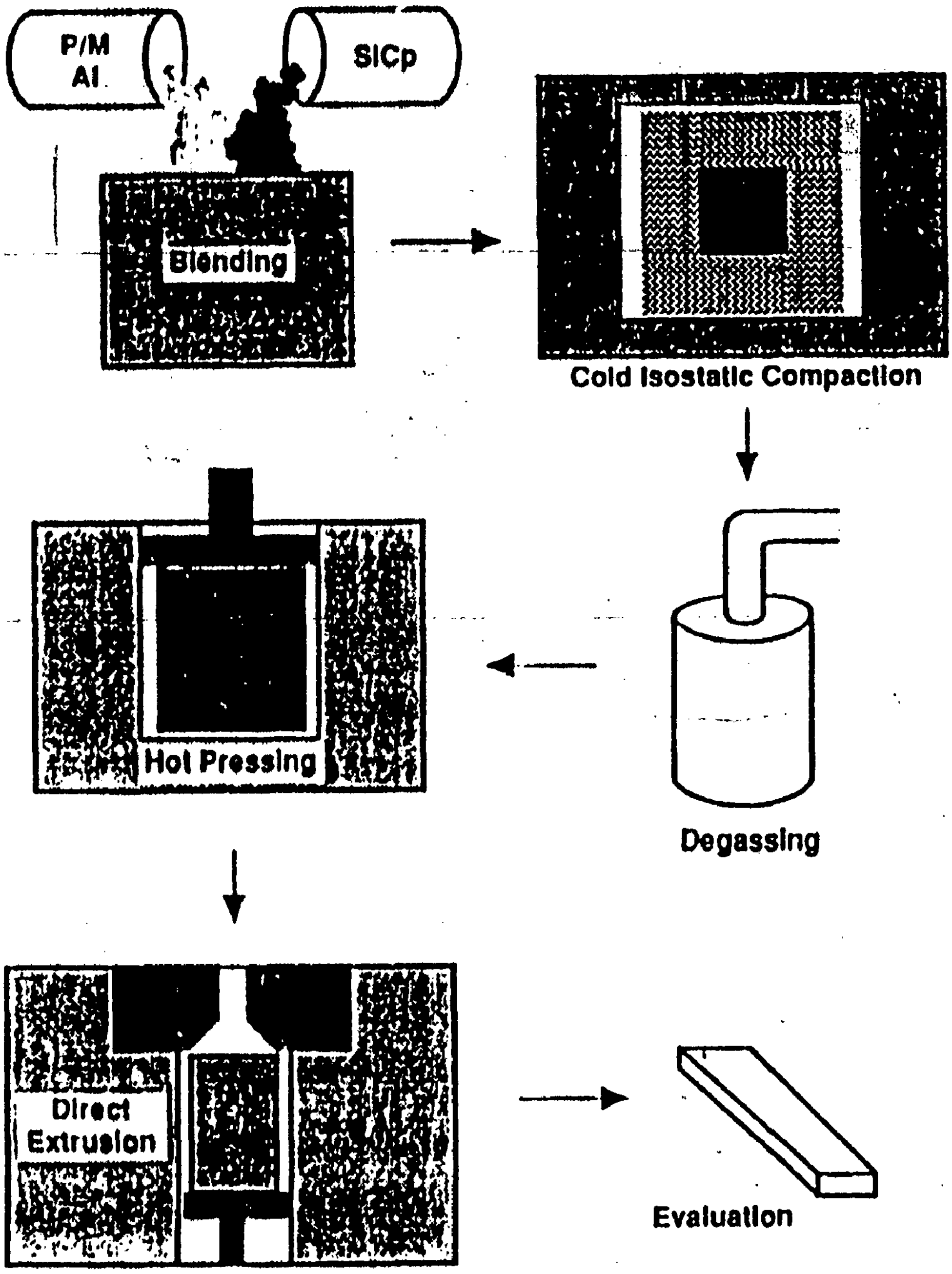


Fig 2.6 Powder metallurgy manufacturing route

homogeneous mixture. To achieve this, the sizes of the metal and ceramic powders need to be carefully chosen so that agglomerates are not left after blending, and carry over into the final product. The appropriate size ratio will depend on the blending process used, butin one case a SiC/Al particle size ratio of 0.7:1 gave a more uniform reinforcement distribution than a ratio of 0.3:1 [36]. In powder metallurgy processing, the brittle ceramic particles are also susceptible to particle fracture, which is dependent on the particle aspect ratio and flaw density. Typically, the atomised aluminium powder particle size is in the range 20-40 μm, and reinforcement particle sizes are 3-20 μm with aspect ratios of < 5:1. The essential features of the powder route are shown in fig.2.6. The metal powder is usually prealloyed atomised powder,in the 20-40 μm size range, but it can also be a blend of elemental powders, or rapidly solidified chopped ribbon or flake, as in the Allied-Signal process [37].

2.3.2 Continuous Casting Technique

This technique is used for the production of steel wire reinforced aluminium rods [17].

2.3.3 High Pressure Squeeze Casting Technique

This technique was used to produce the stainless steel wire reinforced aluminium composites. By this technique the fibre reinforced developed upto 40% approx. by volume fraction using pressure squeeze casting method.

2.3.4 Infilteration Casting Technique

This method is used to produce graphite aluminium composites such as rods, tubes with improved properties in a uniaxial direction but it is difficult of the high temperature involved and relative instability of some filament materials.

Other techniques of producing MMCs include, Diffusion bonding, Electro deposition, hot pressure bonding, rolling, hot extrusion.

2.4. INTERFACE STUDIES

The major function of the interfaces in composites is to transmit the load from the matrix to the reinforcing fibres. The behaviour of the interface determines not only the strength but also the mode of failure and the work of fracture of a composite. In order to optimise the performance of composite materials, it is necessary to gain some fundamental understandning of the nature interfaces [5].

2.4.1 The Metallurgical Aspects of Interfaces

A desired interfacial region in a composite relies on several factors [38]. First, intimate contact betweeen the fibre and matrix needs to be established through satisfactory wetting of reinforcing material by the matrix. secondly, good adhesion between the fibres and matrix is needed in order that adequate bonding can be developed. Thirdly, extensive diffusion between the component phased should be avoided so that the filaments will not be degraded by chemical reaction with the matrix, phase. The choice of the fibre and matrix materials of a composite system often cannot satisfy these requirements at the same time as well as the requirements called for by the service conditions. One of the feasible ways of achieving a satisfactory interface while not having to sacrifice the high performance of the fibres is to apply a thin coating on the reinforcing materials. Besides achieving the purposes mentioned above, the coatings also prevent abrasion between filaments, and protect the filaments from corrosive environment in service. The method of using alloy additions also proved to be effective in reducing the diffusion of the component phases in a composite.

In the aluminium alloy embedded with steel wires, there is wetting between matrix and wire i.e. an interface is created. At this interface an intermatallic layer is formed due to the diffusion of iron and aluminium atoms i.e.at high temperature during the period of casting and during heat treatment. Further it is seen that while subjected to heat treatment at different temperatures, the interface thickness increased as the diffusion is a function of time at a particular temperature. The growth of interface thickness increasesand growth of interface follows the relation [18].

$$\frac{dx}{dt} = K_o$$

where, Ko is the rate constant for growth of interface, X is the thickness of interface and t is the time. As the growing interface reaches a particular interface thickness, the growth mechanism changes from activation to diffusion control and follows the relation

$$\frac{dx}{dt} = \frac{Kp}{x}$$

Kp - Parabolic rate constant, after a very long time of heat treatment a steady state is reached due to this number increase in interface occur because the growth rate of interface is equal to the rate of dislocation of the intermetallic compound layer, taking place in parallel to the layer growth [18].

2.4.2 The Mechanical Aspects of Interfaces

The load transfer across an interface in fibrous composite materials has been examined by Dow [39]. The composite model of Dow was made of two concentric circular components, simulating a fibre surrounded by the matrix material. Anlytical solutions were obtained for the axial load transferred across the interface when either the fibre or the matrix was loaded in uniaxial tension. The interfacial load transferring phenomenon also has been studied by photoelastic experiments.

2.5 EFFECT OF NUMBER OF STEEL WIRES EMBEDDED IN ALUMINIUM BASE ALLOY ON THE MECHANICAL PROPERTIES

Reinforced rods were subjected for tensile stregth for 3.24 and 3.47 volume fraction of steel wires in the matrix. It was noticed that the tensile strength of the reinforced rods increased by 22% [17].

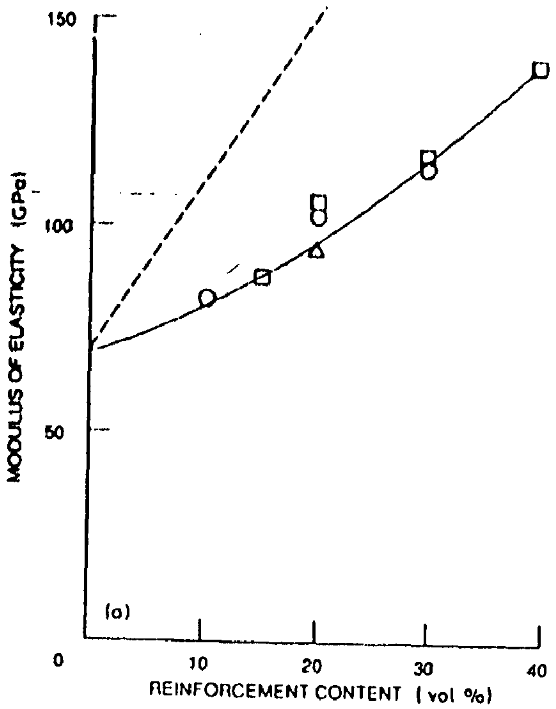
Variation of tesile strength with fibre volume fraction of stainless steel wire reinforced aluminium and aluminum alloy matrix composites was produced by R.B. Bhagat [18]. He showed that as the volume fraction of steel wires in composite increased the strength of the material increased.

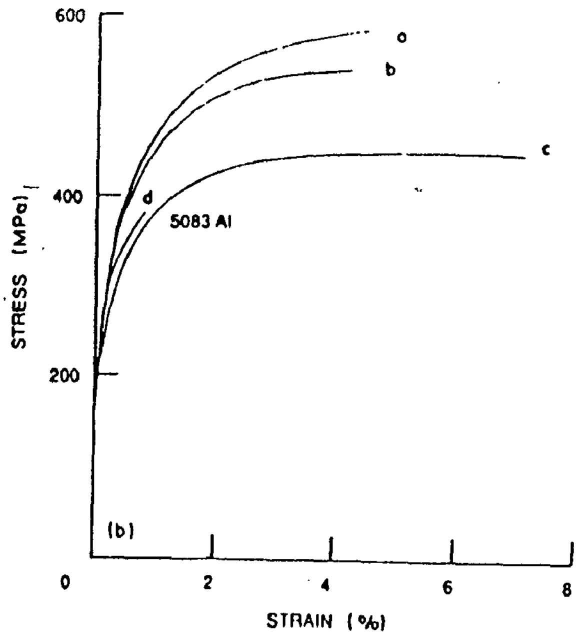
2.6 MECHANICAL PROPERTIES OF REINFORCED CASTINGS

2.6.1 Tensile properties

The strength of composite materials is influenced by a number of factors these include the anisitropic and non homogeneous nature of the material, the mechanical incompatibility of the constituents phases, the effect of interfacial bonding the elastic and plastic behaviour of the matrices and the reinforcing materials, the volume fraction of the component materials and the directions of the applied load.

The fibres in the composite materials are assumed to possess uniform strength the distribution of the load among the matrix and fibres as well as the strength of a composite depend very





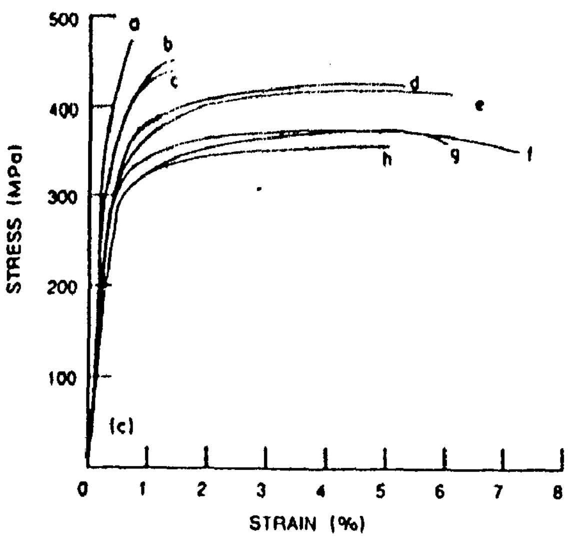


Figure 2·7(a) Effect of reinforcement content (O SiC_w (whisker), △ SiC_n (nodule), □ SiC_p (particulate), ——— isostrain-type behaviour) on modulus of elasticity of discontinuous SiC/6061 Al composites, (b) effect of Al matrix alloy an stress–strain behaviour of composites with 20 vol % SiC_w reinforcement (a 7075 Al, b 2124 Al, c 6061 Al, d 5083 Al), (c) Stress–strain curves of -6 temper SiC/6061 Al composites [85]. (a 40 vol % SiC_p, b 30 vol % SiC_w, c 30 vol % SiC_p, d 20 vol % SiC_p, e 20 vol % SiC_w, f 10 vol % SiC_w, g 20 vol % SiC_n, h 15 vol % SiC_p).

much upon the length of fibres.

