EFFECT OF AGEING ON MECHANICAL BEHAVIOR AL-ALB$_2$ METAL MATRIX COMPOSITES

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***Abstract*: In the present era MMC's prepared with aluminum alloys are used in several applications. Synthesis of aluminum composite material by insitu technique becomes one of the popular methods because of its several advantages over the conventional methods. In this present paper, Al-xAlB$_2$ (x = 1, 3 and 5 wt.%) insitu composite were prepared and fabricated via exothermic chemical reaction between molten aluminium alloy and mixed halide salts KBF$_4$ and cryolyte Na$_3$AlF$_6$ at a temperature of 800^{0}C - 850^{0}C by using vortex method. The as cast matrix alloy and inistu composites specimens have been subjected to solutionizing treatment at a temperature of 535^{0}C for an hour and followed by water quenching. The quenched specimens were subjected to artificial ageing at a temperature of 175^{0}C for an about 10 hours. The composite were subjected to microstructure analysis and the result revealed that fine and clean AlB$_2$ particles distributed uniformly with good interfacial bonding and dislocations was observed throughout the matrix by using SEM/EDS. Most of the AlB$_2$ particulates exhibits with different morphologies including Spherical, cylindrical and hexagonal shapes were found near the grain boundaries. The composites were evaluated for mechanical tests like hardness, tensile and compression by the ASTM standards by using hardness and UTM machine. The composites enhanced the hardness and mechanical properties with increases in the weight fraction of AlB$_2$ particles but ductility of the composite is decreases.**

Keywords*: *Insitu, Solutionizing, Ageing, Hardness etc.

Introduction

AMCs have made considerable impact in the materials arena due to their desirable properties which include high strength to weight ratio, high wear resistance, low thermal expansion etc. AMCs are eventually phasing out conventional aluminum alloys in several products in aerospace, automotive, nuclear and marine industries[1-3]. With increasing demand for light weight and high performance materials in aerospace and automotive industries aluminium–matrix composites (AMCs) are gaining rather more importance and a potential candidate for many applications to fulfill these demands different manufacturing techniques with various ceramic reinforcements have been used [4-5]. Al 6061 is a popular matrix material owing to its good corrosion resistance and good mechanical properties coupled with good formability. Al 6061 is heat treatable and as a result further increase in strength is expected by adopting optimal heat treatment[6-8].

To make engineering applications fit for structurally and physically in automobile and aerospace applications heat treatment is the best fabrication process for the material system at elevated temperature with different quenching medias [9]. Solution heat treatment mean treatment in a solution of any sort, but it refers to the changes which occur within a metal. During age hardening the alloying element appears as a vast number of minute particles at the aluminum crystal boundaries and act as a key which hinder slippage, thus increasing the hardness and tensile strength of the casting [10-11]. Quenching is the process of rapid cooling of material systems to room temperature to preserve the solute in solution. The cooling rate needs to be fast enough to prevent solid-state diffusion and precipitation of the phase[12].

Hence, heat treated AMCs are extensively used in manufacturing of various components such as brake drums/rotors, cylinder liners, connecting rods, cylinder blocks, pistons, gears, drive shafts and suspension systems [13-14]. Various reinforcements in the form of carbides, oxides, nitrides, borides of metals, graphite, fly ash, etc. have been used in aluminium or aluminium alloys to develop AMCs by different processing methods. Many researchers have worked on Silicon carbide (SiC) and alumina (Al$_2$O$_3$) particulates were considered as reinforcement phase over a longer period since the induction of AMCs into materials world [15]. The progress in production techniques enabled researchers to produce AMCs reinforced with various carbides, oxides, borides, nitrides particulate is a good choice for reinforcing. In-situ production of AMCs consists of chemical reactions between elements or between elements and compounds. The inherent merits of in situ production method are generation of fine size of

ISSN: 2394-3696

ceramic particulates, good interfacial bonding between the aluminum matrix and the ceramic particulates, homogeneous distribution of ceramic particulates in the aluminum matrix, thermodynamically stable particulates and economy of processing [16-17]. The feasibility of the in-situ process has been established to successfully produce AMCs reinforced with TiC [18], TiB_2 [19], ZrB_2 [20] and AlN [21] particulates. The in-situ composites pose several advantages as uniform distribution of reinforcement particles, grain refinement, clear interface, enhanced thermal stability and economical processing.

