Investigation of characteristics of hybrid Al 7(075+178) alloy developed through die casting

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KEYWORDS

Al 7(075+178),
Taguchi-DoE,
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ABSTRACT

7XXX series aluminum alloys (Al 7XXX alloys) are widely used in bearing components, such as aircraft frame, spars and stringers, for their high specific strength, high specific stiffness, high toughness, excellent processing, and welding performance. One of the most commonly used aluminium alloy for structural applications is Al7075 alloy due to its attractive comprehensive properties such as low density, high strength, ductility, toughness and resistance to fatigue. Another important alloy in the Al 7XXX series is Al7178. It has exceptional uses in Aviation field, Automobile sector, and Structural industries. In the present research work an attempt is made to prepare a blend of these two alloys and get the optimum composition which yields high strength Al 7(075+178). A medium frequency induction furnace with graphite crucible was used for the melting. Mechanical properties like Tensile strength and Hardness are selected as the output response along with the Microstructural analysis. Taguchi method was adopted for designing experimental composition of the composite which is prepared.

1. Introduction

Aluminium alloys are based on aluminium, in which the main alloying elements are Cu, Mn, Si, Mg, Mg+Si, Zn. In case of 7xxx series Zinc, Magnesium, and Copper are major share in preparation. In Al 7075 alloy, zinc is the dominant alloying element, and was the first alloy of high strength composed by Al-Zn-Mg-Cu that was able to successfully combine the perks of the inclusion of chromium to develop high stress-corrosion cracking resistance in sheet products. The 7178 aluminium alloy is wrought alloy. It has high zinc content. After annealing, aluminium alloy 7178 has high machinability. Die casting process is mainly used for nonferrous materials with high fluidity and low fusion temperature such as zinc and its alloys, copper, aluminium, brass, magnesium, and tin-based alloys. Die casting is a metal casting process that is characterised by forcing molten metal under high pressure into a mould cavity. The mould cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mould during the process. Preparation of hybrid Al 7(075+178) is carried out by die casting process.

2. Objectives and Methodology

The objectives of the current research work is: (i) Preparation of hybrid Al 7(075+178) by die casting process, (ii) To investigate the mechanical properties of the Hybrid Al 7(075+178), (iii) To perform microstructural analysis on the prepared Hybrid Al 7(075+178). The standard composition of Al7075, Al7178 are as prescribed in table 1 and 2. Proposed composition of hybrid Al7(075+178) is given in the table-3

Table 1
Composition of Al 7075.

Component	Zn	Mg	Cu	Cr	Si	Fe	Mn	Ti	Al
Amount (wt. %)	6.3-7.3	2.4-3.1	1.6-2.4	0.18-0.29	0.4	0.5	0.3	0.2	85.51 - 88.12

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Table 2
Composition of Al 7178.

Component	Zn	Mg	Cu	Cr	Si	Fe	Mn	Ti	Al
Amount (wt. %)	5.1-6.1	2.1-2.9	1.2-2	0.18-0.28	0.4	0.5	0.3	0.2	87.32 - 90.02

Table 3
Proposed composition of hybrid Al 7(075+178).

Component	Zn	Mg	Cu	Cr	Si	Fe	Mn	Ti	Al
Amount (wt. %)	5.1 - 7.3	2.1 - 3.1	1.2 - 2.4	0.18-0.29	0.4	0.5	0.3	0.2	87.32 - 88.12

Table 4
Composition of elements for preparation of specimens (%).

S.No/ Element	Zinc (Zn)	Magnesium (Mg)	Copper (Cu)	Chromium (Cr)	Silicon (Si)	Iron (Fe)	Manganese (Mn)	Titanium (Ti)
1	5.1	2.1	1.2	0.18	0.4	0.5	0.3	0.2
2	5.1	2.1	2.4	0.29	0.4	0.5	0.3	0.2
3	5.1	3.1	1.2	0.29	0.4	0.5	0.3	0.2
4	5.1	3.1	2.4	0.18	0.4	0.5	0.3	0.2
5	7.3	3.1	1.2	0.18	0.4	0.5	0.3	0.2
6	7.3	3.1	2.4	0.29	0.4	0.5	0.3	0.2
7	7.3	2.1	1.2	0.29	0.4	0.5	0.3	0.2
8	7.3	2.1	2.4	0.18	0.4	0.5	0.3	0.2

Table 5
Calculation of the mean composition of Al 7(075 + 178) (in grams).

