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Effects of Calcium Carbonate, Magnesium Carbonate and Dolomite in Aluminium Alloy

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ABSTRACT: The aluminium alloy foam is a new class of material with low density, large specific surface, better corrosion and wear resistance and low thermal expansion. Their application is light weight structural components, shock or sound absorbing products, aero planes and ships. As a foam agent are calcium carbonate, Magnesium carbonate and Dolomite powder add process, the composite aluminium foam sandwich structure is fabricated by bottom pouring stir casting furnace through melting route. Further the specimen is examining the experimental test and calculates the readings. Finally compare the three type aluminium foam sandwich structure results from aluminium alloy structure. The results shown the energy absorption capability of the composite structures is much greater than the sum of the energy absorbed by the two components, the foam and the tube.

KEYWORDS: Metallic foam, Melting route, Foam agents, calcium carbonate, Magnesium carbonate, Dolomite and Sandwich.

I. INTRODUCTION

Metal foams are potential materials for light-weight structural sandwich panels, packing material and energy absorbing devices and they can be used in applications such as automobile crumple zones, structural members in air and spacecraft, and even in biomedical prosthesis. Mostly this type of aluminium foams are manufacturing through melting route and powder metallurgy route. The melting route foam manufacturing methods are Alcan / Norsk hydro process and Alporas process. Both methods the foam agent used as a Titanium hydride (TiH_2) [2,3]. This type foam agent is very costly and very danger while handling the foam manufacturing. During the foam manufacturing titanium hydride emits the hydrogen (H_2) gas that makes the nuclear fusion process. So this process handles very carefully and comfort handling equipments are needed.

We studied Alcan, Alporas and gasar are the most widely used to produce closed-celled aluminum foams and analyze the use of an appropriate blowing agent which releases gas at the right temperature to ensure high expansion and the formation of a uniform porosity [10] The alternative sources of blowing agents to produce the foams are calcium carbonate (CaCO₃), magnesium carbonate (MgCO₃) and dolomite (CaMg (CO₃)₂) [17]. These foam agents are very cheaper, easily available in market and very safe while manufacturing. From the literature review calcium carbonate create foams are very stability and less density [10]. The dolomite create foams are homogeneous structure [10]. The aluminium composite materials like as metal matrix composite (MMC), Hybrid composite, Particle reinforced composites, Fiber-reinforced composites & Structural composites only created by stir casting furnace still now [1,2]. In doing so, the aluminium foam created through melting route in bottom pouring stir casting furnace by add as a foam agent are calcium carbonate, magnesium carbonate and dolomite powders. That foam is poured in aluminium tube for create the aluminium foam sandwich structure. These aluminum foam sandwich structures are investigated by shear test and calculate the readings. Normally the density and shear strength of aluminium (6061) is 2700Kg/m³ and 200MPa respectively [22].

These papers explain that calculation the shear strength of aluminium foam sandwich structure is much greater than normal aluminium structure. The above foam agents used to reduce the weight and increase the ductility [17]. So by add the foam agents the mass of the aluminium and shear strength are varied. From this property the quantity of aluminium used reduced, material consumption, cost and drag force in automobiles are reduced. The paper explained that the results for properties of aluminium foam sandwich structures, manufacturing methods, discuss the best



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manufacturing methods is identified and best foam agents is founded from calcium carbonate (CaCO₃), magnesium carbonate (MgCO₃) and dolomite (CaMg (CO₃)₂).