The proposed inistu reinforced AlB_2 AMC will exhibit significant improvement in elastic modulus, strength and wear resistance over continuously reinforced Al-MMC's, resulting in overall weight reduction in flight industries. Potential application are in manufacturing of gears, bearings, erosion resistant skins, bearings, brake rotor compression fitting, seals, sleeves and actuators. Recently researchers have discovered the composite containing AlB_2 particles possessed higher hardness and good wear resistance property. Linlin Yuan et.al [22] fabricated inistu composites by AlB_2 reinforcement using powder metallurgy and subjected heat treatment and concluded that hardness and wear properties are higher in a case of composites when compared to unreinforced matrix material. R.Kayikci et.al [23], prepared AlB_2 insitu composites using B_2O_3 using liquid metulurgy route and reported that the composite having good wear resistance because of increase in hardness of the composite. Dumitru-Valentin et.al [24], prepared the composites were fabricated using Al 6060 with halide salt KBF_4 using stir casting method and reported the presence of AlB_2 compounds in the condition of high cooling rate of the composite material microstructure results shows that particles were are uniformly distributed and having good bonding in the composites. P. Moldovan et.al [25], investigated the inistu composite by Al alloy and KBF_4 by stir casting route, is reported composites behaves better wear resistance and the presence of AlB_2 particles improved the mechanical properties of the composites. Azharuddin Kazi et.al [26], investigated the composite by using Al6061 with KBF_4 using liquid metallurgy route and reported that by increasing the weight % of reinforcement the hardness of the composites increases and shows better wear resistance. B.N.Sharada et.al [27] fabricated composites Al6061/TiO_2 and observed that the quenching has significant effect on hardness and tensile strength, exhibiting significant improvement as compared to as cast composites. Yahya Bozkurt et.al.,[28] investigated on wear behaviour of SiCp/AA2214 AMC. The results show that the hardness and wear rate values of as-received composite were considerably improved up to two third by the aging composite. D.Ramesh et.al.,[29] Al6061-Frit particulate composites were produced by 'VORTEX' method and observed under identical heat treatment conditions adopted, Al6061-Frit particulate composites exhibited significant improvement in hardness when compared with Al6061 alloy. H.N.Reddappa et.al.,[30] fabricated the composite on Al6061/Beryl, and concluded that heat treatment has profound effect on both hardness and tensile strength of Al6061-beryl composites. Many researchers have worked on inistu developed composites but literature on heat treatment of inistu AlB_2 particles and composites are limited [31-32]. There is less research work has been done on ageing behavior of inistu prepared Al6061-AlB_2 composites.

2 Experimental Procedure

Al6061 is taken as a raw material which is in the form of billets acquired form PMC, Bangalore and to fabricate inistu Al-AlB_2 composites two inorganic salts KBF_4 (Madras Fluorine Factory, Chennai) and Na_3AlF_6 (Shwet Multimetals, Mumbai) were used as a reinforcement material and analyzed for the chemical constituents is as shown in the table 2.1.

Table:2.1 Chemical composition of Al6061

Elements	Si	Fe	Cu	Zn	Ti	Mn	Mg	Cr	Al
%	0.78	0.27	0.24	0.04	0.1	0.04	0.92	0.07	Balance