S.no/ Element	Zinc (Zn)	Magnesium (Mg)	Copper (Cu)	Chromium (Cr)	Silicon (Si)	Iron (Fe)	Manganese (Mn)	Titanium (Ti)	Aluminium (Al)
1	51	21	12	1.8	4	5	3	2	900.2
2	51	21	24	2.9	4	5	3	2	887.1
3	51	31	12	2.9	4	5	3	2	889.1
4	51	31	24	1.8	4	5	3	2	874.2
5	73	31	12	1.8	4	5	3	2	868.2
6	73	31	24	2.9	4	5	3	2	855.1
7	73	21	12	2.9	4	5	3	2	877.1
8	73	21	24	1.8	4	5	3	2	866.2

From the table-3, To obtain optimum composition of hybrid Al 7(075+175) alloy we develop a model, from the composition table of Al 7075 and from the composition table of Al 7178 we identify the four parameters that vary (Zn, Cu, Cr, Mg) in composition in the two alloys respectively. We consider two levels of low and high percentages of the 4 parameters (Zn, Cu, Cr, Mg) to develop a model. The model is developed with 4 parameters and 2 levels resulting in eight trails (Taguchi L8 OA). All the eight trail compositions are developed, and samples are prepared using Die casting process. Table-5 shows the weight of elements of table-4

Die is prepared with cast iron metal for a cylindrical shape castings. Al 7(075 + 178) is melted in furnace to 700^0C to 750^0C and poured in to die, molten metal enter into die by the gravity force and casting is taken out after solidification. Die is prepared with cast iron metal for a cylindrical shape and diameter of die is 25mm and length

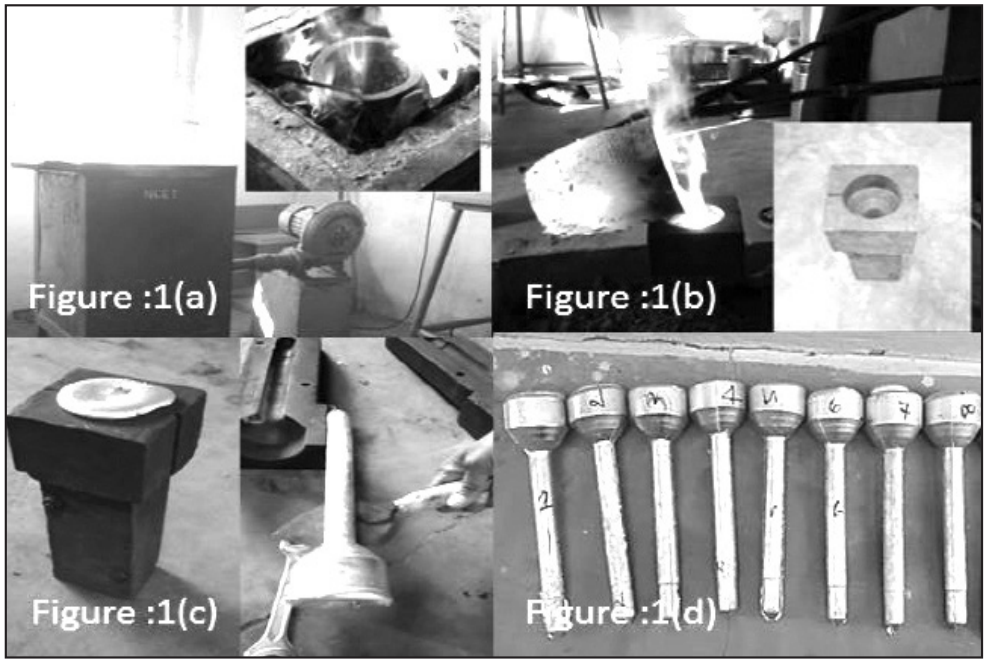

Fig. 1. Die casting process and casting specimen.