II. EXPERIMENTAL PROCEDURE

The aluminium (6061) is containing Al 95.8%, Mg 0.5%, Si 0.6%, and Ca 1.5%. The three types of aluminium foam sandwich structures are fabricated by add calcium carbonate (CaCO₃), magnesium carbonate (MgCO₃) and dolomite (CaMg (CO₃)₂) as a blowing agent through melting route in bottom pouring stir casting furnace. First step the aluminium (6061) melted in stir casting furnace above 600° C after the molten metal is poured into 16mm diameter hollow die. From this process the three type of aluminium hollow tube is fabricated by stir casting furnace. The hollow aluminium tube has 16 mm outside diameter and 9 mm inside diameter. After that the aluminium tube is inserted vertically in a green sand moulding box and fill the moulding sand entire outer surface on the aluminium tube. By using this method of green sand moulding very easily to supply the molten metal foam into a hollow tube and the aluminium does not melted while at high temperature (600° C) foam material poured.



Fig (1) The Raw Material of Aluminium 6061.



Fig (2) (a) Calcium carbonate (CaCO₃), (b) Magnesium carbonate (MgCO₃) and (c) Dolomite (CaMg(CO₃)₂) powders.



Fig (3) The hollow tube.

Next step the aluminium has melted above melting point temperature $(700^{\circ}C)$ in bottom poring stir casting furnace. When added the Calcium carbonate (CaCO₃), magnesium carbonate (Mgco₃) and dolomite (CaMg(CO₃)₂) at a temperature reach above melting point. Once molten aluminium heated to 700 °C [17], the power addition was switched off and melt stirring was initiated until the temperature of melt decreased to 685 °C. After that, the blowing agent powders (10%) was introduced and the melt was stirred (at approximately 1200 rpm) for additional 30-90 s. Finally, foam able precursors were prepared by casting the semi-solid slurry into a room temperature mould with 9 mm diameter hollow tube. The Decomposition of Blowing Agents is taking the following process and emits CO₂.



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 $\label{eq:Galerian} \begin{array}{l} For \ Calcium \ carbonate \\ CaCO_3(s) \rightarrow CaO(s) + CO_2(g) \end{array}$ For Magnesium carbonate $MgCO_3 \rightarrow MgO(s) + CO_2(g) \\ For \ Dolomite \\ CaMg(CO_3) \rightarrow CaCO_3(s) + MgO(s) + CO_2(g) \\ CaCO_3(s) \rightarrow CaO(s) + CO_2(g) \end{array}$



Fig (4) Bottom pouring stir casting furnace



Fig (5) Aluminium tube placed on green sand moulding box (a) Foam filled tube (b) Empty hollow Tube.

The solidified precursors were machined by lathe operations and investigated by double shear test in Universal Testing Machine, Hardness test, and SEM analysis.



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III. RESULTS AND DISCUSSION

SCANNING ELECTRON MICROSCOPE (SEM) TEST ANALYSIS

The normal Al 6061 micro structure is as shown in fig. In this structure is consist more weight because more density. So this structure did not used in commercial applications.



(a)





The different cell structures obtained from the foaming agents are determined by various factors, such as type of gas released and decomposition temperature. Fig 4.2 shows the magnified images of the cell structures.





The microstructure of various foam agents based aluminium foams structures are observed from this SEM images. The magnesium carbonates and calcium carbonates based aluminium foams are not homogeneous and it has sum unwanted cracks during the fabrication. The results shows the grain particle is regularly mixed in dolomite based foam structures. The dolomite based foam structure has a homogeneous structure. SHEAR TEST ANALYSIS

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After that, the three type's specimen applied to double shear test. From this experiment the shear strength of aluminium foam sandwich structure is determined by using Universal Testing Machine (UTM). In this experiment the following equipments are needed. UTM, Shear attachment to the UTM, shear dies and Venire Calipers. Shear strength of the material is the shear stress (τ) attained by the specimen, which under double shear given by,

$$\tau = (P \div A) N/mm^2$$

Where,

F = Maximum load at which the specimen breaks,

A = cross-sectional area of the specimen.

