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Ductile Fracture Prediction of Stir Casted Al 6061 with B_4c and Sic

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ABSTRACT:

Due to the day by day increased in demands of aluminum in industries like automotive industry and building industry, it is required for improvement of its mechanical properties by addition of suitable alloying elements to aluminum. In this work the ductile fracture of stir casted Aluminum alloy analyzed by the help of various methods. Uses the compositions of three different percentage of Aluminium6061 with Silicon Carbide and Boron Carbide analyzed. This various compositions have been compared with the normal AA6061 based on its tensile test, impact test, hardness test and microstructure analysis. It has been observed that ductile fracture of Al alloys is increasing with the addition of boron carbide (B_4C). The microstructure of the stir casted surface of three various compositions has been analyzed using inverted microscope.

KEY WORDS: Aluminum alloys, ductile fracture, tensile test, impact test, hardness test, microstructure

INTRODUCTION:

The mechanical properties of metals and its alloys can be improved by a combination of metallurgical, manufacturing and design measures, which increase the reliability and service life of the component manufactured. Due to good physical and mechanical properties of aluminum and its chemical composition imparts this widely used metal after the steel. Aluminum and its alloys have high strength-to-weight ratio and other desirable properties like non-toxic, non-magnetic, high thermal and electrical conductivities, high corrosion resistance and easy to fabricate. B_4C and sic alloys (i.e. 6061series Al) have widely used in automobile industry and building industry due to its medium strength, corrosion resistance and low cost.

Aluminum alloy 6061 is one of the most extensively used of the 6000 series it is a versatile heat treatable extruded alloy with medium to high strength capability. Originally called "Alloy 61S", it was developed in 1935.

Boron Carbide (B_4C) is one of the hardest materials known; ranking third behind diamond. So the addition of B4Cwith the Al 6061and SiC will help to improve the hardness of Al 6061. During open stir casting it is only possible to cast 91 % Al 6061 and rest other alloys to improve the ductile fracture. So by volumetric analysis Al 6061 is added with sic and B_4C at various compositions. It is found that with the addition of B_4C the ductile fracture of the alloy also increases. Thus we prepared three various composition of B_4C with sic. First we prepared composite alloy having 91% Al6061 with 2% of B_4C and 7% of sic. Then next we increase 1% of B_4C and to balance the volumetric composition we reduce 1% of sic. It is repeated again in next composition.

Thus the mechanical property of three alloys is tested by using various methods such as tensile test, Impact test, hardness test and the Microstructure analysis. From the results, it has been observed that ductile fracture of Al 6061 increase with the increase in amount of B_4C in the composition. The microstructure analysis show that the fracture surface has high strength compare to the pure Al 6061.

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Composite alloy	Al 6061 (in %)	SiC (in %)	B_4C (in %)
Specimen 1	91	7	2
Specimen 2	91	6	3
Specimen 3	91	5	4

Table 1

2. MATERIALS USED:

2.1 Aluminum 6061

Aluminum alloy 6061 is a medium to high strength heat-treatable alloy with strength higher than 6005A. It has very good corrosion resistance and very good weld ability although reduced strength in the weld zone. It has medium fatigue strength. It has good cold formability in the temper T4, but limited formability in T6 temper. Not suitable for very complex cross sections.

Alloy 6061 is one of the most widely used alloys in the 6000 Series. This standard structural alloy, one of the most versatile of the heat-treatable alloys, is popular for medium to high strength requirements and has good toughness characteristics. Applications range from transportation components to machinery and equipment applications to recreation products and consumer durables.

Fig. 1 Aluminum 6061

Alloy 6061 is one of the most widely used alloys in the 6000 Series. This standard structural alloy, one of the most versatile of the heat-treatable alloys, is popular for medium to high strength requirements and has good toughness characteristics. Applications range from transportation components to machinery and equipment applications to recreation products and consumer durables. Alcoa produces 6061 for use in standard and custom shapes, rod and bar products, and seamless and structural pipe and tube. Alloy 6061 has excellent corrosion resistance to atmospheric conditions and good corrosion resistance to sea water. This alloy also offers good finishing. Alloy 6061 is easily welded and joined by various commercial methods.

Component	Amount (wt%)
Magnesium	0.8-1.2
Silicon	0.4-0.8
Iron	Max. 0.7
Copper	0.15-0.40
Zinc	Max. 0.25
Titanium	Max. 0.15
Manganese	Max. 0.15
Chromium	0.04-0.35
Others	0.05
Aluminum	Balance

Table.2. The alloy composition of 6061

2.2 Boron carbide (B_4C)

Boron Carbide (B_4C) is one of the hardest materials known, ranking third behind diamond and cubic Boron carbide powder is mainly produced by reacting carbon with B_2O_3 in an electric arc furnace, through boron nitride. It is the hardest material produced in tonnage quantities. For commercial use B_4C powders usually need to be milled and purified to remove metallic impurities.