There are numerous factors influencing the yield (YS) and tensile (TS) strength of particulate reinforced MMCs. These factors are complex and inter related. For example, one of the most important factors influencing the mechanical behaviour of MMCs is the alloy matrix. Whereas alloys exhibiting relatively high YS ad TS levels result in MMCs with concomittant increases in strength, their deformation behaviour is typically extremely poor. Furthermore, heat treatment affects the transition from elastic to plastic behaviour; hence, peak aged MMCs (i.e. T6-temper) exhibit a slightly greater amount of elastic strain, YS and TS values than those in the as fabricated condition (F-temper) [19]. This increase in the flow stress of the composites with heat treatment is likely to be an indication of the additive effects of dislocation interaction with both the alloy precipitates and the reinforcements [19]. Although increasing the volume fraction of reinforcements generally increases the strength of the MMCs, the magnitude of the increase depends, among other factors,on the volume fraction of reinforcement. In the Al-SiC system for instance the rate of increase in strength with volume fraction decreases beyond approximately 30 to 40 vol. % Sic. Fracture of the MMCs containing reinforcement typically occur while still in the steeply asceding portion of the stress strain curve [19] See fig.2.7.

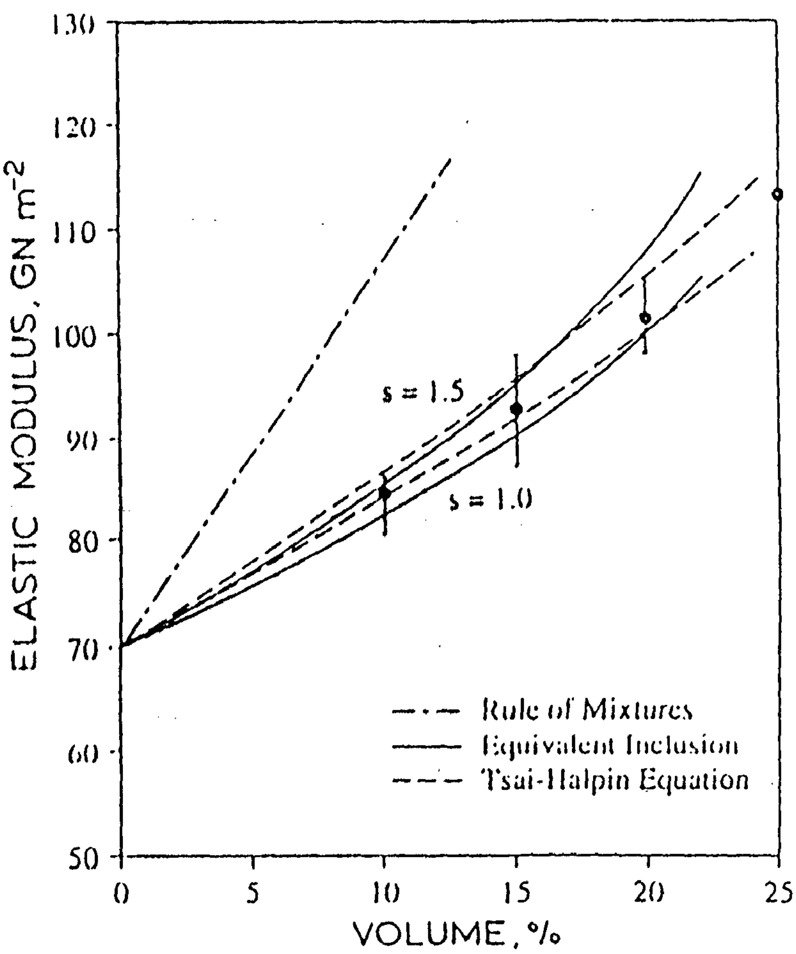


FIG 2·8 Variation of elastic modulus with volume fraction of SiC particles: *s* is particle aspect ratio

The mechanical properties of MMCs are also affected by the residual stresses which form as a result of the differences in the thermal expansion coefficients between the matrix and reinforcement. There are various models which have been developed to estimate the residual stress in MMCs.

The first extensive study of the strength of discontinuously reinforced Al alloys was carried out by McDanels[19], who investigated SiC whisker and particle reinforcement in several different alloy matrices. He reported up to a 60% increase in yield and ultimate tensile strength, depending on the volume fraction of reinforcement, the type of alloy, and the matrix alloy temper. Subsequent work has generally confirmed these findings but the reported experimental results show an extremely large degree of scatter, presumably reflecting the quality of the material and differences in processing. When considering the yield stress there is more fundamental difficulty, as pointed out by Humphreys [22]. The yield strength is usually quoted as the 0.2% proof stress, and since composites work harden extremely rapidly at low strains, this may not be equivalent to a conventional yeild stress.

The strengthening mechanisms which may operate in particle reinforced MMC's have been considered in several recent publications andthe behaviour has also been extensively modelled mathematically [22,23,27].

The composite strength gives as

$$\sigma_c = (V_p \sigma_m S/4) + V_m \sigma_m \qquad \{1\}$$

where σ_m is the yield stress of the matrix, and s the aspect ratio.

For the aspect ratio typically used in particle MMCs, which are in the 1-5:1 range, equation [1] underestimates the strength, but Nardone and Prewo [24] have suggested that better agreement is obtained if the equation is modified to allow for end loading effects. The difficulty with this continuum approach is that it ignores the influence of particles on the micromechanics of deformation, such as the very high work hardening at low strains, and modifications in microstructure, such as grain size and dislocation density.

In the micromechanics approach, the possible strengthening mechanisms are

1. Orowan strengthening.
2. Grain and substructure strengthening.
3. Quench hardening resulting from the dislocations generated to accommodate the difference in coefficient of thermal expansion between the reinforcing particles and the matrix.
4. Work hardening, due to the strain misfit between the elastic reinforcing particles and the particles matrix.

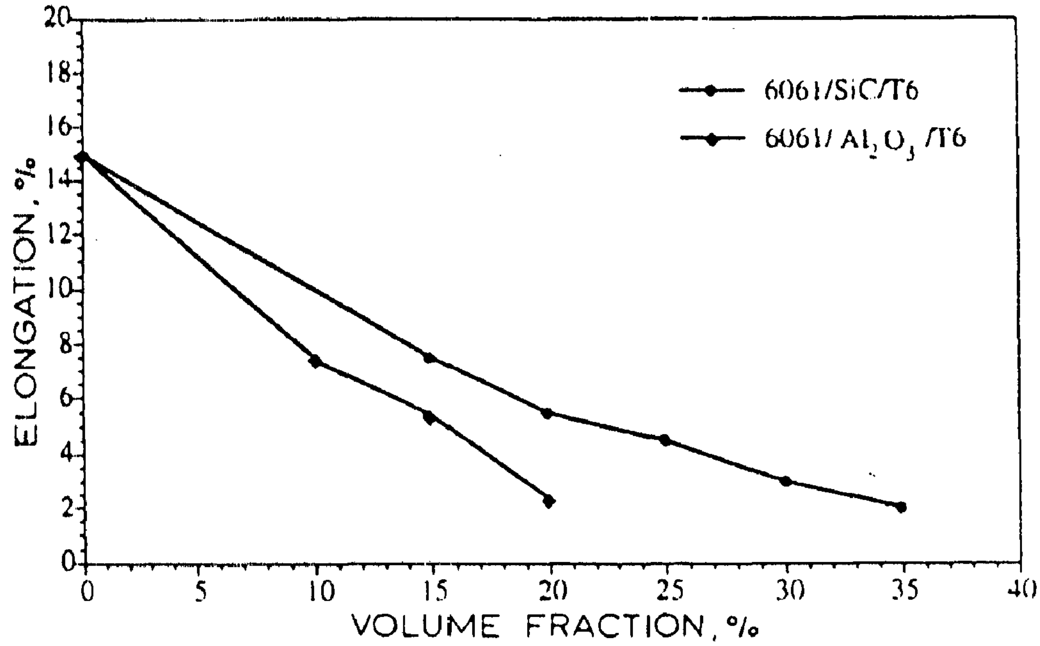


FIG. 29 Variation in tensile elongation of 6061 with volume fraction of reinforcement

2.6.2 Elongation

The major limitation in the mechanical properties of composites is the rather limited ductility, the tensile elongation decreases, rapidly with the addition of reinforcing wires Fig. 2.9.and it also decreass with increased agig time in the heat treatable alloys. Recent work has demonstrated that composite failure is associated with particle cracking and void formation in the matrix within clusters of particles [26,27]

Many models have been developed for void nucleation. Particle cracking by castastrophic propagation of an internal defects is given by the Griffith equation

$$\sigma_f = \left(\frac{2\ E\ Y}{\pi C}\right)^{1/2} \qquad \{2\}$$

where σ_f is the stress on the particle, Y the fracture surface energy, E the Young's modulus of the particle, and C the internal crack length.

For coarser particles there is a higher probability of their containing a defect of length C sufficient to give particles fractures. The particles being loaded through the particle/ matrix interface, so a high degree of particle fracture is indicative of a high interfacial strength, particularly when cracking is occuring in finer particles, < 10 µm.

A criterion for particle matrix decohesion appropriate for coarse particles has been developed Argon et al [28]. The critical stress for interfacial void nucleation σ_c given by

$$\sigma_c = \sigma_e + \sigma_m \quad \{3\}$$

where σ_c is the equivalet stress and σ_m the mean stress. Void nucleation will therefore be a function of the matrix flow stress, which will be influenced by the volume fraction of particles, heat treatment, etc. In the Argon et. al. model the critical stress is independent of particle size, but particle size effects would come into the picture if the particle distribution is a function of particle size, and also through the particle size dependence for particle cracking, equation [2].

2.6.3 Elastic Modulus

The one mechanical property which is always significantly increased by the addition of reinforcement is the elastic modulus. The quantitative value of the elastic modulus is somewhat dependent on the method of measurement, with dynamic measuring methods tending to give larger values than static measurements obtained from the elastic portion of the tensile stress-strain curve. Static values may also depend on whether the measurements are made in tension or compression [20]. Most of these difficulties result from the presence of thermal residual stresses caused by differences in the coefficient of thermal expansion between the matrix and the ceramic particles.

Figure 2.8, shows the increase in Young's mo-dulus with volume fraction of reinforcement for a variety of Al-SiC composites. The rule of mixtures expression

$$E_c = V_p E_p + V_m E_m \quad (4)$$

where E_c , E_m, E_p are the elastic moduli of the composite, matrix, and particle, repectively, and V_m and V_p the volume fractioins of the matrix and particle, considerably overestimates the elastic modulus.

The rule of mixtures expression is most appropriate for continuous reinforcement and it has been modified for discontinuous reinforcement in the Halpin-tsai equation [40].

$$E_c = \frac{Em\ (1+2\ Sq\ Vp)}{1-q\ Vp} \quad (5)$$

where

$$q = \frac{(Ep/Em-1)}{(Ep/Em)+2s} \quad (6)$$

and s is the particle aspect ratio. As seen from the figure, the Halpin-Tsai equation gives a good representation of the results.

The elastic modulus can also be calculated using the Eshelby equivalent inclusion method [21],and this approach is also in good agreement with the data.

2.6.4 Fracture toughness

The fracture toughness of particle reinforced composites, has been reviewed in two recent publications, [29,30]. While the toughness mirrors to some extent the tensile elongation, decreasing with increasing reinforcement, the decrease is most significant from 0 to 10 % reinfocement, with only a slight decrease for higher reinforcement, loadings. The fracture toughness is also much less sensitive to the degree of aging than is the tensile elongation,

In the continuum mechanics approach to fracture, the fracture toughness of a material is normally assessed in terms of some crack tip parameter at the initiation of crack growth. Specifically, fracture will occur when the crack tip strain et is exceeded over some microstructurally significant characteristic distance Io ahead of the crack tip. Under conditions of small scale yielding.

$$e_t = C\,\delta/x \qquad (7)$$

where δ is the crack tip opening displacement, x the distance ahead of the crack, and c a costant of the order of 1. At fracture initiation $e_t = e_f$ over a distance $x = I_o$ when $\delta = \delta_c$ and for small scale yielding.

$$\delta_c = CK^2/E\,\sigma_y \qquad (8)$$

where K is the stress intensity factor, E Young's modulus, σ_y the yield stress, and C a numerical constant depending on the work hardening exponent n, and the stress state, typically $\sim$ 0.5 - 0.6.

2.6.5 Fatigue

Many of the potential applications for composites require a resistance to cyclic loading. One would expect the low cylce fatigue behaviour of MMCs to be somewhat worse than unreinforced alloys because of the lower ductility in composites, whereas the high cycle performance should be improved because of the higher modulus. While there is considerable scatter in the published data, reflecting variations in processing and material quality, these expectations are generally fulfilled. Several studies [32] have shown that the improvement in fatigue life evident in stress life data is eliminated when compared on a strain life basis. Under constant strain amplitude conditions the MMc is inferior in the low cycle regime where plastic strains dominate, and in the high cycle regime the composite is little different to unreinforced material. The improvement observed in constant stress amplitude tests reflects the fact that withthe higher Young's modulus of the composite, the strains in the composite are lower than those in the unreinforced material at the same stress level.

Constant stress amplitude tests involve both fatigue crack initation and crack propagation. Crack initation has been associated with defects in the composite, intermetallic particles, and large reinforcement particle or particle clusters. It has been suggested that fatigue cracks initiate late in the life of composites[33].

CHAPTER 3

EXPERIMENTAL PROCEDURE

3.1 INTRODUCTION

In this present invistigation the material used for preparing the casting for fulfillment of experimental job were 0.2 % carbon mild steel wires of 0.5 mm diameter which embidded in aluminum copper alloy for automobile and aerospace applications.

This particular material selected as per following selection creteria.

3.1.1 Reinforcement Selection

This creteria includes,

(i) Elastic modulus,

(ii) Tensile strength,

(iii) Density,

(iv) Melting temperature,

(v) Thermal stability,

(vi) Coefficient of thermal expansion,

(vii) Size and shape,

(viii) Compatibility with matrix, and

(ix) Cost

The structural efficiency of reinforced MMCs is a function of the density, elastic modulus, and tensile strength of the reinforcing phases. The chemical stability and compatibilityof the reinforcements with the matrix material are important, not only for the end application, but also during material fabrication.

3.1.2 Matrix Selection

The aluminium alloy with low weight to volume ratio is used as matrix. The use of MMC for elevated temperature application necessitiates the presence of . thermo dynamically stable dispersoids. This requirement has been achieved by using an alloy dispersoid system in which elemental solubility, solid state, diffusivity and interfacial energies are minimized, thereby minimizing coarsening and interfacial reaction [35].

