COMPARATIVE STUDY OF MECHANICAL PROPERTIES OF ALUMINUM ALLOY A356 (AL-12SI) FABRICATED BY DIRECTED ENERGY DEPOSITION METHOD AND PRESSURE DIE CASTING

Ragavanantham Shanmugam[a], Jishu Chandran[b], Mohanavel Vinayagam[c], OsamaFakron[d]

Seth Dennison[e], Seth Romine[f]

[a,d,e,f] School of Engineering, Mathematics and Technology, Navajo Technical University, NM-87312, USA

[b] Department of Mechanical Engineering, Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology, Chennai, India

[c]Department of Mechanical Engineering, Bharath Institute of Highere Education & Research, Selayur, India

Abstract:-

Additive Manufacturing technology is rapidly gaining traction in many manufacturing applications due to its process parameters control and wide range of applications. There are other AM technologies accessible, however Direct energy deposition (DED) is a critical approach in metal matrix additive manufacturing. The significant two mechanical properties tensile strength and hardness of additively created Al-12Si Aluminum alloy by DED process and pressure die casted Al-12Si components are compared in this study. The strength and modulus of the DED and PDC manufactured components were identical if the load direction in the UTM machine was the same as the construction directions, however other mechanical parameters differed slightly. Mechanical qualities of fabricated products made from reused powders were also comparable to those made from unused powder.

Keywords: Direct energy deposition (DED), AlSi12 alloy, Pressure die casting, ultimate tensile strength, hardness, building directions

1. INTRODUCTION

Additive manufacturing (AM) technology provides significant advantages over traditional production procedures against components such as casting moulds, punches, and dies. This method uses a computer-generated 3D model and prepares the data for printing the specified object. Unlike traditional manufacturing procedures, complex pieces with acceptable accuracy can be manufactured in one step, considerably reducing the number of parts assembled in a single product [1]. Furthermore, bespoke products can be created without sacrificing inventory spare or production lead time. Because of its various advantages over previous manufacturing techniques, AM is regarded as a unique method for developing and producing customised components for the space bus, automotive, and biomedical industries [2-3]. Previously, the fuel injector nozzle was assembled from numerous pieces in the aircraft industry. In addition introduction of AM technology, it is now possible to create a lightweight designed nozzle at a substantially lower cost. It is simple to create patient-friendly equipments utilising AM processes by using patient medical photos, and AM processes may also produce high-performance biocompatibility devices. Burner tips that mix and swirl in complicated forms composed of high-temperature materials to save cost, fuel, Prototyping, quick fabrication, and service of industrial equipment such as punches, dies, bespoke tooling, and so on, are made more accessible in the automotive industry [4-6]. Significant advancements in the underlying concepts of AM metal processing, software and hardware, and feedstock technology have allowed AM to become a cutting-edge technology over the previous two decades. It has now achieved an acceptable level as a result of strong development in commercial system sales. Initially developed in research facilities, AM technology is now being illustrated and accepted by industry [7].

Mechanical anisotropy and internal stress are two areas where AM and traditionally produced components differ. Unique faults to the AM process must also be carefully communicated in aerospace fields where components such as fuel injector nozzles, etc., are subjected to more fatigue [8]. other components, such as turbine blades, are still in the early stages of development. Powder metallurgy, beam welding, and prototyping are the fundamental concepts for developing additive alloy production. Nonetheless, available knowledge from these methodologies does not demonstrate many important aspects of additive manufacturing. A rather mature expertise in welding and powder metallurgy has been created through many decades of research effort. This has paved the way for future study and development in metal alloy additive fabrication [9]. Still, it appears to be a lengthy and complicated path.Aside from that, AM technology offers some distinct advantages that are propelling this sector forward, notably in metallic materials.

Aluminium is widely used in die-casting, although it is prone to breaking or shrinking at high temperatures, thus it is frequently alloyed with copper or silicon. The addition of these elements to aluminium increases its hardness and fluidity. Aluminium is used to make components with thin walls and complex shapes because of its great dimensional stability. Aluminium's corrosion resistance makes it useful in components that are subjected to thermal or electrical energy exposure [10]. The compositions of AlSi10Mg and AlSi12 are close to the eutectic points, which have a lower melting point and a narrower solidification temperature range. As a result, general alloys have good casting characteristics and lower shrinkage porosity, making them better for DED processing. The maximum alloys SLM research is focused on processing [11]. The alloy, on the other hand, has recently gotten a lot of interest reason it's a near-eutectic alloy with good castability and strength [12]. Heat treatment of DED-processed AlSi12 specimens was thoroughly investigated. Heat treatment has been discovered to modify the microstructure and effect mechanical characteristics [13]. Furthermore, it have found the protective gas employed during the DED process has no effect on the AlSi12 densification behavior. They do, however, have a minor impact on ductility. The cast alloy was compared to AlSi12 specimens generated by DED (as-fabricated and heat-treated) in terms of tribological and corrosion behaviour. The effect of cooling rate on microstructure and characteristics has been determined [14]. The table.1 shows AlSi12 alloy composistions