In common with other non-oxide materials boron carbide is difficult to sinter to full density, with hot pressing or sinter HIP being required to achieve greater than 95% of theoretical density. Even using these techniques, in order to achieve sintering at realistic temperatures (e.g. 1900 - 2200°C), small quantities of dopants such as fine carbon, or silicon carbide is usually required.

Due to its high hardness, boron carbide powder is used as an abrasive in polishing and lapping applications, and also as a loose abrasive in cutting

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applications such as water jet cutting. It can also be used for dressing diamond tools.

Fig. 2 Boron carbide

2.3 Silicon carbide (SiC)

Silicon carbide is also known as carborundum a semiconductor containing silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite. Synthetic silicon carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Electronic applications of silicon carbide such as light-emitting diodes (LEDs) and detectors in early radios were first demonstrated around 1907. SiC is used in semiconductor electronics devices that operate at high temperatures or high voltages, or both. Large single crystals of silicon carbide can be grown by the Lely method; they can be cut into gems known as synthetic moissanite .

Fig. 3: Silicon carbide

3. SPECIMEN CASTING:

Stir casting is an economical process for fabricating aluminum matrix composites. There are many parameters in this process which affect the final microstructure and mechanical properties of the composites. First pieces of aluminum 6061 is placed in the casting furnace and heated above 900 degree Celsius for 5 to 10 minutes. When the aluminum gets molten the impurities present in the aluminum are removed. B_4C and sic are then added to the molten aluminum and stirred and mixed. This molten alloy is then kept at 920 degree Celsius for about 5 to 6 minutes. The molten alloy is then poured to the casting mould and let to cool. This process is repeated for preparing with various compositions and the alloys are prepared for testing.

Fig. 4: stir casting Furness

4. TEST PROCEDURE:

This research has considered aluminum alloys to study the effects of added alloys on mechanical properties of the material. Pure aluminum is a weak and ductile material, but by adding small % of impurities in aluminum its tensile strength as well as hardness increased considerably. Aluminum 6061 has a general purpose alloy having medium strength; here we added the impurities such as silicon carbide (SiC) and the boron carbide (B4C) for increase the mechanical properties of aluminum 6061.

The tensile test is used to determine the tensile strength for a material. The Brinell hardness test is used to determine the brinel hardness number of the specimen. Charpy impact test which determines the amount of energy absorbed by a material during fracture. In microstructure analysis the structure of material is studied under magnification.

4.1 Tensile test

The standard specimens for materials aluminum has been used to find tensile strength of the materials. One piece of pure Al 6061 and one piece of each composite alloy has been used for determine the tensile strength. The improvement in the strength of new composite alloy can be Easley understood from this result. Here total four equal dimensions having specimens are used for determining the tensile strength by using the Universal Testing Machine. The specimens are prepared with the dimension of 150mm gauge length and 15mm gauge diameter.

Fig. 5: specimen before test

The specimen was loaded into the jaws of the Instron load frame so that it was equally spaced between the two clamps. The axial and transverse extensometers were attached to the reduced gage section of the specimen, ensuring that the axial extensometer was set correctly when attaching it to the gage and that the transverse extensometer was across the complete diameter of the specimen. This precaution results in better data and prevents damage to the extensometers. The Instron load frame was preloaded using the scroll wheel to ensure that the specimen was properly loaded in the frame, and that it wasn't slipping in the jaws. The load was released, and the extensometers were zeroed using the software. The test was started, and the specimen was loaded, resulting in a measureable strain

Formulas used in tensile test

Initial Area = $\pi/4(D)^2$

Tensile yield strength = Yield load (N) / Initial area (mm²)

Ultimate tensile strength = Ultimate load (N) / Initial area (mm²)

Tensile breaking strength = breaking load (N) / Initial area (mm²)

Tensile test results

Initial Area $(A) \;=\left(\frac{\pi}{4}\right)10^2 = 78.5\text{mm}^2$

Material	Yield strength (N/mm²)	Ultimate strength (N/mm²)	Breaking strength (N/mm²)
Al 6061	130.09	154.01	182.82
Specimen 1	133.12	156.05	184.59
Specimen 2	137.32	161.5	189.17
Specimen 3	140.76	164.96	192.99

Table.4: tensile strength of materials

4.2 Brinell hardness test

The Brinell scale characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test-piece. The value of the Brinell Hardness Number (BHN) is obtained by performing calculations using the following formula:

$$BHN = 2P/\pi D(D - \sqrt{(D^2 - d^2)}$$

Where P = Load applied, D = Diameter of indenter, d =Diameter of indentation

The specimen having the dimensions of 6mm thickness and 30mm gauge length. Specimen is placed on the anvil. The hand wheel is rotated so that the specimen along with the anvil moves up and contact with the ball. The diameter of the indentation made in the specimen by the pressed ball is measured by the use of a micrometer microscope, having transparent engraved scale in the field of view. The indentation diameter is measured at two places at right angles to each other, and the average of two readings is taken.