The low weight to volume ratio of the Al-Cu alloy reduces the energy consumption of the moving parts. The present investigation was carried out to develop aluminium alloy, a material of high strength to weight ratio, wide alloy range, high corrosion resistance etc. so that it can be used in automobile and aerospace area in place of steel. In this study the MS wire reinforced embidded in aluminium alloy produced by reinforced casting technique is chosen and for meeting all the desirable requirements. A suitable mould was designed and prepared for casting purpose. The MS wires were passed through the strip of 30x5x1 mm, having five holes of 1 mm Ø. The strip was fixed on the steel mould of size 20x10 cm Ø, forenabling the pouring alloy into the mould, 30 mm ϕ. Opening at the top of the mould was giving. The furnace which was used for preparing the reinforced casting have the following details.

Three phase thermax electrical furnance

Volt - 440

AC ~ 50

KW — 7.4

Maximum temperature 1450° C

Accuracy ± 10° C

The alloy composition in weight percentage was determined as Cu - 5.2, Fe - 1.1, Si < 1.5, Mg < 0.2, Mn< 0.2 and remaining aluminium. The nine number of castings of 20 cm x 2 cm ϕ where cast and then heattreated at different temperature like 425° C, 450° C, 475° C and 500°C. The casting were machined on lathe for preparing the tensile specimen. Then Ultimate tensile stress (UTS)were determined by universal testing machine (UTM), % of elongation, proof strength, were determined. Fractography studies were carried out for the fractured surfaces. Under SEM, samples were prepared for metallography studies and thickness of interface was determined for as cast condition and heat treated condition by the help of optical microscope.

3.2 REINFORCED CASTING TECHNIQUE

3.2.1 Mould Design

Dimension of plate "a" - 46 x 18 x 195 mm

Dimension of plate "b" - 46 x 18 x 195 mm

Dimension of plate "c" - 112 x 52 x 17 mm

Strip dimension - 48 x 5 x 2 mm

Top opening of mould - 36 mm ∅

Inner diameter for preparing the casting - 20 mm ∅

Bolt size for tightening the mould - 8 0 x 8 x 54 mm

3.2.2 Preperation of Mould

For production of mould, three M.S. rectangular plates "a", "b","c",were taken,two "a",and "b",of same sizeof46x18x195mm and third "c" of size112x52x17mm these plates were machined and given the fine surface finish for accurate and sound casting. Both the plates "a and b"designed like that, if both the plates come into contact, there exsists a hole of 20 mm ∅ at the centre so that half of the hole comes in each plate"a and b". The base plate 'c' having the hole impression of same diameter on the top centre of base plate 'c' one of the rectangular plate from "a"or "b" was welded perpendicular on base plate at the centre position so that it comes half of the hole of base plate 'c'. The other rectangular plate remain movable and comes on the another side of base plate with the help of four bolts. The hole impression of the base plate having five holes of 1 mm diameter and on the other side a steel strip prepared which also having five holes of samo diameter of 1 mm at the same distance, as shown in fig.3.1.

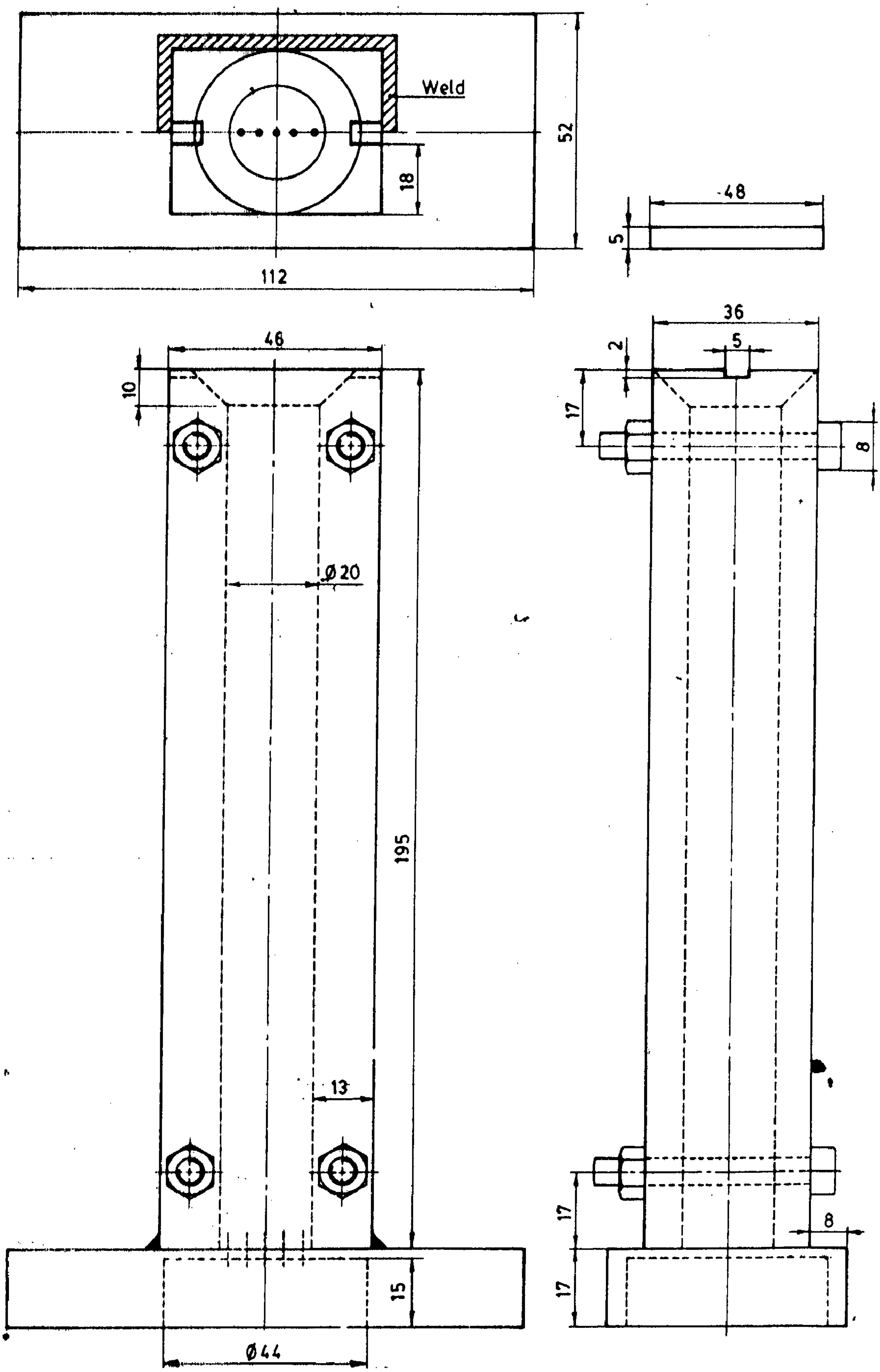


Fig. 3.1 The diagram and dimensions of M S mould used for reinforced casting.

On the top of the rectangular plate 'a' and 'b' a 5 mm wide and 1 mm deep impression cut from the plate so that half of the impression will come on both the plates. This impression were required for fitting of steel strip for making the wire tight. About 36 mm diameter widening space was cut at the top such that it facilitates the pouring of alloy into the mould.

3.3 CASTING PROCEDURE

For preparing the casting of MS wires reinforced aluminium alloy, the furnace used has the following details.

Thermax Electric furnace

Volt 440, AC ∿ 50

Phase - 3

KW - 7.4

Maximum temperature 1450°C

Mild steel wires of 0.5 mm diameter used for preparation of casting. The wires were passed through the hole of steel strip and through the hole on base plate of mould and tighten it, so that the wires were kept in tension. But before casting, the wires were cleaned by emery paper followed by acetone to remove tho oxide layers, and impurities etc.

The temperature of the furnace was maintained at about 800° C. The alloy ingut was cut into small pieces and placed into the crucible then this crucible was placed in the furnace.
When the alloy melted,it was poured into the mould from the top

pouring area. Nine number of such casting were prepared, one of casting was without MS wires and balance eight castings were with different number of MS wires.

3.4 HEAT TREATMENT

After preparation of castings they were heat treated in thermax electric furnace of 440 V AC, 3 Phase, 36 KW and maximum temperature 1300° C with an accuracy of ± 10°C for different temperatures for 20 hours.

The details of heat treatment given to the specimens are tabulated in table 3.1

TABLE 3.1

Details of the reinforced casting heat treated for 20 hours

Sl.No.	No.of wires Al-Cu reinforced casting	Temperature of heat treatment ° C
1	04	425
2	04	450
3	04	475
4	04	500
5	01	500
6	03	500
7	20	500
8	without wires	500
9	without wires	500

All the casting specimens were furnace cooled.

3.5 SPECIMEN PREPERATION

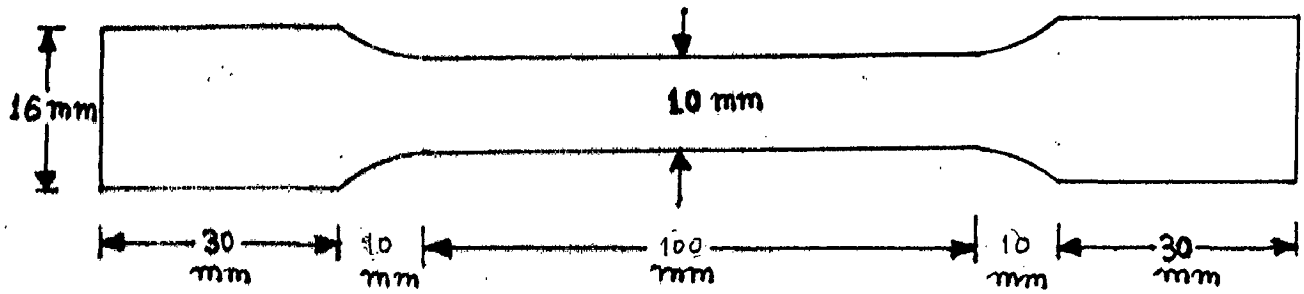
3.5.1 Tensile Specimen

The heat treated reinforced casting were machined on lathe to get tensile specimen of 180 mm x 16 mm ∅ and gauge length was kept as 100 mm. The gripping length and dimeter was kept 30 mm and 16 mm ∅ . The dimensions of tensile specimen are shown in Fig.3.2.

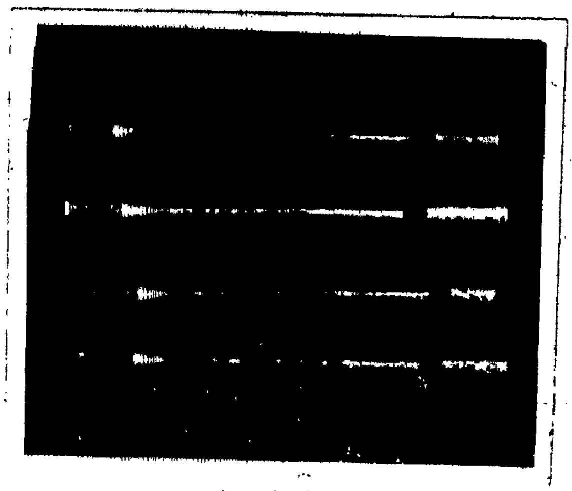
The tensile specimens were tested on the UTM, where the specimen was clamped between two jaws. The bottom jaws of the UTM was fixed and the upper jaw was movable. The specimen were first clamped in upper jaw then in lower jaw. Applied the load and note down the readings the load applied and % elongation for all the specimen were recorded. The broken specimen are shown in Fig.3.3 and and micrographic view of broken specimen are shown in Fig.3.4.

3.5.2 Fractography Studies

The fractured surfaces were cutout from the tensile specimens with the help of saw cutter. The other surface was smoothed (i.e. from where it was cut) so that it could be mounted for Scanning Electron Microscope (SEM), fractography studies.



(a)

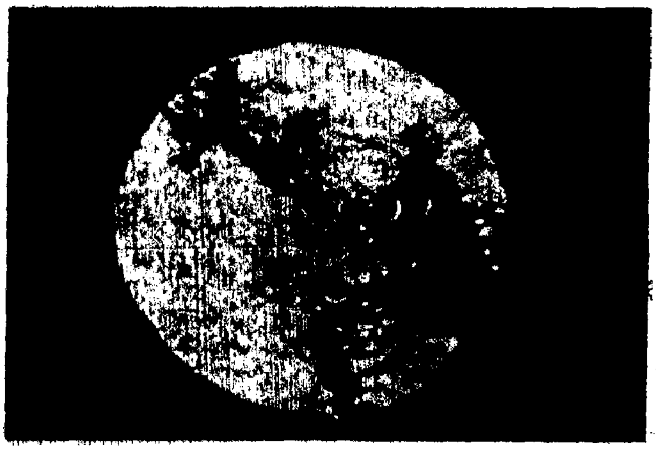


(b)

Fig. 3.2 Tensile specimen.

Fig. 3.3 Broken specimens after tensile test.

(a)



(b)

Fig. 3.4 Optical sterio microscopic view of ms wire embedded in aluminum alloy matrix ,

(a) Heat treated at 500°C, magnification 4 x

(b) Heat treated at 450°C, magnification 4 x

In the SEM analysis a beam of high energy electrons incident on a solid surface interacts with it in several ways the emitted radiations from the surface consists of x-rays light and secondary electrons in addition to reflected and secondary electrons. These intensities of different radiations are detected to form an image the maximum resolution of the SEM is 4x, 160000 x magnifications. By observing the fractured surface under SEM type of fracture of the tensile specimen were found out by observing the SEM micrograph. The details of scanning electron microscope is given below and the block diagram is shown in Fig.3.5.

Resolution - 70° A

Accelerating Volage - 30 KV

Magnification 4 x - 160000 X

Vacuum - 10^{-5} Torr

Maximum Specimen size 85 x 65 x 50 mm

Image recording facilities - 35 mm camera

- Polaroid Camera

- Sheet Film.

