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Effect of Forging condition on Mechanical Properties of Al/SiC Metal Matrix Composites

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Abstract - The objective of the research work to investigate effect of forging condition on mechanical properties of Al/SiC composites prepared in open die at the temperature of 450 °C with three different stages then specimens are aged at T6 conditions. Forged specimens subjected tensile, compression and hardness tests to evaluate effect of forging levels on Al/SiC composites. The effect of plastic deformation and high temperature during forging led to a recrystallization of the Al/SiC matrix with a grain refinement. At first and second stage higher grain refine could be seen but at third stage no further grain refinement could be absorbed. The modification of grain which was influenced an enhancement in the mechanical strength. The scanning electron microscope shows the brittle and ductile mixture failure was absorbed in all type of the specimens. Forging improve the mechanical properties with nominal loss of ductility.

Key words: Forging, Mechanical properties, Composites, Al/SiC

1. INTRODUCTION

Metal matrix composites (MMCs) especially aluminium based MMCs are excellent material to replace the conventional material due their high specific strength and good resistance to wear and tear[1]. But they are weak in formability of MMCs associated with particle fracture and matrix-reinforcement decohession. Conventional fabrication methods of MMCs produce low ductility due to high brittle reinforcements and uneven microstructure such as porosity, and agglomeration [2]. To overcome the above cited problems by secondary forming such as such as rolling, extrusion or forging, to obtain the final component. These process minimize or eliminate porosity, improve the particle distribution and strengthened the interfacial bonding between matrix and reinforcement [3]. Moreover, when MMCs are hot deformed they show superplastic behavior along with reinforcements. Many researchers investigated combined loads such tensile, compression and torsion to improve the understanding of the MMCs hot deformation[4-5].

Although several composites parameters such as particle size, particle concentration, strength of the particle / matrix interface bonds are influence the MMCs forgeabiity but only few are influenced[6-7]. In other had only few research reports dealing with forging of MMCs performed by using industrial equipments. The objective of the work to investigate the hot forging behaviour of Al/SiC composites on microstructure, strength and fracture surface changes possibly resulting from material forging.

2. EXPERIMENTAL WORK

In present study a high strength aeronautical Al6061 alloy, which exhibits excellent casting properties and reasonable strength, was chosen as the matrix. The chemical composition is given in Table 1.

Table 1 Chemical composition of Al6061 alloy

Mg.	Si	Cu	Al
0.92	0.76	0.22	Bal.

SiC reinforcement was cleaned in distilled water and dried at 90°C. Liquid metallurgy technique was used to fabricate the composite materials in which the SiC were introduced into the molten pool through the vortex created in the molten metal by the use of an alumina-coated stainless steel stirrer. The stirrer was immersed to about one-third of depth of the molten metal pool from the bottom of the crucible and rotated at 550 rpm. The pre-heated (500 °C) SiC were added into the vortex of liquid melt, which was then degassed using pure nitrogen for about 3 to 4 min. The resulting mixture was tilt poured into preheated permanent mould. SiC was varied from 5 to 20% in steps of 5% by weight.

Forging was carried out in an open die in both single, double and trible stage, using a 20 MN press and a graphite-based lubricant. The temperature of the composites at the beginning of the process was about 500 °C, while at the end of the forging it was 425 °C. The forging parameters were: temperature of the die 400 °C; initial billet diameter 75 mm, final billet diameter of 25 mm, deformation ratio 3:1; average engineering strain rate 0.1 s-1 as per Zhao. [8]. The second stage forging ratio 5:4 that is reduction of 25 mm to 20 mm diameter. The forged specimens are heat treated to remove residual stress which is accumulated at the time of forging. The heat treatment (T6) used to achieve these conditions was a solution treatment of 10 hours at a temperature 532°C followed by water quenching on hot water at 80°C aged at room temperature for 12 hrs followed by ageing at 175°C for 3 hours. All mechanical tests were conducted in accordance with ASTM standard. Tensile tests were conducted at room temperature using universal testing machine (UTS) in accordance with ASTM E8-82. Fracture surface was studied using scanning electron microscope. The compressive loads were applied gradually and corresponding strain were measured until failure of the specimen occurred. This test was conducted according to ASTM E9 standard in the UTM at room temperature.

