Journal of Manufacturing Engineering, 2008, Vol.3, Issue.4

THE EFFECT OF FORGING AND SIC PARTICLES FRACTION ON THE MECHANICAL PROPERTIES OF AL 6082 / SIC_P COMPOSITES

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ABSTRACT

In this paper the effect of percentage of SiC particles (SiC_p) on the mechanical behaviour of Al 6082 alloys were studied. Three different fractions of SiC_p (5%, 10% & 20% by %wt) in the cast and forged conditions were considered. The samples were fabricated by stir casting technique. The characteristics of the samples were studied by optical microscopy, porosity, hardness and tensile test. The results show that secondary fabrication process – forging, reduces porosity, increases hardness and tensile strength of the matrix and the reinforced alloy. The grain distribution is refined in the matrix due to forging. The presence of porosity adversely affects the fracture behaviour. The change in mechanical properties may be attributed to the changes in the microstructure of the matrix and the composites material

Key words: Metal matrix composites, forging, porosity, hardness and tensile behaviour

1. Introduction

Metal matrix composites (MMCs) offer high strength, stiffness and wear characteristics even at good high temperatures combined with high strength to weight ratio and easy manufacturability. They can be manufactured at relatively low cost compared to continuous fiber reinforced composites. Particulate metal matrix composites can be produced economically by conventional casting techniques [1]. As the stiffness and strength are increased, a substantial decrease in ductility is obtained. It has been shown that some improvements in strength and ductility are observed with the application of plastic forming processes to the composites [2]. Recent widespread publicity on the increasing use of light metals in the transport sector replacing steel has possibly overlooked the tried and proven technology of forging aluminium in a wide range of applications. The observed improvement in properties to the composites is attributed of the factors, which control the mechanical properties of these materials.

For applications involving metal matrix composites the study and knowledge of the mechanical behaviour is an important factor. The effect of reinforcing an aluminium alloy depends upon the following factors either in combination or in independence such as (i) processing method (ii) reinforcement type (whisker, particulate etc.,) (iii)

Geometrical constituents (shape, size and volume fraction) (iv) ageing or heat treatment and (v) reinforcement / matrix interphases [3]. Several related studies have focused on understanding the

Mechanical properties of MMCs. Density and distribution of dislocations precipitates and interfaces in the matrix alloy plays a vital role on crack initiation and growth. However a complex relationship does exist between the mechanical and fracture characteristics of forged MMCs.

In this study the mechanical properties of stir cast aluminium 6082 reinforced with SiC particles were considered. Three different percentages of SiC particles (5%, 10% & 20% by wt%) were studied. The objective of this paper is to establish a relationship between mechanical properties the porosity, hardness and tensile strength with the inclusions and the effect of secondary processing-forging on the mechanical properties of MMCs.

2. Experimental Procedure

The matrix material used in this work and its chemical compositions are listed in the Table: 1.The metal matrix composites 6082 / SiC_p were prepared in a crucible furnace. The composites were fabricated by stir casting technique. The reinforcing particulate silicon carbide (SiC_p) is of abrasive grade in the particle size ranging from 11 to 45 microns with an average particle

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size of 22 microns. The silicon carbide was pre oxidised at 650° C for 2 hours and poured into the liquid matrix stirred at a constant rate. After the incorporation the melt was poured in to a permanent iron die to obtain composites of size 17mm diameter and 230mm length after the sprue pins were removed. No evidence of macro casting defects was seen. The ingots were then forged in a closed die forging to obtain composites of size 12mm diameter and 230mm length. The forging processes were performed at 500° C [4].

Table. 1 Typical chemical composition of the matrix alloy 6082

Element	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
%	1.0	0.5	0.1	0.8	1.0	0.2	0.1	0.25	Reminder

Specimens for metallography were obtained using standard metallurgical technique and etched with Keller's reagent. The porosity was determined using the Archimedean method. The samples with high and low porosity content were studied and an average porosity content of the produced samples in as cast and forged conditions was determined. The porosity content was estimated from the difference between the calculated and experimentally observed density of each sample [3].