The specimens were examined under Philips SEM to study the nature of fracture. The fractograph of specimens were taken at different magnifications as shown in Fig. 3.6.

3.5.3 Metallography

Five specimen of size 15 mm x 18 mm x 18 mm ϕ were cut from

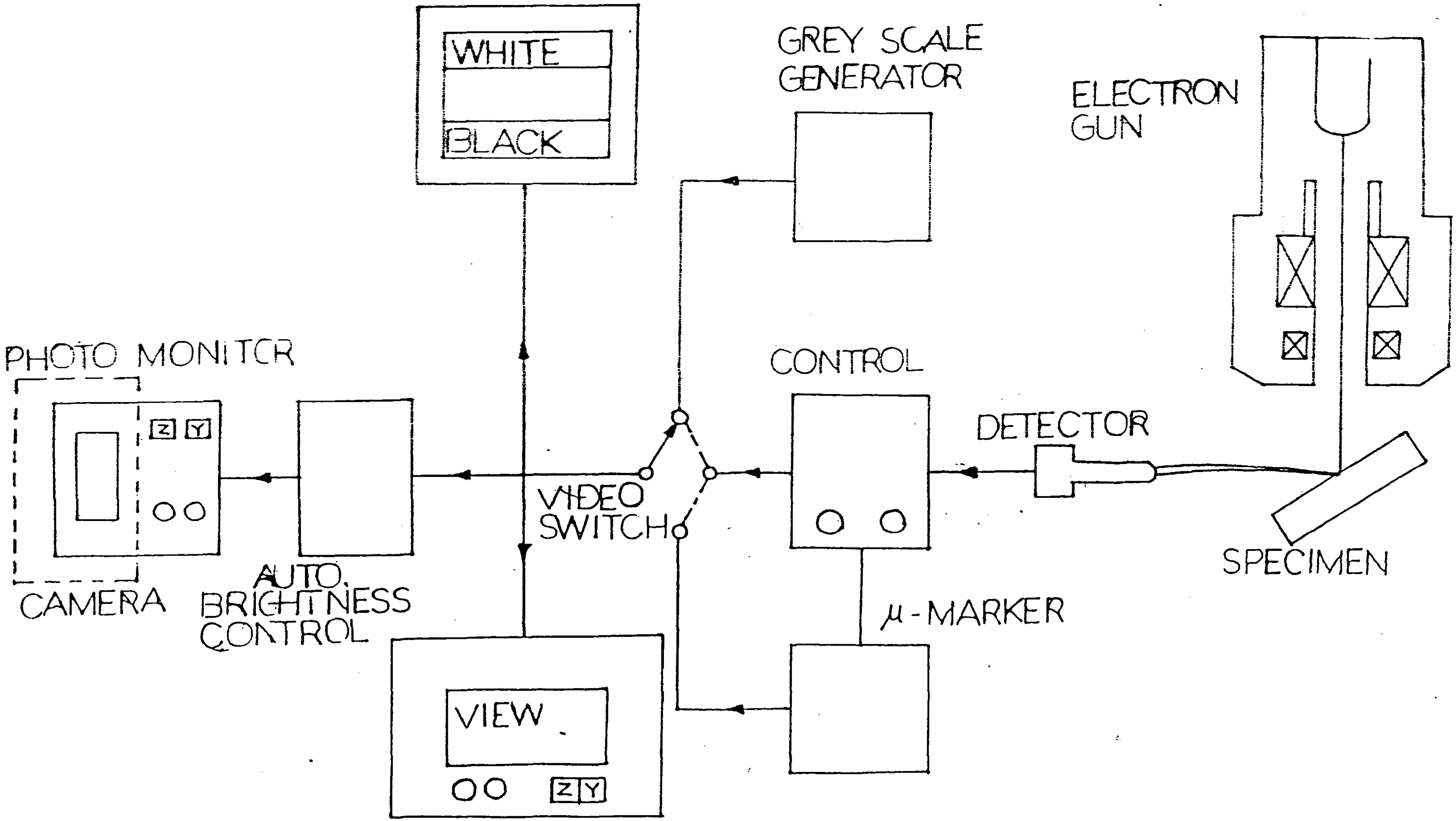
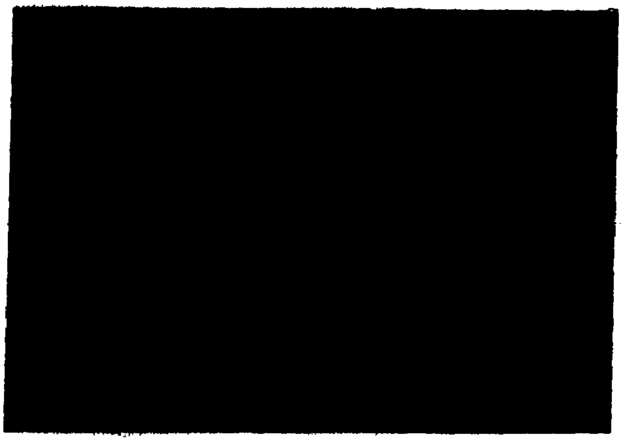


FIG 3.5 BLOCK DIAGRAM OF SCANNING ELECTRON MICROSCOPE (SEM)



(a)

(b)

Fig. 3.6 SEM fractographs of ms wires reinforced in aluminum alloy matrix

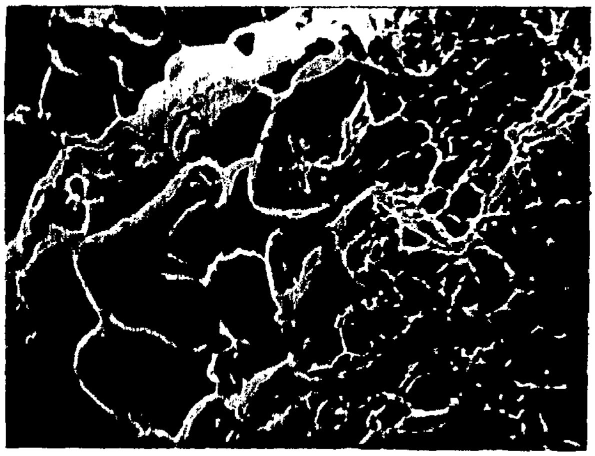
(a) Fracture specimen of MS reinforced casting showing two number of wires in as cast condition , Magnification (4x1.2)x

(b) MS wire embedded , aluminum alloy matrix showing wires, heat treated at 500° C for 20 hours, magnification 40 x

160x

(c) SEM micrograph of heat treated ms wire, magnification 160 x

(d) M. S. wire , magnification 320 x



(e) SEM micrograph of heat treated ms wire reinforced aluminum alloy matrix, magnification 320 x

(f) SEM micrograph of reinforced casting interfaces, heattreated at 500°C
(i) showing wire ,interface, and matrix , magnification 160x

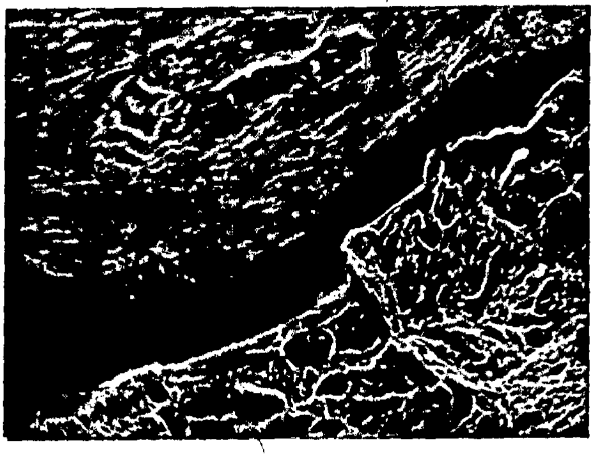


Fig. 3.6 (f) (ii) Interface, magnification 320 x

Fig. 3.6 (f) (iii) SEM micrograph showing interface, magnification, 640 x

the reinforced castings from different specimens. One specimen is observed in the as cast condition and one specimen each from that reinforced castings were heat treated as 425, 450, 575, and 500°C for 20 hours. These specimens were polished by different number of emery papers graded like 0/0, 1/0, 2/0, etc. Successively, followed by cloth wheel polishing using alumina paste of 1 (500 cc). After polishing, etching was carried out with etching reagent Nital of composition 2% Nitric acid and 98% alcohol. (Nital etches the mild steel wire but not the aluminium matrix).

3.5.4 Microhardness Studies

The preparation of specimen for the studies of microhardness is as much as similar the metallography specimen. The microhardness across the interface will be studied. The variation of VHN of MS wires reinforced in aluminium alloy at different distances and at 10 gm load applied were tabulated.

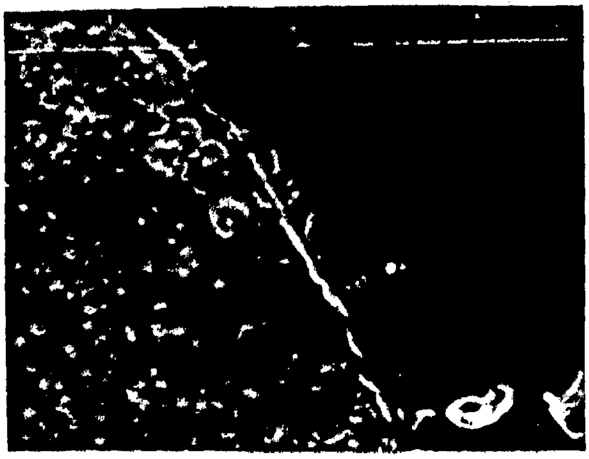


Fig. 3.6 (g) SEM micrograph shows the crack in interface in quenched condition, magnification 320 x

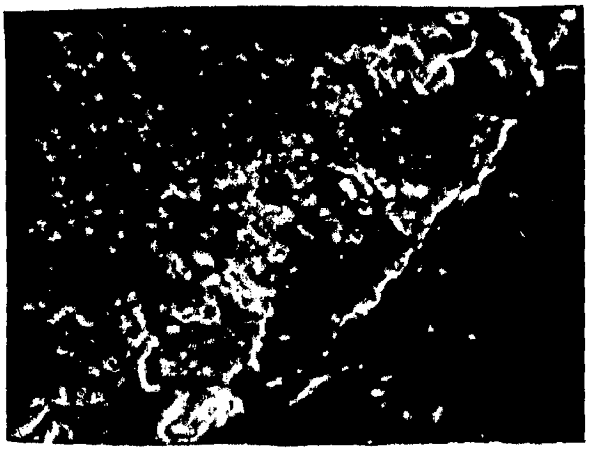


Fig. 3,6 (h) SEM micrograph of ms wire showing the interface in as cast condition, magnification 320 x

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In the present investigation, the aluminum alloy reinforced with mild steel wires were cast and heat treated at different temperature. The thickness of the reaction interfaces were measured. The effect on heat treatment of the mechanical properties like UTS, % elongation, Proof strength of the mild steel wire reinforced aluminium alloys casting were evaluated and compared with the as cast specimen. The variation of UTS with number of reinforced MS wires for a particular heat treatment was studied.

The fractured surface of the tensile specimens were cuted out and that fractured surface was analysed by SEM to study the fractured behaviour. The reaction interface were examined by metallography studies.

4.2 CHEMICAL ANALYSIS

The chemical analysis of aluminium matrix embedded with mild steel wires is as follows (in weight percentage).

Cu - 5.2	Cr < 0.1
Fe - 1.1	Ni < 0.1
Si < 1.5	Zn < 0.3

Mg < 0.2 MM < 0.2

and remaining aluminum.

4.3 DISTRIBUTION OF MS WIRES IN ALUMINIUM ALLOY MATRIX

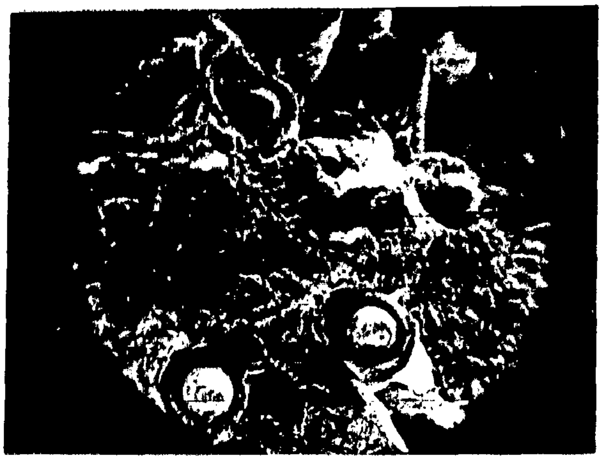
To find out the distribution a piece was cut from the specimen and given the shape to study the distribution of MS wires were in the matrix. It was observd that the distribution of wire was not in uniform position as it was before casting because when the melted material comes in contact with the MS wire and therefore sudden increase the temperature of MS wire and due to this increase in temperature the MS wire moves in longitudinal direction. The wires distribution of such type is shown in Fig.4.1.

4.4 MECHANICAL PROPERTIES

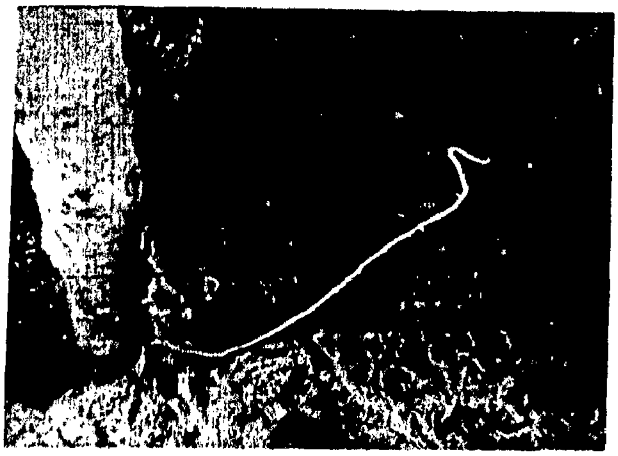
4.4.1 Tensile Test

The mild steel wire embedded in aluminium base alloy were heat treated at different temperatures. The tensile testing were carried out to all the nine specimens. Table 4.1 shows, the variation of UTS with number of wires heat treated at 500°C for 20 hours.