3. RESULTS AND DISCUSSION

3.1 Microstructure studies

Typical micrographs of the Al /SiC MMCs in the ascast and double stage foring condition are shown Fig. 1. Image shows that similar distribution of the reinforcement particle size for the as-cast and forged composites, where the distribution of reinforcing particle size is shown. The dimension of the major axis of the equivalent ellipse associated with the particle was adopted as the particle size. The forging process did not induce any variations in the reinforce.

3.2 Mechanical properties

The mechanical properties of ascast, first stage, second state and third stage forged conditions of different wt. % of SiC particles reinforced composites given in Fig. 2, 3, 4, 5 and 6 show the average and standard deviation (SD) of Young's modulus, ultimate tensile strength, ductility, hardness and compression strength respectively of the tested composites as function of without forged and single, double and third stage forged conditions

3.2.1 Ultimate tensile strength

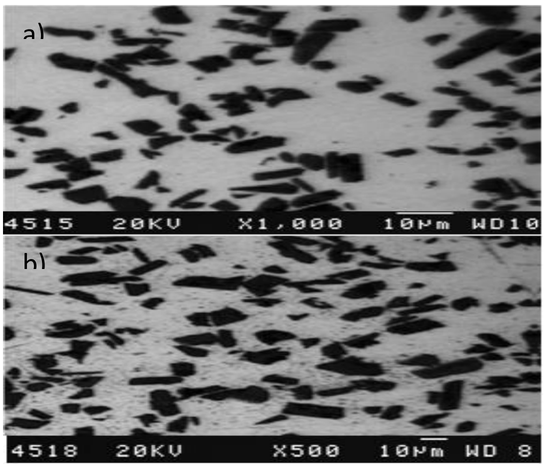

Fig. 1 Micrograph of Al/20% SiC as cast (a) and forged (b)

The effect of the % SiC particles content on the tensile strength of the as-cast, single and double forged samples is illustrated in Fig. 2. The curve for the as-cast samples shows that the tensile strength is increasing with the addition of up to 15 wt % SiC, but it is reduced with SiC

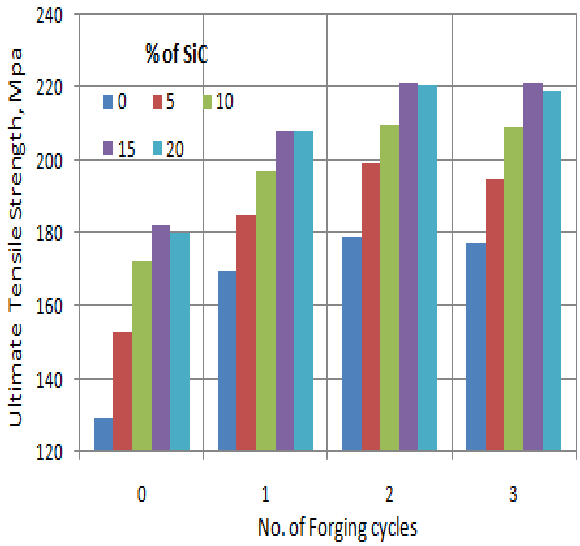

Fig. 2 Shows the effect of % of SiC particles and forging condition on UTS of Al/SiC particles composites

particles additions more than 15 wt.%.