The hardness tests were conducted on a Vickers hardness testing machine with diamond indenter and 5kgf as the force applied. An average of four to six tests are conducted on each polished specimen and average value is taken. The tensile test specimens having gauge length of 96mm and 8mm diameters were machined from the cast and forged specimens. The room temperature tensile tests were carried out in a universal testing machine.

3.Results And Discussions

3.1 Initial microstructure

The examinations of the microstructure have generally shows the uniform distribution of SiC particles in the matrix, but some local clusters of particles exist in the as cast samples. The microstructure of the cast and forged samples are shown in Fig.1-3.

After the application of the forging process relatively uniform distribution of SiC particles were found. Although the holding time at 500°C is short the accelerated coarsening of the phases has occurred to a certain extent, which is expected during annealing and hot working. The decrease in porosity in forged condition can also be attributed to the rearrangement of particles in the forged samples.

3.1.1. Porosity

Porosity of castings is an important defect, which tends to cause appreciable reduction in mechanical properties. Porosity in aluminium casting is caused by the precipitation of hydrogen from liquid solution or by shrinkage during solidification and more usually by a combination of these effects [2].. There are other sources of internal voids, mold reactions, high temperature oxidation, blow holes and entrapped gases result in defects that adversely affect mechanical and fatigue properties as well as physical acceptability. The density and porosity of the unreinforced alloy and the composites are given in table.2 and the effect of variation of SiC fraction on the porosity is illustrated in fig. 4

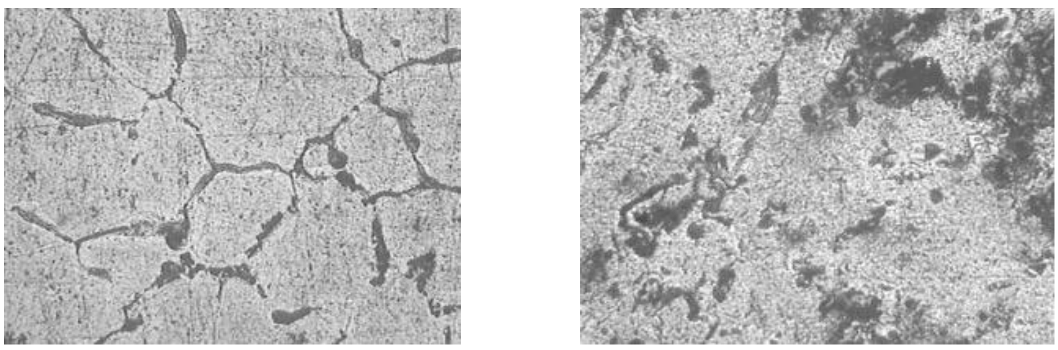
Table.2 The densities and porosity content of the matrix alloy and the composites in the as cast and forged conditions

Material	Calculated density g/cm^3	Experimental density- as cast g/cm^3	Experimental density – forged g/cm^3	Percentage of porosity – as cast %	Percentage of porosity – forged %
Al Matrix	2.7	2.6474	2.672	1.9481	1.037
Al 6082 /SiC/5p	2.724	2.6498	2.687	2.7229	1.3582
Al 6082 /SiC/10p	2.74	2.66	2.704	3.2023	1.6011
Al 6082 /SiC/20p	2.796	2.65	2.713	5.2217	2.968

The density and porosity of the samples slightly increases with the increase in volume fraction. The forged samples show the improvement in density and decrease in porosity with the increase in volume fraction. The decrease in porosity and increase in density of the forged samples may be attributed to the changes in the microstructure of the matrix and the composite. The graph (Fig. 4) shows the increase in density with forging and increase in percentage fraction of particles, which is still lower than the calculated densities.