From the UTS values it is seen that strength of reinforced casting is more than the strength of matrix of the material i.e. Base Casting. Further it is seen that the value of UTS increased with increase in number of reinforced wire.



(a)



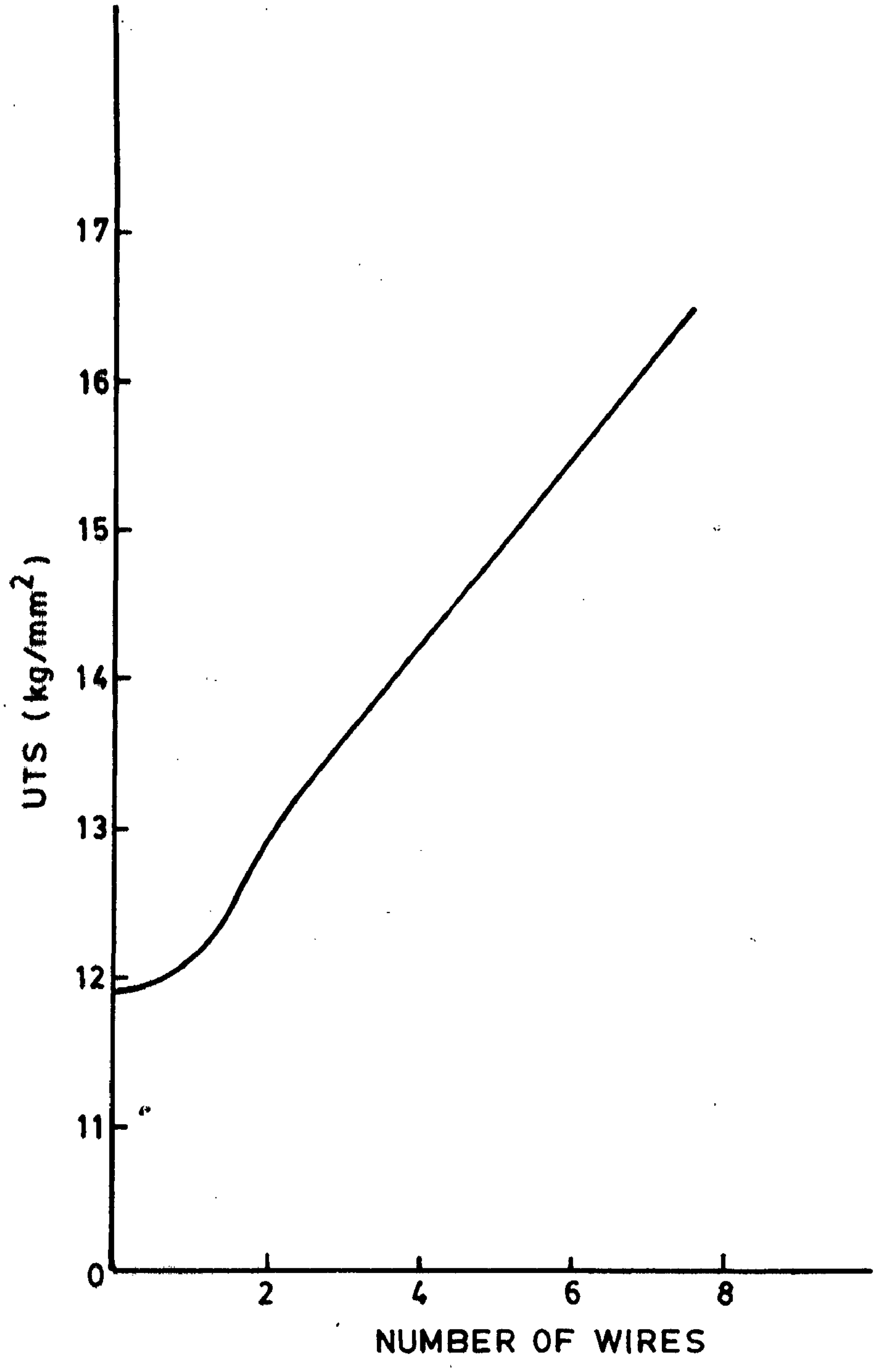
(b)

Fig. 4.1 SEM micrograph showing wire distribution in reinforced casting (a) magnification 20x and (b) magnification 40 x

TABLE - 4.1

The variation of Ultimate Tensile Strength (UTS) with number of wires heat treated at 500°C for 20 hours

Sl. No.	specification of specimen	UTS in kg/mm^2	proof strength in kg/mm^2	% elong.
1	Base alloy	11.94	3.89	4.2
2	Single wire	12.10	4.22	2.4
3	2 wires	12.95	4.55	3.4
4	3 wires	13.60	4.87	4.6
5	4 wires	13.24	4.30	3.03
6	20 wires	16.45	5.52	3.0



The variation of Ultimate Tensile Strength (UTS) with number of wires heat treated at 500°C for 20 hours

The tensile proporation of casting with 4 MS wire reinforced at different temperature is shown in Table 4.2. It is seen that specimen with 4 wires, heat treated at 500°C for 20 hours, showed that the UTS lower than the other heat treated specimens, at same time of heat treatment but at different temperature. The UTS is decreased because of the formation of thicker intermetallic interface. This interface is brittle and any crack which is nucleated propogats at a faster rate.

This is further confirmed by the lesser percentage elongation of 3.03% with respect to the once observed ie 4.71 and 4.04 in case of 450 and 475°C heat treating temperatures.

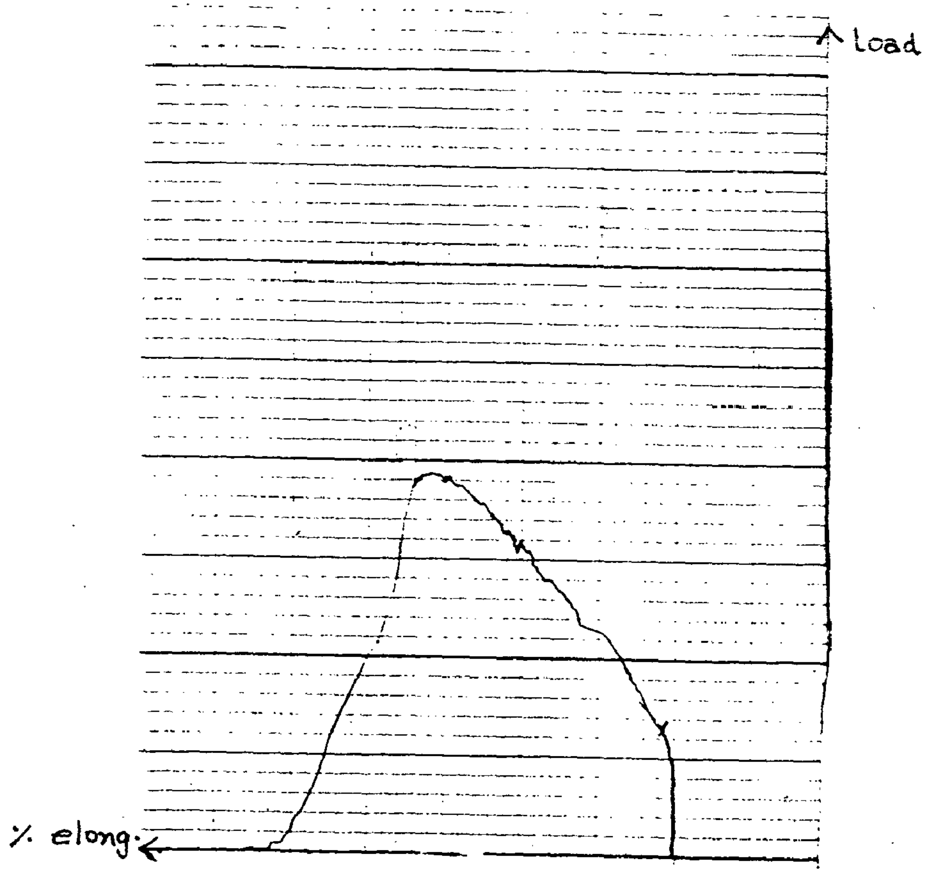
4.4.2 Microhardness Measurements Across the Interface

The variation of microhardness of mild steel reinforced aluminium alloy is given in the table 4.3. The microhardness across the interface has observed as shown in Fig.4.3.

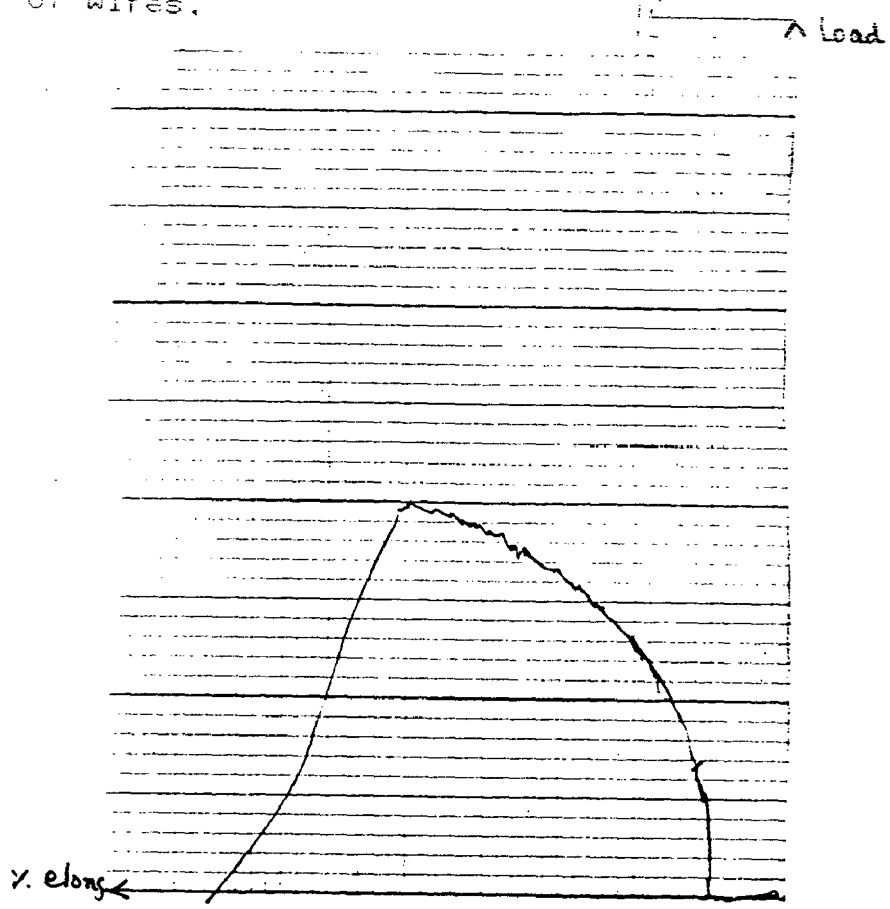
Points 1 and 2 are on the mild steel wire,points 3 and 5 are at interface and point 4 is within the reaction interface. Point 6 , 7, and 8 are at aluminium alloy matrix. The distance has taken from point 1. The diameter of the indentation of VHN are given in table 4.3 and plotted in Fig. 4.4.

It is seen that the value of hardness at wire is more as compare to the value of hardness at matrix. Also it is seen

Fig. 4.2 The variation of UTS with % elongation of heat treatment at different temperatures in case of aluminum alloy embidded with different no. of wires.

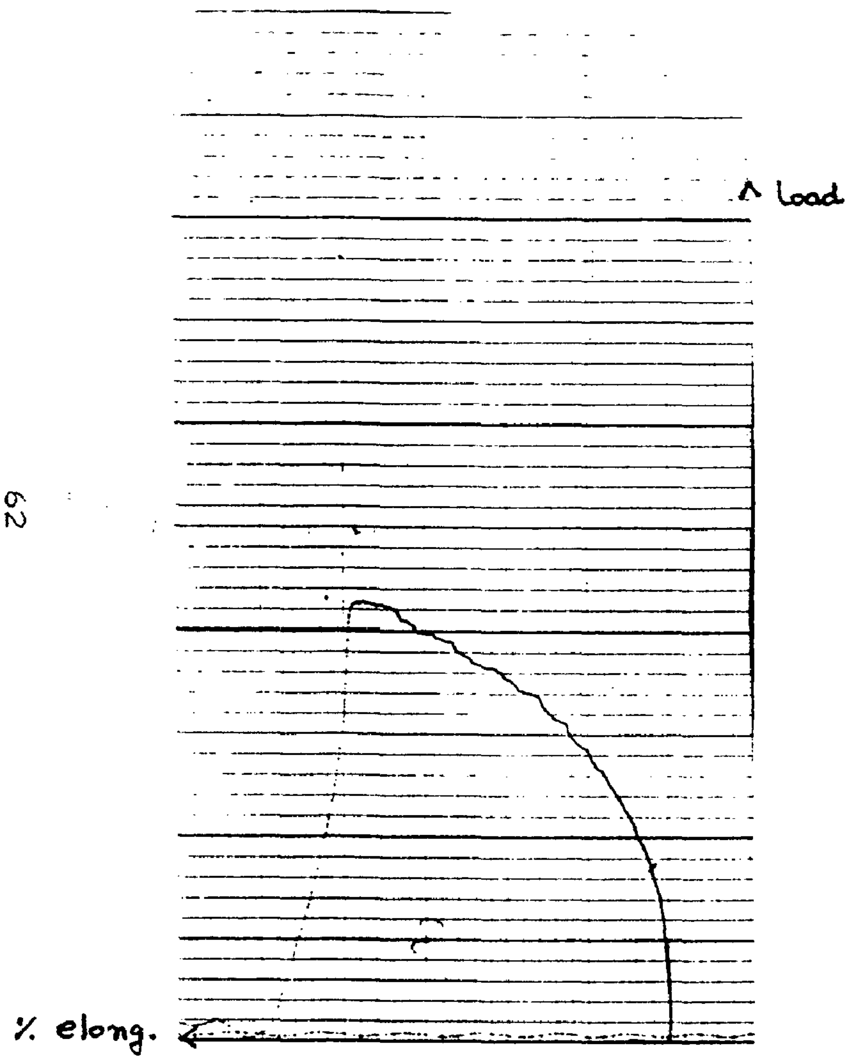


4.2(a) MS casting with base alloy .heat treated at 500°C.