A similar trend is observed for the case of forged specimens, the samples containing above 15 % SiC particles exhibit decreasing values of tensile strength. In the forged composite specimens containing below 20 wt. % SiC particles the values of tensile strength observed after two stage forging are marginal increment can be seen in three stage forging. The strength of discontinuously reinforced aluminium alloys was extensively studied by Cavaliere [9], who investigated the effect of SiC particle reinforcement in several different alloy matrices. It was observed a substantial increase in UTS, depending on the wt.% fraction of b SiC particle, the type of alloy, and the matrix alloy temper

3.2.2 Young's Modulus

The change in Young's modulus as a function of the wt.% SiC particles for the as-cast, single and double forged specimens as shown in Fig. 3. The curves show that all the specimens exhibit a common behavior with increasing SiC particles content. The Young's modulus in all the specimens in the as-cast and in the forged states increases with the addition SiC particles irrespective of forged and as cast condition. But at between 10 to 20wt.% of SiC particles no significant enhancement can be seen in otherwise there is small decrement of Youngs modulus. The application of forging the Young's modulus curves are pushed upward, exhibiting much higher values than those of the without forged material. But two steps forging shows only smaller

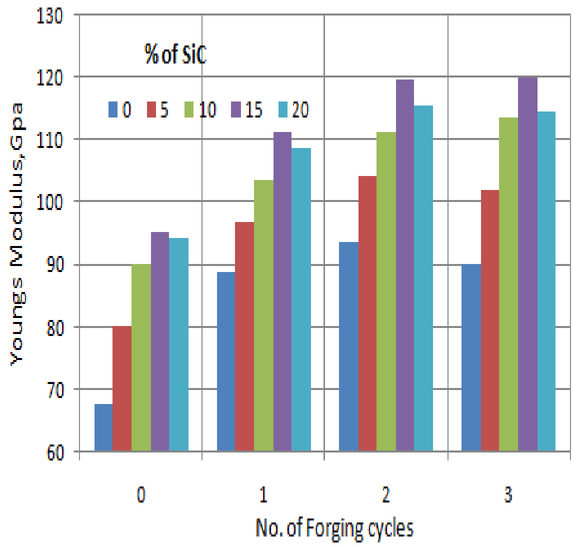

Fig. 3 Shows the effect of % of SiC particles and forging condition on ultimate tensile strength of Al/SiC particles composites

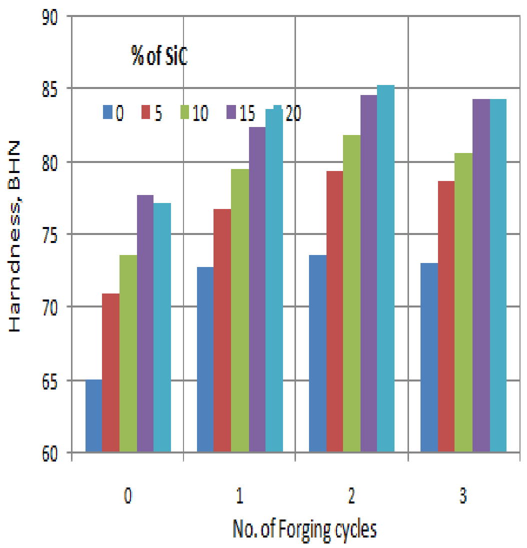

Fig. 4 Shows the effect of % of SiC particles and forging condition on hardness of Al/SiC particles composites

improvement in Young's moudulus. The dominant factors controlling the elastic modulus in these materials are the volume fraction of the SiC particles reinforcement, the aspect ratio of reinforcement and the load-transfer capability of the interface, but the presence of porosity and microcracks would reduce the modulus [2-4].