To develop a composite with different weight fraction of (3 and 5 wt.%) of AlB_2 particles the measured quantity of premixed halide salts are wrapped in a aluminum foil and incorporated into the molten aluminum at a temperature of 800^0C to form and attain maximum and uniform distribution of AlB_2 particles[33]. The melt was continuously stirred using a zirconia coated stirrer at a speed of 150-200 rpm to attain the proper chemical reaction. Stirring was continued until interface interactions between the halide salts and the matrix promotes wetting. After attaining 60 minutes of chemical reaction time [34-35] the slag formed and floated on the melt is skimmed off and is poured into the preheated cast iron die [35]. The prepared composites specimens were machined according to ASTM standards and characterize for the different microstructure and mechanical characterization studies. The specimens were polished as per the

ISSN: 2394-3696

following standard metallographic procedure by using polishing machine with SiC paper of 220 grit to 1200 grit and fine polished with diamond paste and finally etched with Keller's reagent. Microstructures of the prepared composites were examined using SEM equipment to determine the formation and morphology of AlB_2 compound in the composite[36-38].

3. Results and Discussions:

3.1 Microstructural studies:

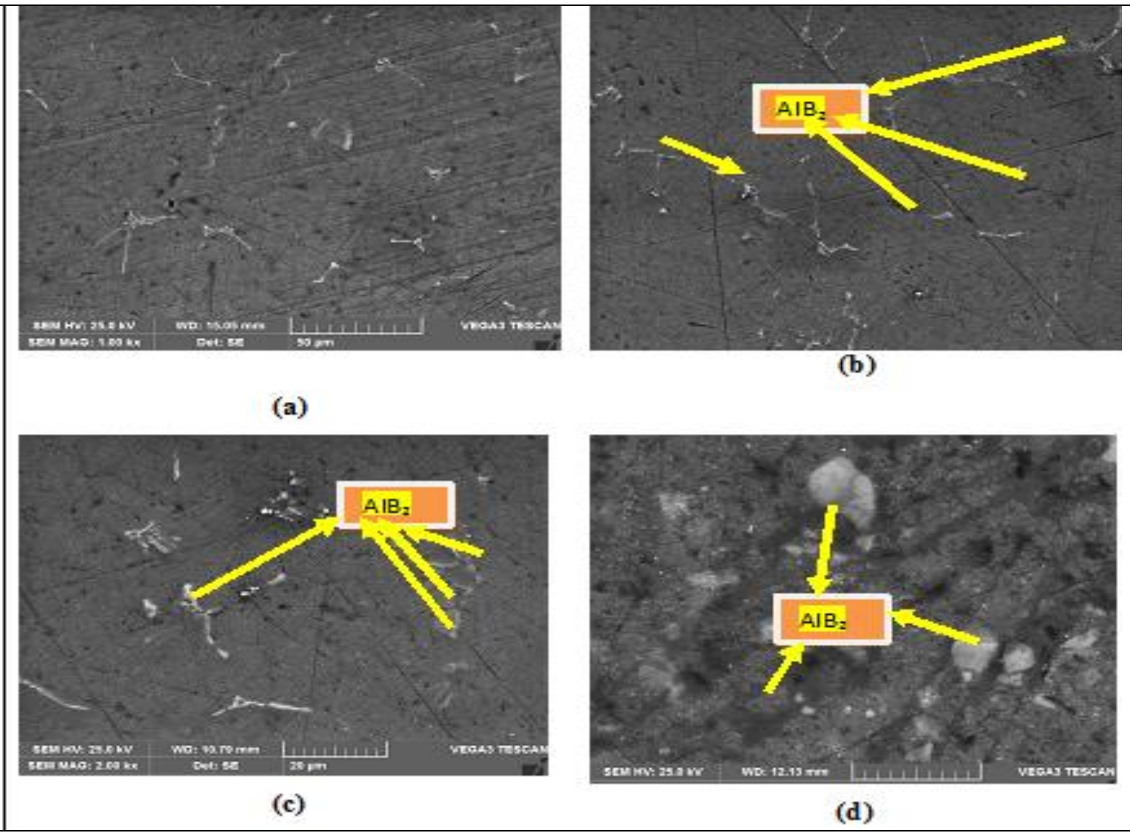
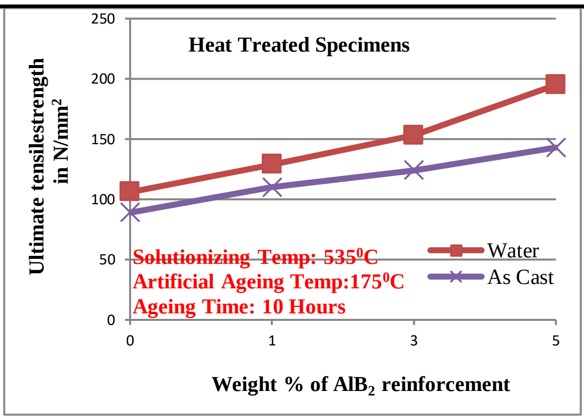