Table 1: The Aluminium foam structure (a) CaCo₃ (b) MgCo₃ (c) CaMg (CO₃)₂

Type of test specimens / Foam agent	SEM test	Shear test	
CaCo3			
MgCo3			
CaMg (CO3)2			

The three type's specimen applied to double shear test. From this experiment the shear strength of aluminium foam sandwich structure is determined by using Universal Testing Machine (UTM). The load range to which the machine is to be set for the test is selected bases on the expected maximum load F to be applied on the specimen. Measure the diameter of the specimen.

Calculate the maximum load expected to be applied on the specimen using equation and select the load range to be used. Set the UTM for the selected load range. Set the correct set or dies to assemble the shear attachment with the right set of dies in it. Insert the specimen in to the dies so that it projects equally on either side.

Place the entire bear assembly with the specimen in it centrally over the baring plate on the lower table. Bring the lower cross- head close to the top surface of the assembly. Float the lower table and set the load pointer to zero.

Apply the load gradually until the specimen breaks. Note the ultimate load applied on the specimen. From the shear test experiments the shear load of the specimens founded and tabulate the readings. The shear stress is calculated by using double shear stress formulae. Already note the specifications and dimensions of test specimen aluminium foam sandwich structure.



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Fig (8) (a) Tested specimen of aluminium foam sandwich structure by add CaCO₃



Fig (8) (b) Tested specimen of aluminium foam sandwich structure by add MgCO3



Fig (7) (c) Tested specimen of aluminium foam sandwich structure by add CaMg (CO₃)₂

Table 2: Density and Shear strength of aluminium foam sandwich structure.

S.No	Blowing Agents	Percentage %	Density (ρ) Kg/m ³	Shear Stress (τ) MPa
1	CaCO ₃	10	2670	203
2	MgCO ₃	10	2785	207
3	CaMg (CO ₃) ₂	10	2570	200



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Fig (9) (a) Comparison of density between the different foam agents specimens



Fig (9) (b) Comparison of shear stress between the different foam agents specimens

From the shear test experiments the shear load of the specimens founded and tabulate the readings. The shear stress is calculated by using above formulae. The values are noted in graphs and compare the variation of density and shear stress between different aluminium foam sandwich structures based on utilizing different foam agents. From these results the density and mass of the specimen is very less by using dolomite foam agent specimen compare with others.

HARDNESS TEST ANALYSIS

The hardness of different aluminium foam structures is measured by using Rockwell Hardness Tester and the hardness values of the different composition with different types foam structures are tabulated. The hardness of the foam material is based on the different types of foam agents.

S.No	Blowing Agents	Percentage of Blowing Agent %	Hardness HRB
1	CaCO3	10	81.5
2	MgCO ₃	10	86
3	CaMg (CO ₃) ₂	10	86.5

Table 3: Hardness of various aluminium foam structures



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Fig (10) Comparison of Hardness between the different foams

From the results the dolomite based aluminium foams are very high Rockwell hardness number compare with other structures. It is indicating the graph



Fig (11) Comparison of Density, Shear stress & Hardness between the different foam structures

IV. CONCLUSION

The following conclusions can be drawn from this work. The aluminium foam sandwich structure successfully fabricated by bottom pouring stir casting furnace with add foam agents are calcium carbonate (CaCO3), magnesium carbonate (MgCO3) and dolomite (CaMg(CO3)2) through melting route.

The titanium hydride is replaced by calcium carbonate (CaCO3), magnesium carbonate (MgCO3) and dolomite (CaMg (CO3)2) as a foam agents. So the stir casting process is one of the foam manufacturing processes. The dolomite based aluminium foam sandwich structures has a homogeneous structure as shown in SEM image. The foam efficiency of dolomite is very higher than other foam agents. So decide in mostly foam fabrication process the dolomite is as a foam agent. The shear strength and hardness of different specimen is slightly same.

Best choice of foam agent for foam manufacturing process is dolomite due to produce high efficiency foam core otherwise, less density aluminium material has produced and the best manufacturing method is stir casting method due to easily manufacturing techniques. From the conclusion in future work dolomite based aluminium foam sandwich structure is used in wide applications.

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