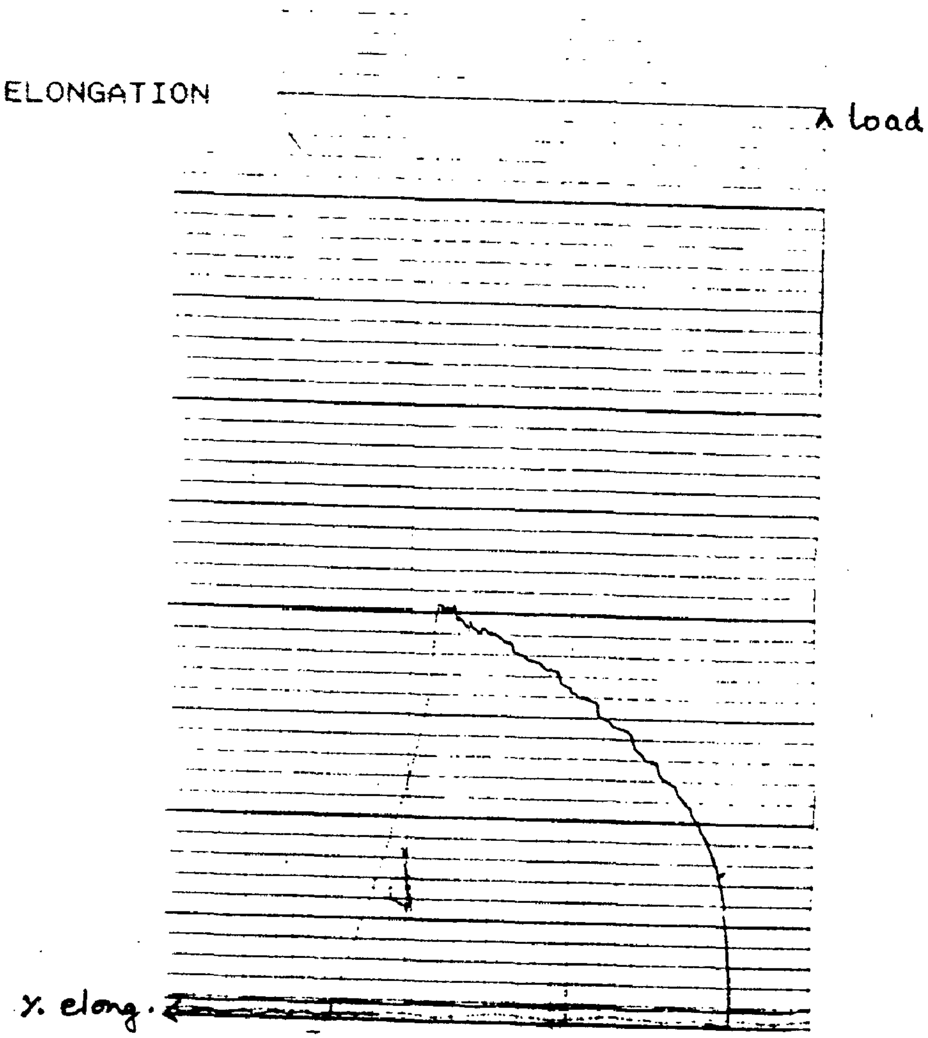


4.2 (i) single wire heat treated at 500°C

UTS Vs % ELONGATION

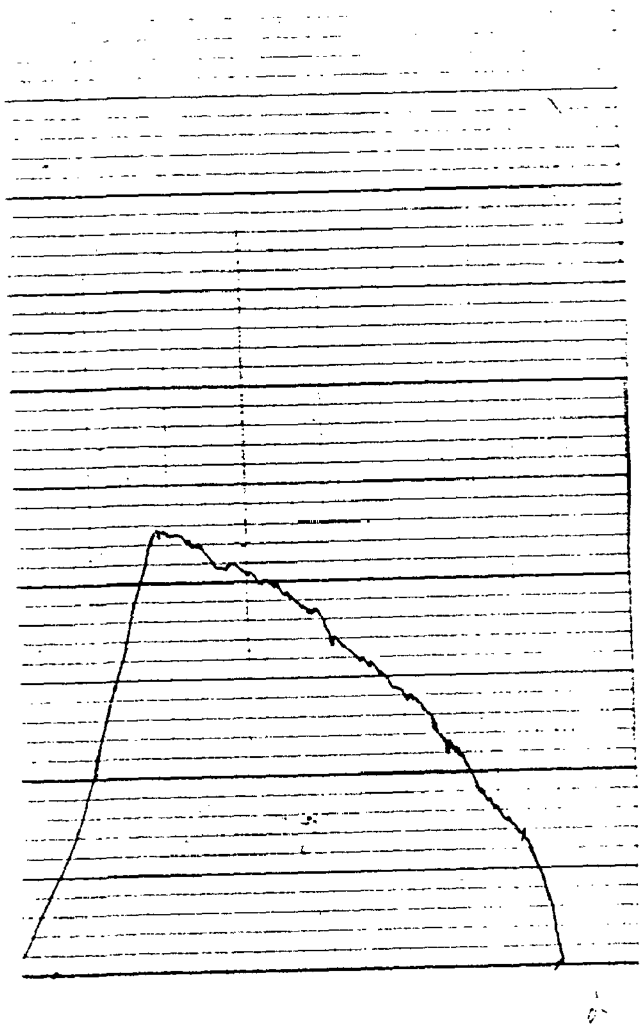


4.2(b) 20 wires , heat treated at 500°C

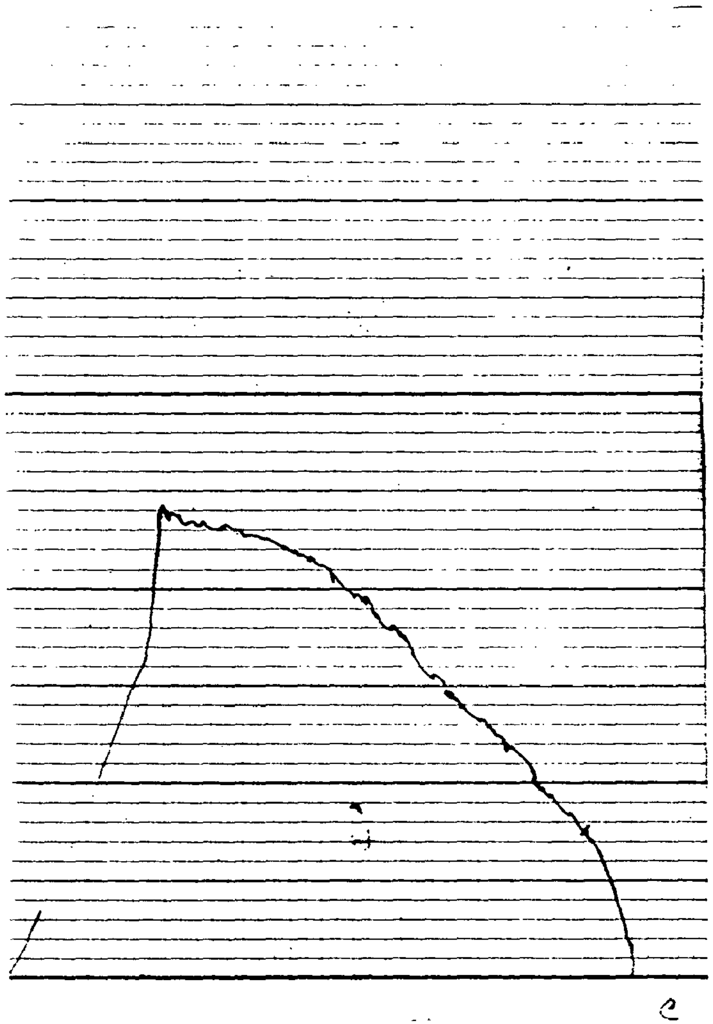


4.2(c) 2 wires heat treated at 500°C

UTS Vs % ELONGATION

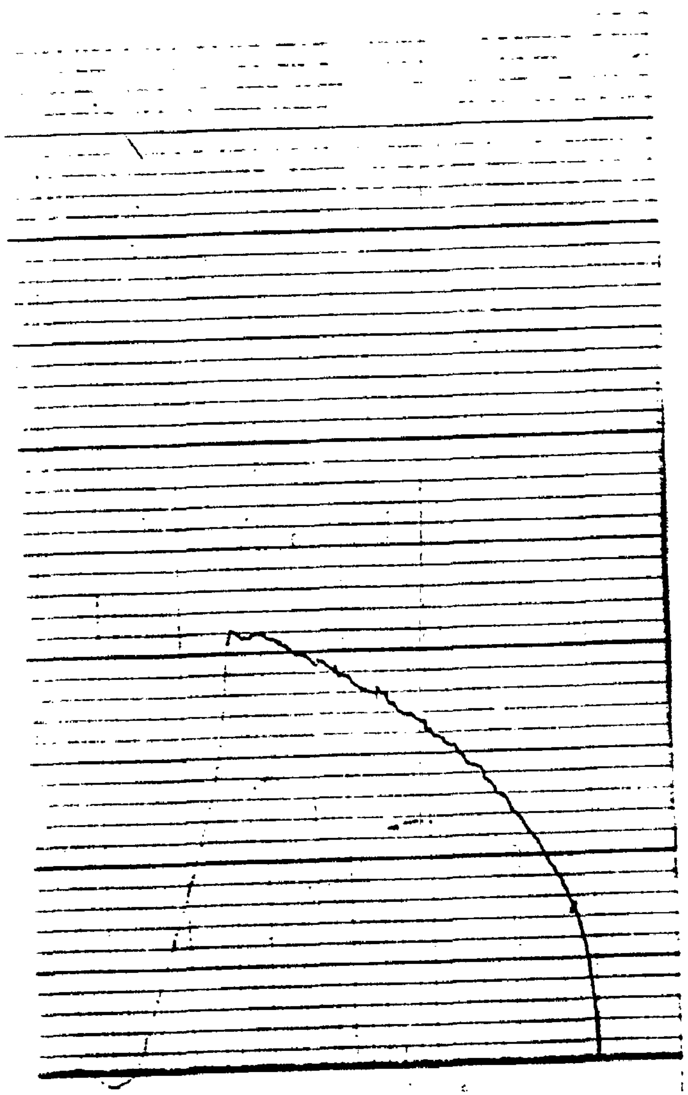


4.2 (d) 4 wires, heat treated at 450°C

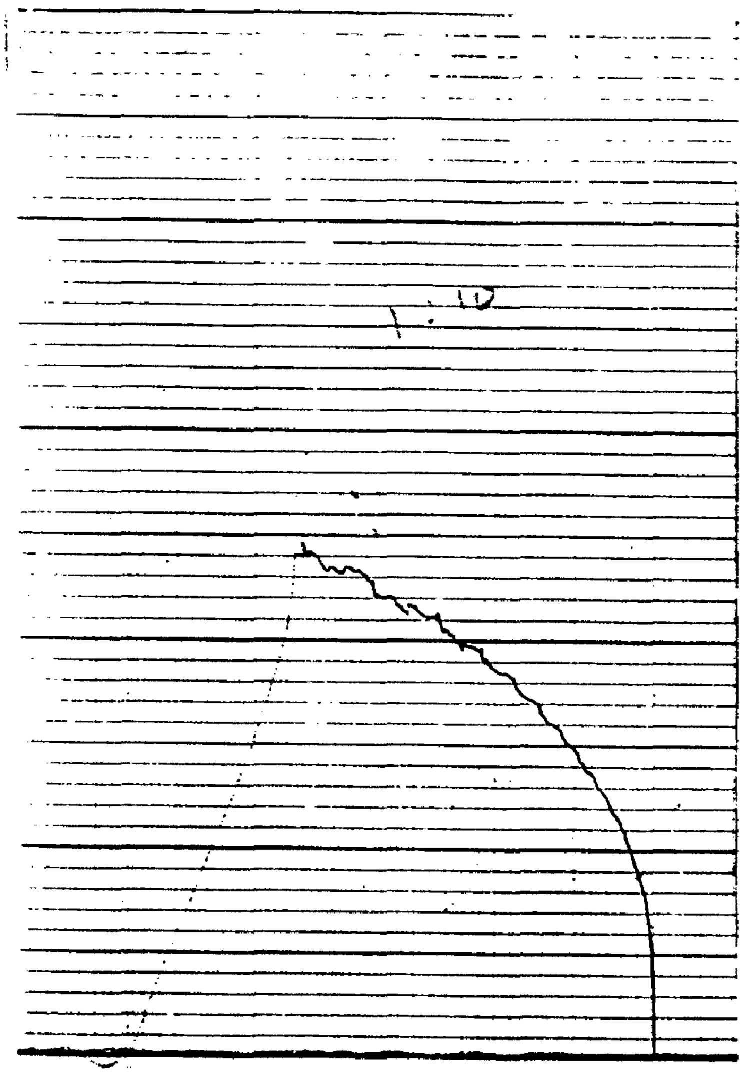


4.2 (e) 4 wires, heat treated at 425°C

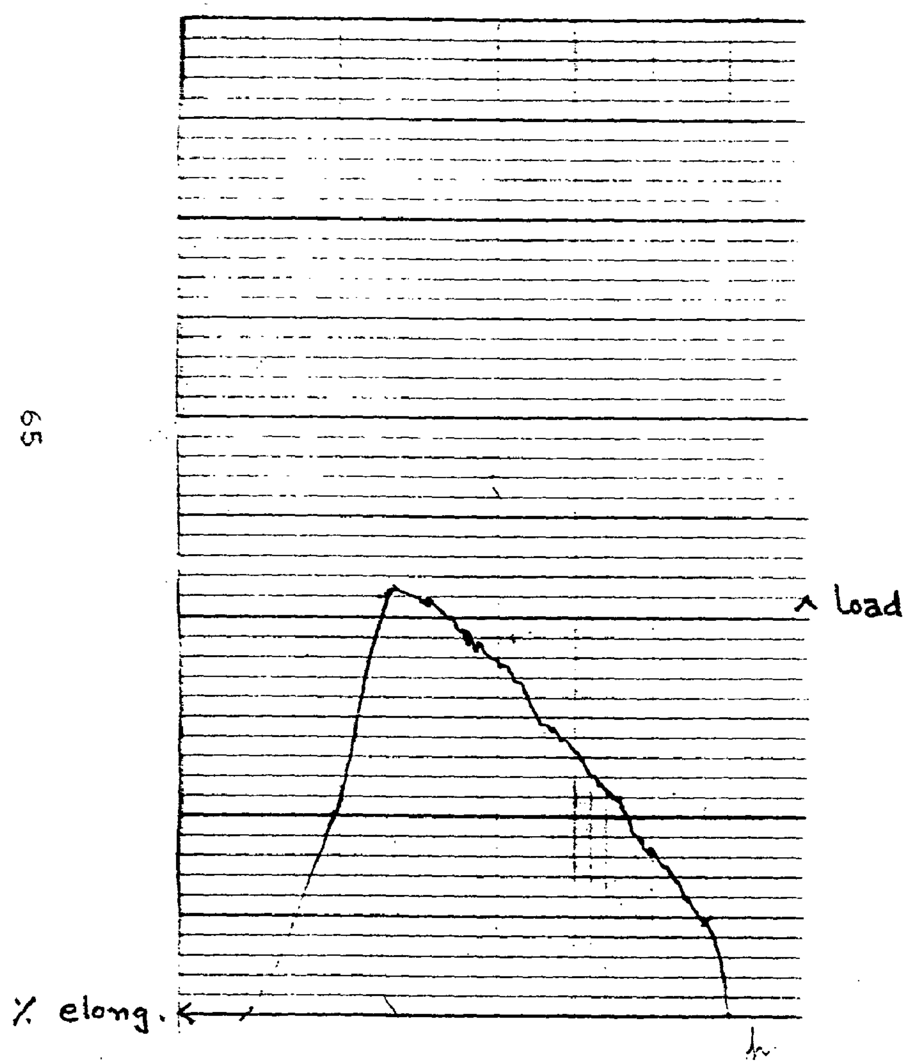
UTS Vs % ELONGATION



4·2 (f) 3 wires, heat treated at 500°C



4·2 (g) 4 wires, heat treated at 475°C

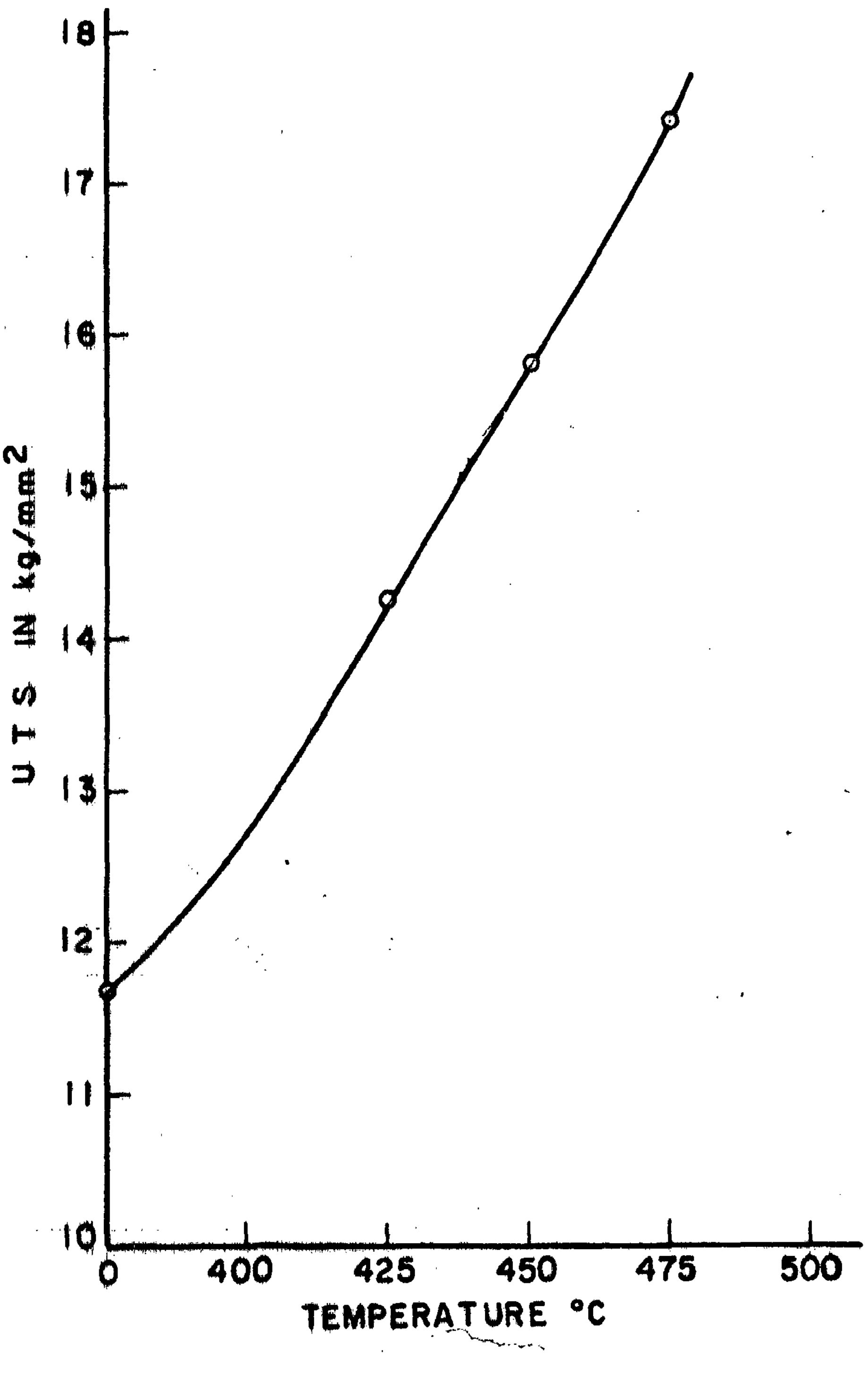


42 (h) 4 wires, heat treated at 500°C

TABLE 4.2

Tensile properties of casting with 4 MS wire reinforced at different temperatures for 20 hours

Sl.No.	No. of wires	Temperature (in° C)	UTS (kg/mm²)	Proof strength (kg/mm²)	% elong.
01	04	425	14.25	4.95	3.45
02	04	450	15.80	5.2	4.71
03	04	475	17.41	5.85	4.04
04	04	500	13.24	4.30	3.03

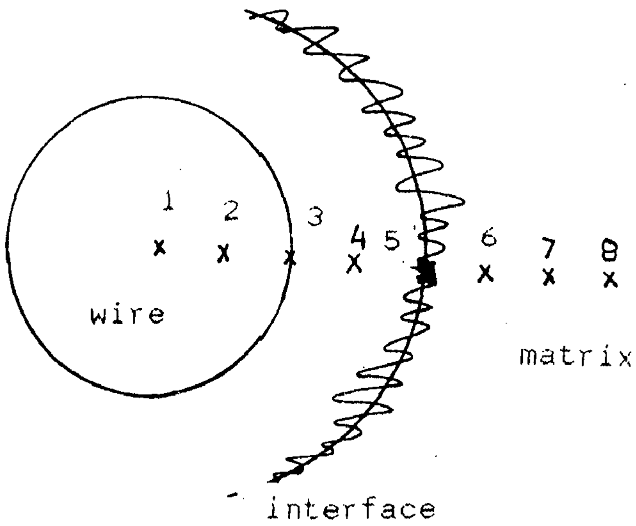


The variation of UTS with 4 number of wires heat treated at different temperatures for 20 hours