3.2.3 Hardness

The average hardness of without forged condition and single stage forged composites is almost 20 % of that of the aluminium matrix. It is observed from Fig. 4 that individually all the process parameters have positive sign and hence contribute significantly,

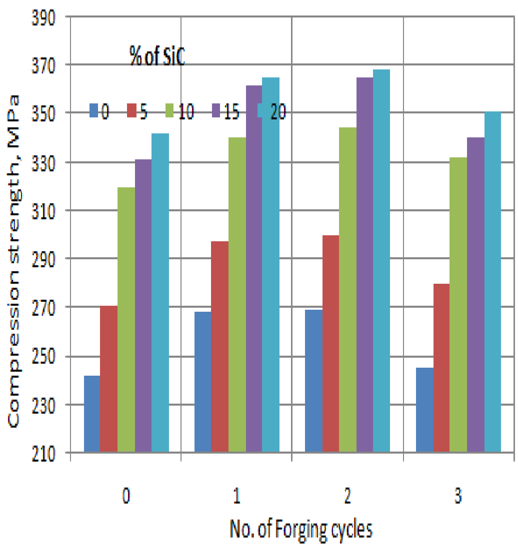

Fig. 5 Shows the effect of % of SiC particles and forging condition on compression strength of Al/SiC particles composites

in improving the hardness. The effect of wt. % reinforcement is more pronounced up to 15 wt.% and after that it has a tendency to reduce the hardness. Maximum hardness is obtained at 15 wt.% of SiC particles irrespective of forging conditions. The double forged condition shows only small significant enfacement hardness both matrix and composite alloys.

3.2.4 Compression strength

The effect of the % SiC particles content on the compression strength of the as-cast, single and double forged samples is illustrated in Fig. 5. The curve for the as-cast samples shows that the compression strength is increasing with the addition of up to 15 wt % SiC particle, but it is reduced with SiC particles additions more than 15 wt.%. A similar trend is observed for the case of forged specimens, the samples containing above 15 % SiC particles exhibit decreasing values of compression strength. In the forged composite specimens containing below 20 wt. % SiC particles the values of compression strength observed after two-step forging are marginal increment can be seen in two step forging.

3.2.5 Ductility

The ductility (% of elongation) to fracture are plotted in Fig. 6 and also the effect of SiC particles content on ductility is illustrated. With increasing SiC particle content decreases values of ductility was observed in all the as cast condition but in forged condition two types of behaivour can be seen. For matrix alloy decreased with forging but composites ductility increase with forging condition. This observation could be explained in a similar way to the increase in ductility due to reduction of porosity, thus early void formation and some interfacial debonding in the forged high reinforcement composites would result in a substantial increase in ductility.

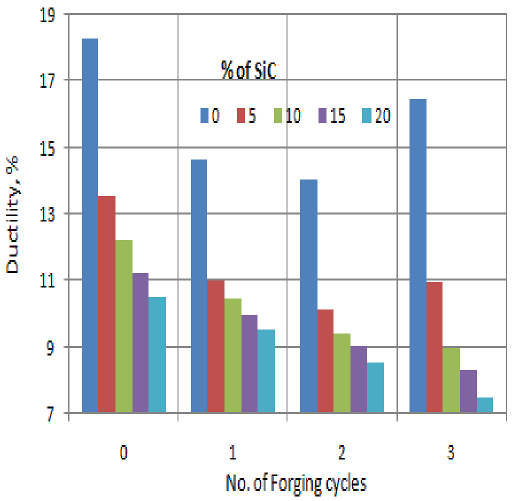

Fig. 6 Shows the effect of % of SiC particles and forging condition on ductility of Al/SiC particles composites

3.3. Fracture studies

During tensile test it is accepted that matrix / particle cracking along with matrix material fracture and debonding between SiC particle and Al matrix alloy interface are some of the reasons for failure MMCs. The as cast Al (without forged) alloy fracture mode is a ductile fracture mode as shown in Fig. 7(a-1). Which has large number of dimple shaped structures no crack can be seen.

Fig. 7.(b-1) shows that as SiC particle reinforced MMCs fracture structures it also shows ductile failure which evidence by the extensive matrix deformation around the reinforcements is evident and matrix is necked to a knife edge between the SiC particle. The extensive matrix deformation around the particle is evident, and the matrix is necked to a knife edge between the particle. Also the interfacial region between the particle and the matrix alloy appears discontinuous with a gap. However, the matrix alloy softens gradually, the critical particle aspect ratio increase accordingly [10-11].