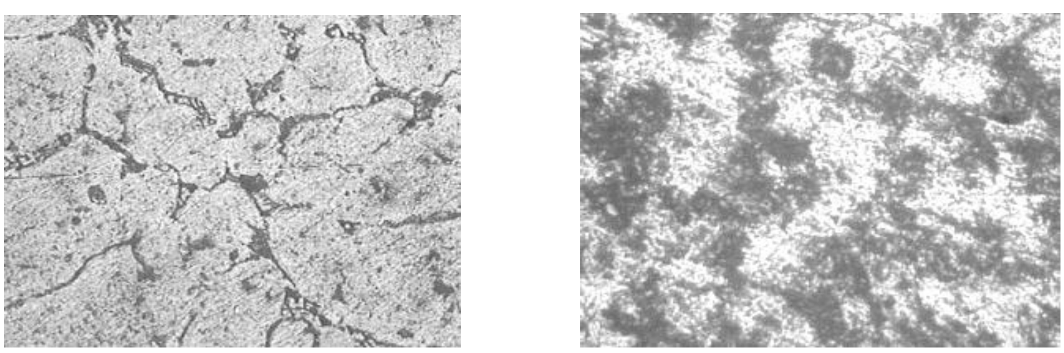
3.1.2. Hardness

Hardness is the characteristic of a solid material expressing its resistance to permanent deformation.The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness.



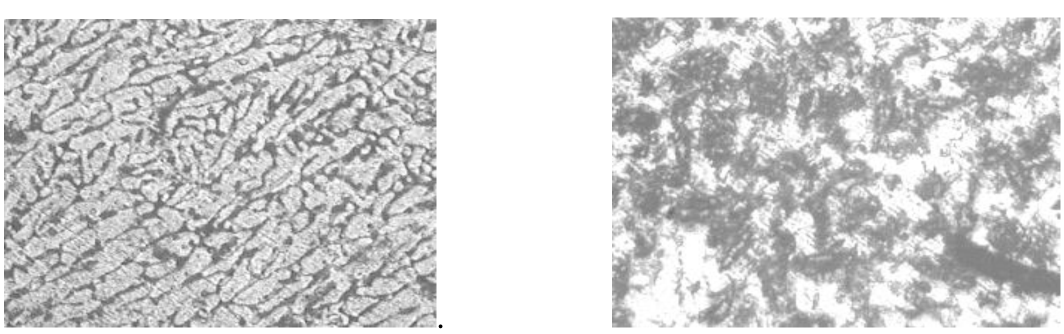
(a) (b)

Fig. 1. The microstructure of the composite Al6082/SiC/5p in the (a) cast (b) forged conditions Mag: 100X



(a) (b)

Fig. 2. The microstructure of the composite Al6082/SiC/10p in the (a) cast (b) forged conditions Mag: 100X



(a) (b)

Fig. 3. The microstructure of the composite Al6082/SiC/20p in the (a) cast (b) forged conditions Mag: 100X.

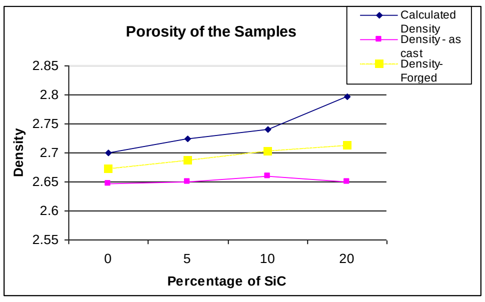


Fig. 4 Variation of porosity of the composites with the variation of percentage of SiC

The basic principle, as with all common measures of hardness, is to observe the questioned materials' ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness tests. The unit of hardness given by the test is known as the Vickers Pyramid Number (HV).

Table.3 The Hardness of the matrix alloy and the composites in the as cast and forged conditions

Hardness [Vickers] of the samples		
Material	**As cast**	**Forged**
Al 6082	61.67(55)*	98(91)
Al6082 + 5 % SiC	67.48(62)	102.56(97)
Al6082 + 10 % SiC	72.8(68)	108.23(102)
Al6082 +20 % SiC	76(72)	111.47(102)

*The values given in the bracket indicates the lowest values obtained

The hardness tests show marginal increase in hardness with the addition of SiC particulates and greater increase with the secondary processing of the material. The graph (Fig. 5) shows increase in hardness with the increase in fraction of the particulates in the as cast and forged conditions.