Figure 3.1 (a)-(d) shows the SEM Microstructure images of heat treated (a) Al6061 (b) Al6061 + 1wt.% ofAlB_2 (c) Al6061 + 3wt.% of AlB_2 (d) Al6061 + 5wt.% ofAlB_2

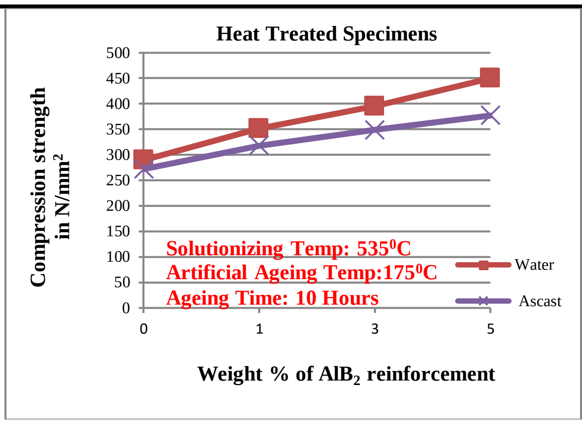
Figure 3.1(a) presents SEM image of heat treated Al6061 matrix alloy. It is clearly seen that the uniform distribution of grains through the region. The microstructure of as cast AA6061 displays a typical dendritic structure as a result of solidification. The dendritic structure is formed due to high cooling rate. The dendritic structure is completely absent in the microstructure of the composite as shown in the figure 3.1(b)-(d). It is interesting to observe the interface between the AlB_2 particulate and the aluminum matrix. These characteristics of the interface indicate that the AlB_2 particulates are well bonded to the aluminum matrix. During reaction the formation of in situ formed AlB_2 particulates can suspend in the molten aluminum for longer time. The molten aluminum begins to wet the AlB_2 particulates immediately after the formation of particulates by in situ reaction. The wetting action helps to restrict the free motion of AlB_2 particulates. The local raise in the molten aluminum temperature due to the exothermic nature of the reaction further ensures good wettability [39]. The coefficients of thermal expansion (CTE) of aluminum matrix and the AlB_2 particulate are having large variation. This creates a thermal mismatch during solidification which forms large number of dislocations [38, 40]. Microstructural analysis highlights a good interfacial integrity between the AlB_2 particles and matrix. It clearly shows the formation of AlB_2, in figure (b) this indicates the there is a uniform distribution of AlB_2 throughout the base alloy and also agglomeration at few places were observed in the figure (d) composite reinforced with 5 wt% of reinforcement.

3.2. Mechanical properties

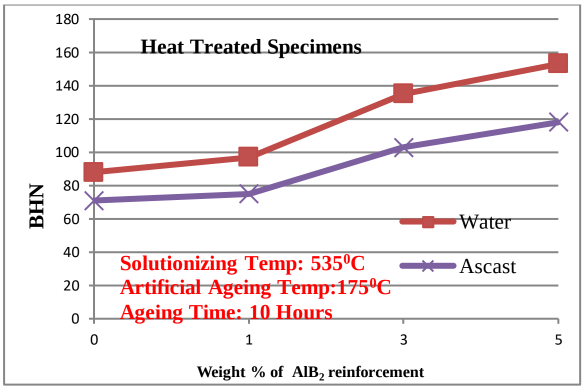
The effects of AlB_2 particles on mechanical properties like hardness, ultimate tensile strength (UTS) and compression strength (CS) of the composites has been evaluated.