Fracture surfaces of the forged specimen of Al matrix alloy and Al/10% SiC particle MMCs as shown in Fig. 7(a-2) and Fig 7.(b-2) respectively. The Al matrix alloy showed mixed mode failure i.e the ductile and brittle failure. The along with dimples

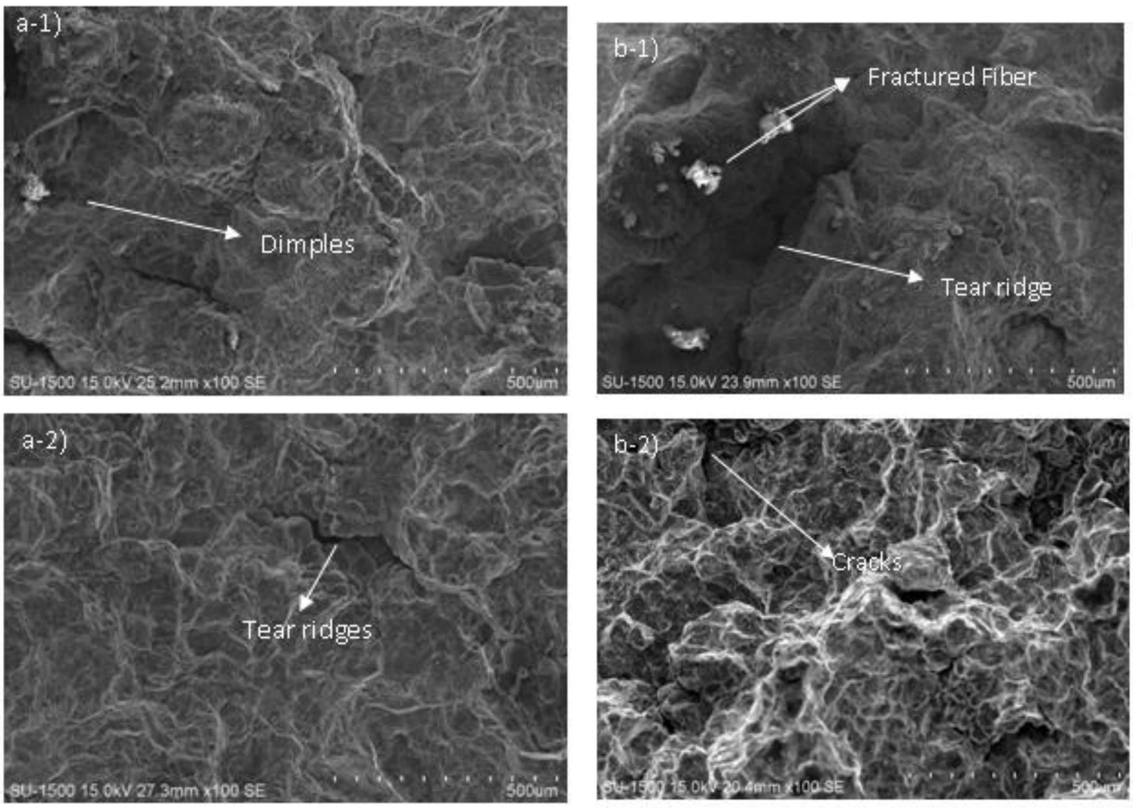

Fig. 7. Fracture surfaces of (a-1 and b-1) as-cast and (a-2 and b-) forged samples tested for tensile test (a- Al matrix alloy and b- Al/20% SiC particles MMCs)