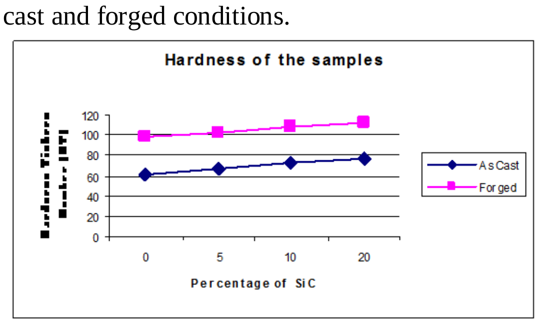


Fig. 5 Hardness of the composites with the variation of percentage of SiC

3.1.3. Tensile strength

The ultimate tensile strength of the as cast Metal Matrix Composites decreases with increase in volume fraction of the SiC. The reason may be due to the formation of weak compounds at the interface of the MMC as established in earlier works [3]. The proof stress and the elastic constant increases with the increase in percentage fraction of SiC.

Table.4 The tensile strength of the matrix alloy and the composites in the as cast and forged conditions

Material	As cast			Forged		
	$\delta_{0.2}$ Mpa	δ_{Uts} Mpa	%ε	$\delta_{0.2}$ Mpa	δ_{Uts} Mpa	%ε
Al6082 matrix	52	127	2.8	54.5	166.7	9.96
Al6082+5%SiC	53	107.6	1.04	62.4	152.23	2.64
Al6082+10%SiC	54	83.11	0.6	70.3	173.6	3.3
Al6082+20%SiC	51	79.21	0.29	63.8	164.9	0.79

The percentage of elongation to fracture decreases with the increase in SiC fraction. The effect of forming processes on the structure and properties of metal matrix composites was clearly seen with the improvement in the strength and ductility of the particulate containing composites (Fig. 6). The effect of forging processes on the observed increase in yield and tensile strength may be attributed to the changes in microstructure, the reduction of porosity and the alteration of matrix microstructure.

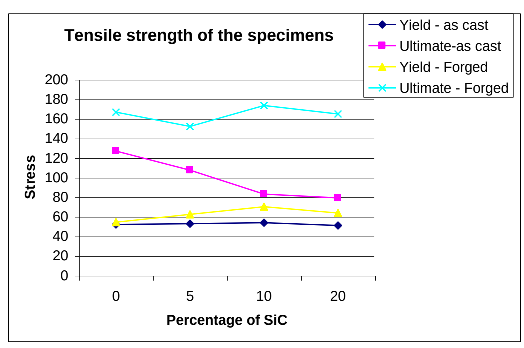


Fig.6 Tensile strength of the composites with the variation of percentage of SiC

4.Summary And Conclusions

The influence of SiC fraction on the mechanical properties of the forged aluminium6082 metal matrix composites reinforced with three different volume fractions of SiC particles (5%, 10%

and 20% , by wt%) was studied. Based on the analysis the following points may be concluded

1. The density and porosity of the as cast samples slightly increases with the increase in volume fraction.
2. The density of the samples is increased with the secondary process forging and the porosity of the samples is decreased.
3. A slight increase in hardness is found with the increase in volume fraction and shows a marked increase due to forging
4. Due to the formation of weak compounds in the interface of the matrix and SiC reinforcement, the strength of the composites decreases with the increase in volume fraction of the as cast composites
5. The proof stress and elastic constant increases with the increase in volume fraction
6. The forging increases the strength and ductility of the composites
7. The remarkable changes in the properties due to secondary processing may be attributed to the changes in the microstructure of the matrix and the composites material

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Acknowledgement

The author wishes to acknowledge Prof. Dr. Raghukandan, Prof. Dr.Ganesan and staffs of Production Engineering Department of Annamalai University for their support of the project