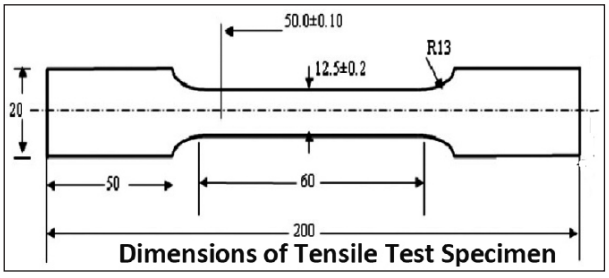

Fig. 2. Specimen dimensions for tensile testing.

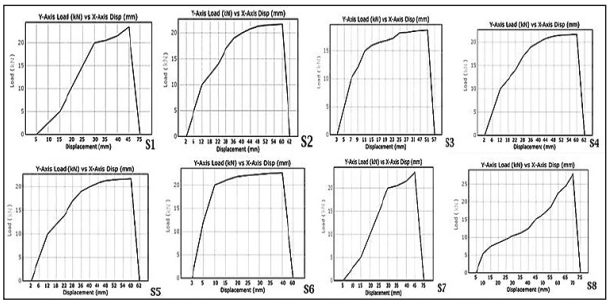

Fig. 3. Load vs displacement for the samples.

250mm. The processing and casted components is shown in Figure 1(a),(b),(c),(d). After the casting, the components are machined according to ASTM (American Society for Testing and Materials) standards on highly sophisticated lathe for tensile test process as shown in figure 2.

3. Tensile Testing

Tensile testing is a destructive test process that provides information about the tensile strength, yield strength, and ductility of the metallic material. It measures the force required to break a composite or plastic specimen and the extent to which the specimen stretches or elongates to that breaking point. A controlled force is applied on the sample and its elongation is measured which helps in obtaining several material properties like stress and strain. The test properties include Young's modulus, poisons ratio, ultimate tensile strength etc. It is performed as per ASTM standards. The prepared 8 samples are subjected to tensile test on Make : FIE/UTN-40, Serial No : 11/96-145, Load Capacity: 100N to 100kN and the results are demonstrated in table 6. The graphical representation of Load vs displacement for the samples are shown in figure 3.

Table 6
Tensile test observations.

Specimen/ Properties	Yield Stress (MPa)	Ultimate Tensile Strength (MPa)
Al 7(075+178) -1	182.6	216.90
Al 7(075+178) -2	171.8	186.34
Al 7(075+178) -3	151.4	196.26
Al 7(075+178) -4	168.2	201.23
Al 7(075+178) -5	179.8	208.69
Al 7(075+178) -6	179.8	222.90
Al 7(075+178) -7	151.7	209.56
Al 7(075+178) -8	180.8	225.36