TABLE 4.3

The variation of VHN of MS wire reinforced in aluminum alloy at different distances and at 10 gm load

Sl. No.	position	distance (mm)	diameter of indentation (micron)	VHN
1	wire	0.0	9.25	216.5
2	wire	0.14	9.0	228.0
3	interface	0.17	6.6	426.0
4	interface	0.20	7.5	330.0
5	interface	0.23	21.25	41.1
6	matrix	0.25	13.75	98.1
7	matrix	0.33	14.0	94.6
8	matrix	0.40	13.9	96.0



(a)

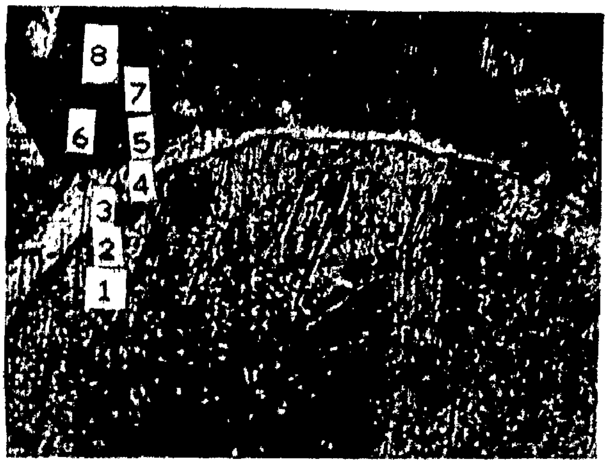


Fig. 4.3 Microhardness points position on wire, interface and matrix (a) sketch, and (b) micrograph, showing the position of points, magnification, 200 x

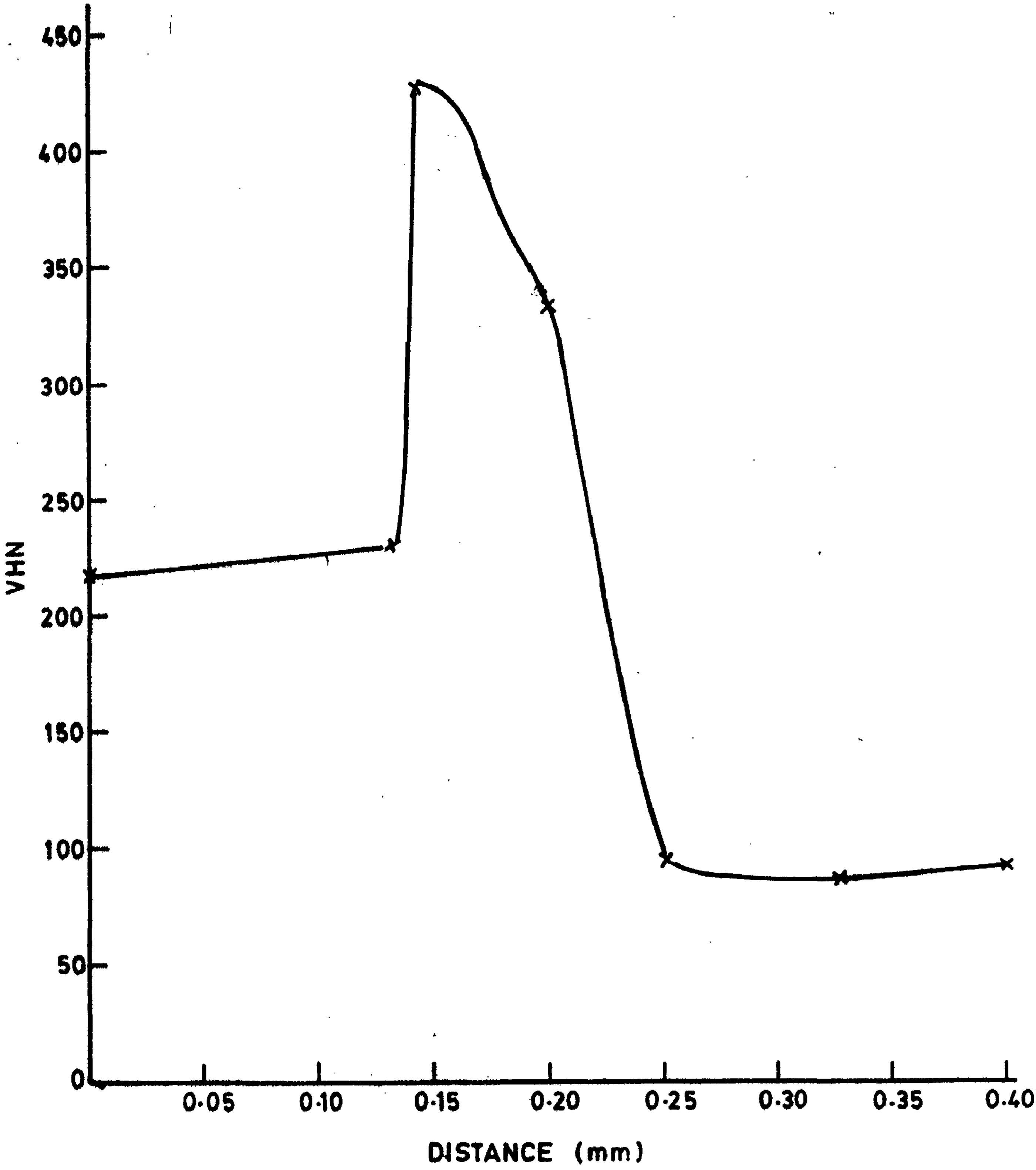


FIG. 4.4

The variation of VHN of MS wire reinforced in aluminum alloy at different distances and at 10 gm load that the hardness is very high at the reaction interface. This high value of reaction interface is due to formation of iron aluminide at the interface is very hard and the hardness value exceeds above 350 VHN [34].

Point 5 shows very less value of 40 VHN. This is due to the porosity at the interface, which is visible in the micrographic Fig.4.5.