some tear fracture can also seen in this microstructure. In Al/SiC particle MMCs showed that the main failure mechanisms are particle debonding and matrix ductile failure, while only a small amount of cracked was observed. The fracture surfaces also displayed the presence of cracks, probably originated from casting defects or during cooling from the fabrication or forging temperature. The microstructures of the as-cast and even the forged condition of the MMCs exhibit fairly uniform distribution of SiC particles with some regional clusters were seen. The Young's modulus observed in the MMCs has higher than the matrix alloy and forging increase the young's modulus due to reduction of porosity but second step does not improve the young's modulus significantly. The tensile strength and compression strength of Al/SiC MMCs increases with the addition of wt. % of SiC particle and by the forging process. The ductility of MMCs is decreased with increasing the wt. % of SiC particle but in forged condition the matrix materials show decrease trend and composites show some improvement of ductility. However in the case of hot rolling and hot forging, the strengthening effect is caused by recrystallization phenomenon. Forging in steps makes the composites stronger than if forged in one step, for the same final load.

4. CONCLUSIONS

1. Microstructure reveal that forging did not induce damage on the Al/SiC composites and it minimize the porosity of the composites
2. Forging did not alter the particle distribution in the matrix materials but it modified the grain boundaries which induced higher mechanical properties.
3. Forging improve the mechanical properties such as tensile, compression and hardness of Al/SiC MMCs without compromise the ductility due to super plastic deformation during forging
4. Particle fracture could be seen at the interface due to weak bonding between particle and matrix and failure of composites are ductile in nature.

REFERENCES

1. P. Cavaliere, E. Cerri, E. Evangelista, Isothermal forging modelling of 2618 + 20% Al2O3p metal matrix composite, Journal of Alloys and Compounds, vol. 378, (1–2), (2004), pp. 117-122
2. J. LLorca, "High temperature fatigue of discontinuously-reinforced metal–matrix composites", *International Journal of Fatigue*, Vol.24, No. 2-4, 2002, pp.233-240.
3. S Seshan, A. Guruprasad, M prabha and A Sudhakar, "Fibre-reinforced metal matrix composites a review, J. Indian Inst. Sci., Jan.Feb. 1996, 76, 1-14.
4. Suganuma, K. and Naratomo, K., Fabrication of Al_2O_3 fibre preform with T-Al 203 powder binder for 6061, alloy matrix composites, Mater. Sci. Engng A, 1994, 188, 353-357.
5. RasmussaN, N. W., Hansen, P. N., and Hansen, S. F., High pressure die casting of fibre-reinforced aluminium by perform, infiltration, Mater. Sci. Engng A. 1991, 135, 41-43.
6. Z. Y. Ma and S. C. Tjong, "The high-temperature creep behaviour of 2124 aluminium alloys with and without particulate and SiC-whisker reinforcement", *Composites Science and Technology*, Vol.59, No.5, 1999, pp. 737-747.
7. S. C. Tjong and Z. Y. Ma, "The high-temperature creep behaviour of aluminium-matrix composites reinforced with SiC, Al_2O_3 and TiB_2 whiskers / particles", *Composites Science and Technology*, Vol.57, No.6, 1997, pp.697-702.
8. A.H. Nakagawa, M.N. Gungor, in: P.K. Liaw, M.N. Gungor (Eds.), Fundamental Relationships Between Microstructure & Mechanical Properties of Metal–Matrix Composites, The Minerals, Metals & Materials Society, 1990, pp.127–144.
9. T Chandra D Yu, Deformation behaviour and microstuctural development in 6061 aluminium alloy containing large Al_2O_3 particle at elevated temperature, Mater, Forum, 17, (1993), 361-368.
10. S J Barnes, P B Prangnell, SM Roberts, P J Withers, the influence of temperature on microstural damage during an axial compression of aluminium matrix composites, Scripta Metall Mater, 33, (1995), 323-329.
11. S M Roberts, J Kusiak, P J Withers, S J Bames, P B Pragnell, Numerical prediction of the development of particle stress in the forging of aluminium metal matrix composites, Journal Material Process Technology, 60 (1996), 711-719.