Hardness test results

P/D² value in kg/mm² = 5 kg/mm²

Diameter of steel ball indention (D) =10mm

Material	Major loads (N)	d in mm	BHN (kg/mm²)
Al 6061	2000	7.8	34.02
	1000	5.8	34.34
		Average BHN	**34.18**
Specimen 1	2000	7	44.54
	1000	5.1	45.53
		Average BHN	**45.04**
Specimen 2	2000	5.5	77.2
	1000	4.2	68.84
		Average BHN	**73.04**
Specimen 3	2000	4.7	108.50
	1000	4	76.26
		Average BHN	**92.39**

Table.5: brinell hardness of material

4.3 Charpy impact test

The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture Working procedure of the charpy test is given below raise the swinging pendulum weight and locks it. Release the trigger and allow the pendulum to swing. This actuates the pointer to move in the dial. Note down the frictional energy absorbed by the bearingsRelease the trigger and allow the pendulum to strike the specimen at its midpoint. Note down the energy spent in breaking (or) bending the specimen

Impact strength of the specimen = ***Energy Absorbed/Cross sectional area*** in N/mm2

Charpy hardnesstest is mainly used for mechanical property analysis because we use the charpy test here. The dimensions of chary specimen is 64 X 10 X 10 mm

Cross sectional area of specimen = 100 mm²

Material used	Energy absorbed by force (A) (J)	Energy for break the specimen(B) (J)	Energy absorbed by the specimen (A-B) (J)	Impact strength J/mm²
Al 6061	300	150	150	1.5
Specimen 1	300	100	200	2.0
Specimen 2	300	28	272	2.72
Specimen 3	300	26	274	2.74

Table. 5: impact strength of material

4.4 Microstructure analysis

Microstructure is the very small scale structure of a material, defined as the structure of a prepared surface of material as revealed by a microscope above 25× magnification. Here we used 50 X magnification microscope for the microstructure analysis.

From the analysis we determined that in this aluminium 6061 the contents have been bonded with

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medium strength and silicon is the main content which brings out the strength in this composition.

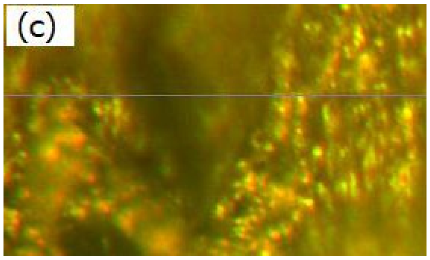

Fig.6 :Microstructure of Al 6061

In the specimen 1,7% of silicon carbide and 2% of boron carbide have been added to AL 6061 thus the strength have increased due to its bonding.

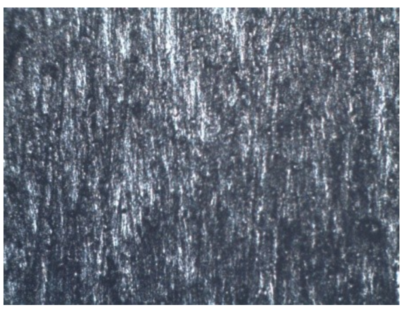

Fig.7: Microstructure of specimen 1

In specimen 2 it has been found that boron carbide and AL6061 had made a stronger bond which indicates the increase in strength of the composition.

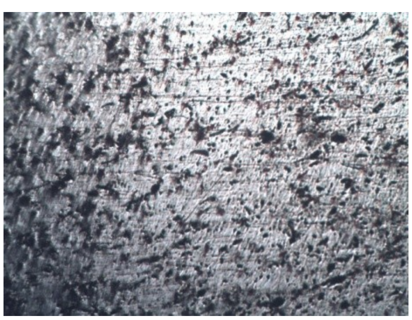

Fig.8: Microstructure of specimen 2

In specimen 3 with the more increment of the boron carbide in the composition the strength also increases. Thus a composition with high strength and low ductility component has been produced.

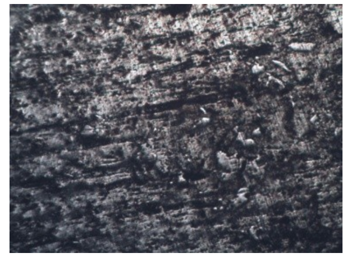

Fig.9: Microstructure of specimen 3

CONCLUSION:

This study investigated the influence of alloy element addition on the ductile property of Al 6061. The ductile fractures of Al 6061 alloy have medium tensile strength and hardness. On other hand addition of silicon carbide (SiC) and boron carbide (B_4C) increase the ductile fracture of Al 6061.According to the micro structural analysis we analyzed that the bonding strength of composite specimens is increasing by the addition of B_4C .The 4% of B4C having specimen 3 shows the maximum bonding strength. It is near to bonding strength of Aluminum T6 series. It having high strength and mach inability.

Tensile test ,impact test , and hardness test giving the results of heavy strength of specimen 3 than Pure Al6061.So we can concluded that Addition of Boron Carbide with Al 6061 increase its strength and also the ductile property.

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