4.5 METALLOGRAPHY ANALYSIS

4.5.1 Interface Studies

Five specimens of the reinforced casting are taken for metallography study. One specimen is from as cast and other four that reinforced casting which were heat treated at 425, 450, 475 and 500°C.

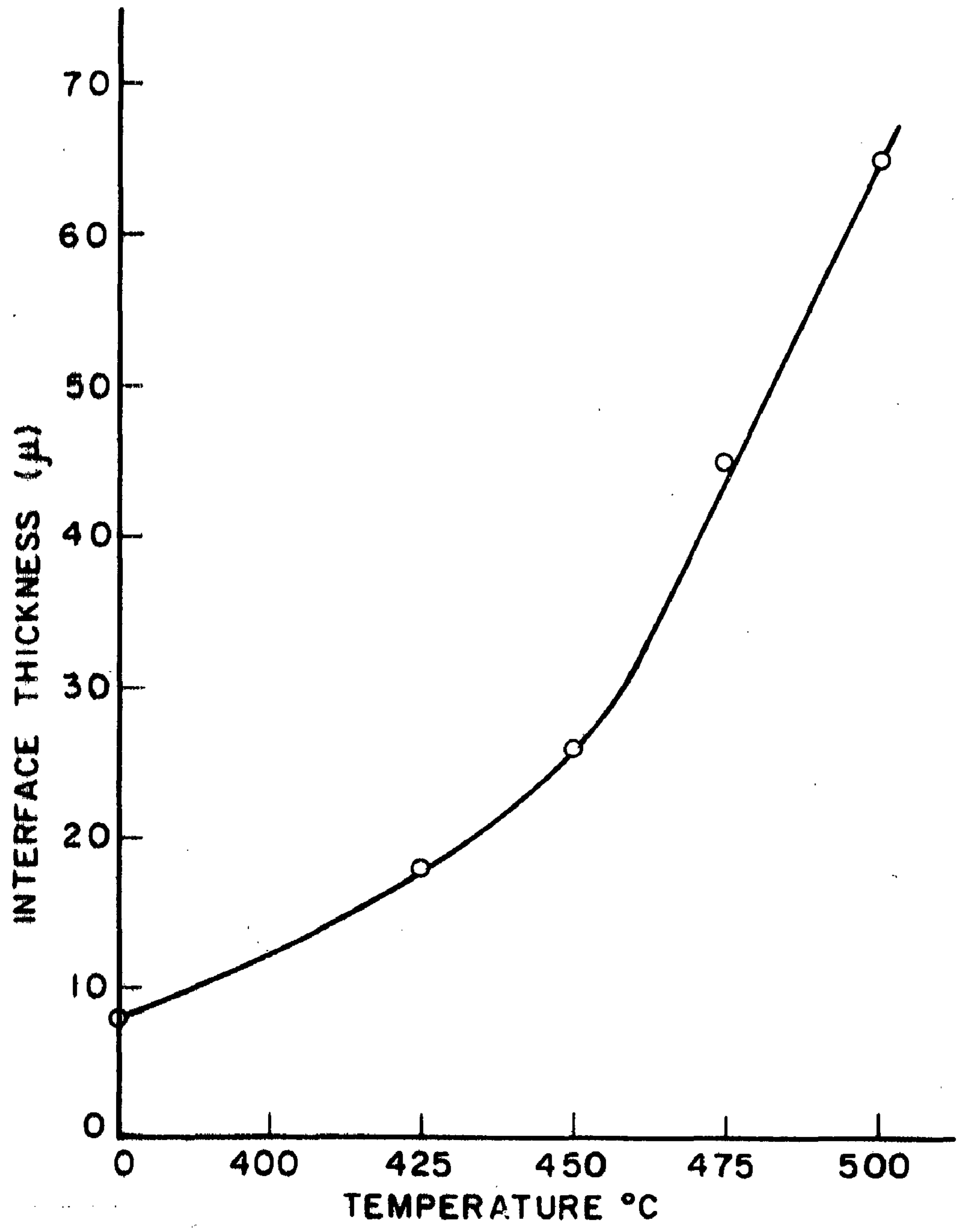
After polishing and etching the microstructures were observed in as cast condition at low and high magnifications to show the wire and interface as shown in Fig.4.6. The heat treated specimen were observed under the optical micrscope and it is seen that the interface thickness is increased after specific temperature. Similarly the interface thickness are measured for all the heat treated specimen as shown in Fig.4.7 and tabulated. the interface thickness as shown in Table 4.4.

It is seen that the interface thickness is increased with increasing the temperature of heat treatment, the obey an

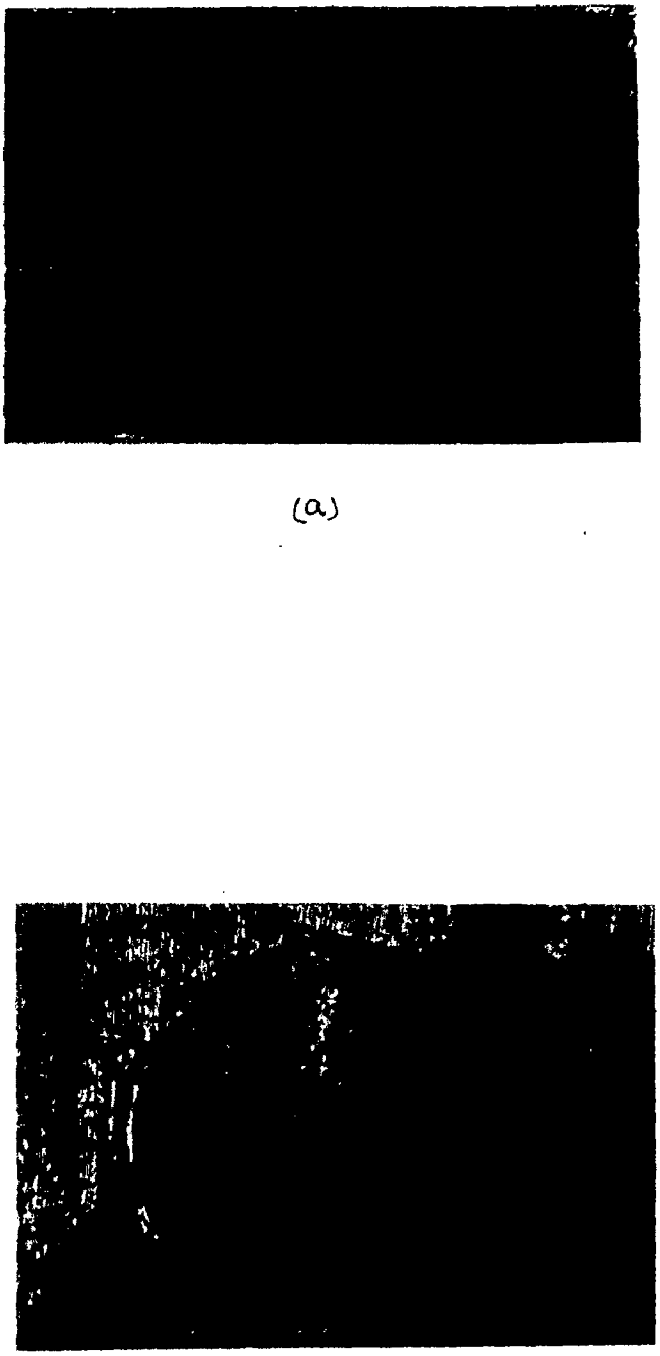
TABLE 4.4

The variation of reaction interface thickness of MS wire reinforced in aluminum alloys matrix at different heat treatment temperature for 20 hours

Sl. No.	No. of wires	Temperature (°C)	Interface thickness (micron)
1	04	as cast	08
2	04	425	18
3	04	450	26
4	04	475	45
5	04	500	65



The variation of reaction interface thickness of MS wire reinforced in aluminum alloys matrix at different heat treatment temperature for 20 hours



(a)

(b)

Fig. 4.[illegible] Micrograph showing porosity (a) heat treated at 450 C, magnification, 100 x, (b) heat treated at 500 C, magnification 100 x

Fig. 4.6 Metallography of wire , interface , and matrix , heat treated at 450°C , magnification 200 x

Fig. 4.7 Interface micrograph, magnification,200 x

expression as

$$Y = a x^2 + b x + c$$

Where 'a', 'b' and 'c' are constant & the value is a=.024, b = 10,28, and c = 8.

The increase in thickness is because of the counter current diffusion of iron and aluminium which slows down as a study state condition has reached.

4.5.2 Distribution of Pourisity

The microstructural analysis of the wires from the surface to the centre were made. It is seen that the mild steel wire have almost good mechanical contact with the matrix from the figure 4.8, it is clear that certain amount of pourisity level does exist at the interface.

The entraped air during the casting is pushed towards the mild steel wire surface during solidification, but the solidification from martix at a faster rate that the gas is entraped near the surface of mild steel wire.

4.5.3 Fractography

After analysis the specimen at different heat treatment under SEM, it is observed that the nature of fracture that has taken pkace in the matrix and wire are occured by wire pull out, as shown in Fig.4.9. But the extent of fibre pull out is minimum for the heattreated specimens, and is maximum for as cast specimen as shown in Fig. 4.10 (a) & (b). Also it is seen that the fracture in matrix and wire is ductiles in nature.

Also Fig. 4.11 shows the cracks and some casting defaults.

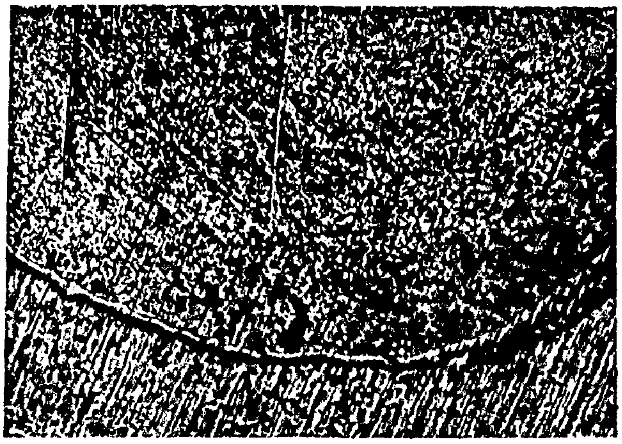


Fig. 4.8 Metallography of interface showing good mechanical contact, magnification 200 x

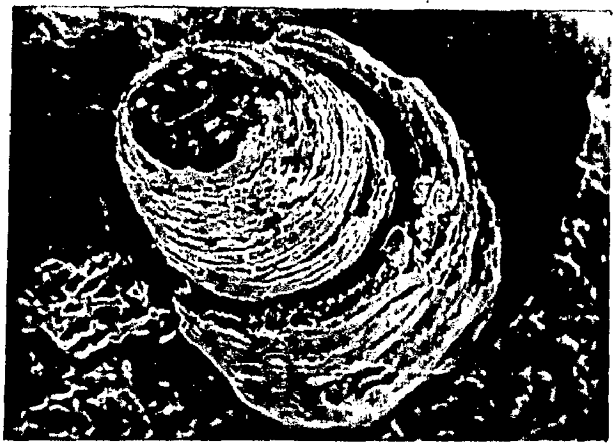


Fig. 4.9 SEM micrograph showing wire pull out, magnification 80 x

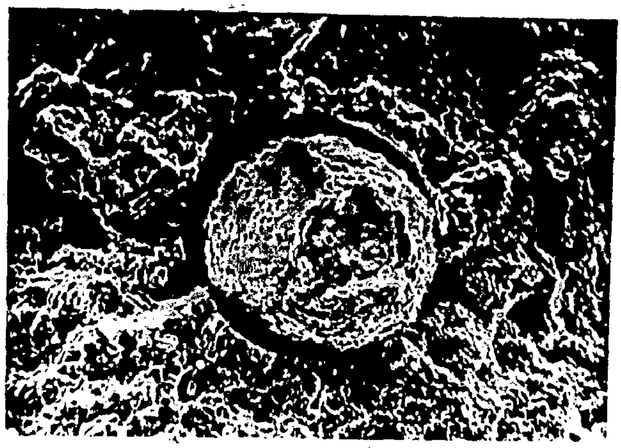


Fig. 4.10 SEM micograph showing wire pull out in as cast condition ,magnification 80 x

(a)

Fig. 4.11 SEM micrograph showing cracks in casting (a) magnification 320 x (b) crack in matrix , magnification 320 x

CHAPTER 5

CONCLUSION

Following are the conclusions incurred from the present investigation on the MS wire of 0.5 mm ø embedded aluminium alloy matrix.

1. It is found that the porosity distribution is not uniform throughout the casting.

2. It is found that tensile strength improved with increase in number of reinforced MS wire from 12.10 kg/mm^2 for single number of wire to 16.45 kg/mm^2 for 20 number of wires when heat treated at 500° C for 20 hours. Also it is found that tensile strength improved with increase in heat treatment temperature from 14.25 kg/mm^2 for 4 number of wires, heat treated at 425°C to 17.41 kg/mm^2 for 4 number of wires heat treated at 475° C.

3. It is found that tensile strength decreased with increasing temperature of heat treatment.

4. It is found that percentage elongation increase with increasing temperature of heat treatment.

5. SEM fractography revealed that the the fracture occured predominently by fibre pull out.

6. It is found that interface thickness increase from 8 micron

for as cast conditions to 65 micron after heat treated at 500° C for 20 hours.

7. Metallographic examination indicates that crack initiation occurs in the matrix phase, and subsequent crack growth is confired to the matrix phase.

CHAPTER 6

SUGGESTION FOR FUTURE WORK

In the future work the skill to be made to introduce of new fibre matrix system. The fibre material can be used for work as Titanium, Ni, cromium, Tungsten, Molybdenum, Beryllium, etc. and considering the factor as heat treatment at the different time for the different numbers and different diameter of wires used for reinforced casting and study to optimization of these foctor to get the improved mechanical properties.

The future work to be done by making the specimen of reinforced M S wire through out all the casting and make an EPMA study for a detailed analysis of the different phase.

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