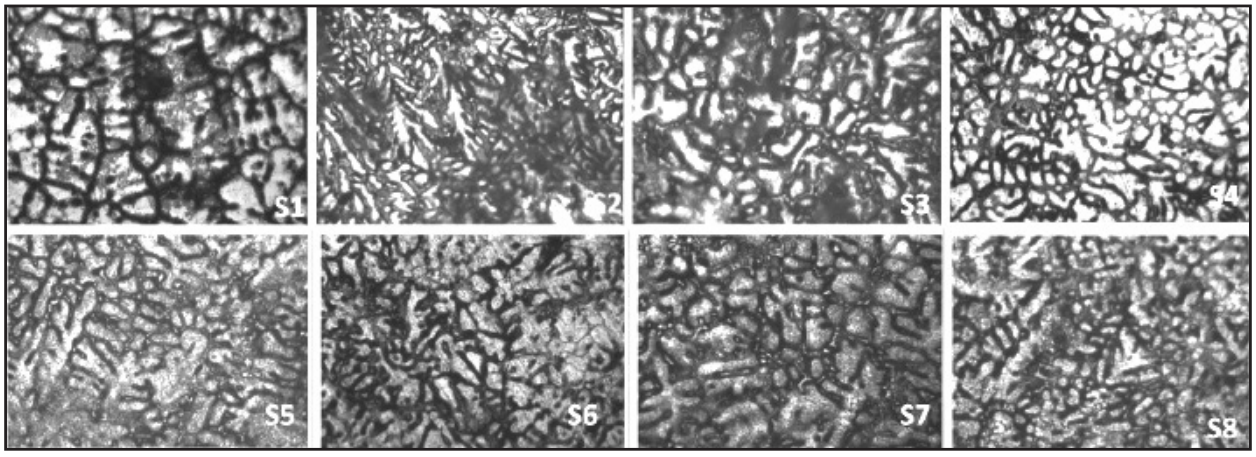

Fig. 4. Microstructure of the samples at 100X magnification.

From the figure 4 it is interpreted that the sample S1 is exhibiting a well-defined linear elongation deformation upto 20kN of load and undergoes a displacement of 30mm. The yield stress of sample S1 is higher out of all samples, which explain the presence of higher percentage of Aluminium. The sample S8 reveals a highly non-linear elastic deformation nature because of higher amount of copper content and coarse grain structure. S6 sample stands next to S8 sample with respect to ultimate tensile strength; however yield strength is decreased because of higher amount of Magnesium content. The analysis suggests that sample S8 is preferable because of its high yield and tensile strengths.

4. Microstructure of Hybrid Al 7(075+178)

Microstructure is the very small-scale structure of a material, defined as the structure of a prepared. These properties in turn govern the application of these materials in industrial practice. as metals, polymers, ceramics, or composites) can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behaviour or wear resistance. These properties in turn govern the application of these materials in industrial practice. A microstructure's influence on the mechanical and physical properties of a material is primarily governed by the different defects present or absent of the structure. These defects can take many forms, but the primary ones are the pores. Even if those pores play a very important role in the definition of the characteristics of a material, so does its composition. In fact, for many materials, different phases can exist at the same time. These phases have different properties and if managed correctly, can prevent the fracture of the material. The experimental setup used for microstructure analysis is Equipment / Make : Meta scope, Etchant used : Keller's Reagent, Test method : ASTM E407 & ASM Metallic Handbook Volume –IX, Magnification : 100X. Figure 4 represents the microstructure of 8 samples casted. The observations says that the microstructure images of Al 7(075+178) consist of fine dendritic structure with precipitation of Zn and Mg in higher phase and the presence of other inter metallic compounds. Sample S8 microstructure shows a clear coarse dendritic structure with higher tensile in nature which may be preferable for industrial applications.

5. Results & Conclusions

The highest tensile strength of Al 7(075+178) can be observed for the sample 8 i.e., Tensile Strength of 225.36 MPa which has the following composition of elements: Zn – 7.3 %, Mg – 2.1 %, Cr – 0.18 %, Cu – 2.4 %, Si – 0.4 % , Fe – 0.5 %, Ti – 0.2 % , Mn – 0.3 %. While comparing with the Tensile Strength of Al 7075 and Al 7178; the casted hybrid metal matrix i.e., Al 7(075+178) has more tensile strength. It can be observed that Aluminium metal matrix composites i.e., Al 7(075+178) can be successfully fabricated by Die casting. The tensile test provides various applications and determines the various mechanical characteristics such as yield strength, tensile strength, with different category of ductile and brittle materials. Appreciable improvements in mechanical properties were observed in the prepared Hybrid Al 7(075+178) compared with the base materials i.e., Al 7075 & Al 7178. The purpose of development of aluminium material as of composites with the help of different

reinforcements leads to huge amount of application in different sectors like automobile, defence, military, and general engineering applications.

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