(a)



(b)



(c)

Fig 3.2 (a)-(c) shows the heat treated specimens (a) UTS Vs wt. % of reinforcement (b) CS Vs wt. % of reinforcement (c) BHN Vs wt. % of reinforcement

It is observed that with in all the above conditions increased weight % of reinforcement in the matrix alloy, there is a significant improvement in the hardness and strength of the composites. In the Figure 3.2 (a) present the effect of AlB_2 particulate content on hardness graph of AA6061/AlB_2 AMCs. The Brinell hardness is found to be 68% increase, tensile property in UTS are improved by about 78% and compression strength of 76% N/mm2 in Al-5wt%. AlB_2 reinforcement when compared to unreinforced heat treated aluminum alloy. The in situ formed AlB_2 particulates remarkably improved the hardness of the composite. This improvement is mainly attributed to increased percentage of AlB_2 particles in the matrix alloy. Increasing in the strength is attributed to the decrease in the inter particle spacing between the AlB_2 particles, since AlB_2 is much harder than the Al6061 aluminium alloy[41-44]. The presence of the AlB_2 resists deforming stresses, thus enhancing strength of the composite material. However, the addition of hard AlB_2 particles into the composites caused he metal matrix composites to behave as brittle rather than ductile materials.

3.3 Effect of ageing duration

The effect of ageing duration on the hardness of the inistu composites which are quenched in water. It is observed that water quenched specimens at Al-5 wt% of AlB_2 composites gives shows maximum hardness of 154 BHN for the ageing duration for 10 hours. The improvement in the hardness of the composites with increase in the ageing duration. Ageing duration accelerates the kinetic precipitation hardening in composites[45-46]. The improvement in hardness may be attributed to the high dislocation density around the AlB_2 particles due to difference in coefficient of thermal expansion (CTE) between Al-rich matrix and AlB_2 particles.

3.4 Effect of quenching media

It is observed from the different researchers N.A.Oguocha et.al [47] hardening at higher cooling rate is due to the vacancy / GPB zones (Guineir-Preston-Begaryaskii) and the dislocation of the atoms. As the cooling rate increases, the amount of quenched vacancies that is necessary for the GPB zones formation also increases[48-54]. Moreover the density of the composites is more so the strength of the composites. Another reason for the resulting strengthening is due to the interaction between dislocations and AlB_2 particles when the composites bear a load and also due to the presence of a number of appending dislocations around the AlB_2 particles because of the difference in the thermal expansion co-efficient between the matrix and AlB_2 particles[55-62]. The improvement of UTS of all composites may be attributed to the grain boundary strengthening compared with matrix metal[63-66]. The uniform distribution of AlB_2 particles along the grain boundary effectively improve the UTS, as the UTS of the composite with stirring speed and the reaction time. Presence of cryolite in the composites forms uniform distribution of AlB_2 particles and reducing of large agglomerations, the ductility can be improved[67-70]. This improvement in strength may be attributed to grain refinement due to the presence of AlB_2 particles, which is also in agreement with Hall–Petch relation[71-72]. Increase in overall dislocation density around the AlB_2 particles due to mismatch of thermal expansion coefficients of aluminium matrix and AlB_2 particles during solidification also contributes to strength.

4.0 Conclusions

The following conclusions are derived from the present work.

- AA6061/AlB_2 composites containing different weight % of AlB_2 can be successfully developed by in-situ reaction between molten aluminium alloy with two inorganic salts KBF_4 and Na_3AlF_6 by exothermic chemical reaction.
- The microstructure of the composites reveals a clean, clear and fairly homogeneous dispersion of AlB_2 particulates in aluminium matrix.
- Mechanical properties increases with the increases in the weight % of AlB_2 Content in the base matrix but ductility of the composites decreases with increases in weight % of AlB2 reinforcement.

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