Chemical composition, wt. %									
Si	Fe	Mn	Zn	Cu	Mg	Ti	Pb	Ni	Al
11.2	0.45	0.42	0.12	0.10	0.10	0.10	0.10	0.08	bal

Table 1. chemical composition of raw AlSi12 alloy

2. AM PROCESSES

The AM technique is also called as 3D printing, There are many different types of additive manufacturing (AM) procedures, each with its own way of layer manufacturing, material, and machine technology. The ASTM developed standards that divide Additive Manufacturing into seven distinct categories.

A brief summary of each technique is provided. Using UV laser light, vat polymerization is used to create a product or model from a pool of liquid polymer. UV light is utilized to make solid the polymer liquid at a specific area based on computer-generated design data. Once each layer of the thing being made has formed, the platform lowers it. The support structure must be introduced throughout the product's construction; after the product is finished, the support structure must be removed in order to obtain the final product.

Powder and a binder are the main components of binder jetting. The binder acts as a glue to hold the powder layers together. Liquid binder and powdered building material are both common. Construction and binding materials are deposited in layers as the print head translates horizontally along the x and y axes. The object is deposited onto its building platform after each layer. Because of the binding technique, the material properties are manufactured suitable for structural components. No matter how fast the printing process is, further post-processing might take a significant amount of time. In the same way as previous powder-based manufacturing methods, the printed object is self-supported inside the powder bed and removed from the unbound powder after finishing. In the material extrusion process material is pushed through a nozzle where it is heated, and then deposited layer by layer. The nozzle and platform may move horizontally and vertically after each layer is deposited. Many low-cost, home-based 3D printers uses this technology.

There are additional additive manufacturing methods namely ultrasonic additive manufacturing and laminated object manufacturing. Metal sheets and ribbons are used in ultrasonic additive manufacturing but laminated object manufacturing make use of cross hatching technique for smooth removal of printed parts after the process. The printing parts made by laminated objects manufacturing are not structurly sound however they often used for visual modelling. In ultrasonic additivie manufacturing commonly used materials are Aluminium, copper, stainless steel, and titanium, after printing the parts CNC machining required for removing unbound metal, which is commonly done during the welding process. PBF processes employ a laser or an electron beam to melt and fuse the powder. Although electron beam melting (EBM) needs a vacuum, it may be used to create useful components out of metals and alloys. In all PBF methods, the powder material is disseminated across the previous layers. This may be done using a number of tools, such as a roller or a blade. A hopper or reservoir underneath or to the side of the bed supplies fresh material.

3. EXPERIMENTAL PROCEDURE

In this present study laser engineering net shaping method was used to manufacture three dimensional specimens. Samples are fabricated by using LENS™, Optomec Inc, the model of the specimen is designed by using solid works software, then the model is converted into STL file before feed into system. Various parameters used to manufacture the specimens are indicated in Table 2. AlSi12 alloy powder was prepared by gas atomization process wherein diameter of powder particles is kept in the range between 5μm to 15μm. By using LENS various samples are prepared for doing mechanical test, a Universal testing machine [model 150ST, Transverse speed: .05 to 500 mm/min] with a maximum capacity of 150 kN is used. Rockwell hardness tester is used to find out hardness with B scale used to check it out. Al-9Si and Al-12Si two basic alloy groups used in high pressure die casting. Only a very tiny fraction of the whole market is made up of other alloys. A force is imparted to the dies in use in pressure die casting. Based on the specimen, the temperature of the dies is kept between 120°C and 280°C. An alloy metal shot sleeve is filled with 600–750°C alloy metal. The plunger pressurises the molten metal, which then goes forward and into the die. As the molten metal travels through the die's runners, it passes through a tiny channel known as a "gate" before entering the casting's hollow. In aluminium die casting, high pressures of 30–150 MPa are used, as well as the molten metal is reduced in the die to the point where it freezes. After that, the ejector pins are used to extract the cast item from the dies. To cool and lubricate the dies, the water/oil emulsion is subsequently applied. Afterward, the dies are reunited and the procedure is performed once again [16-18].

4. RESULT AND DISCUSSION

4.1. Tensile properties

Tensile test was performed aluminium alloy specimen manufactured by direct energy deposition and pressure die casting based on ASTM E8M standard. Three samples are taken for test, below table and graph indicate mean variation in three mechanical properties of ultimate tensile strength, percentage of elongation, yield strength. The result variation shows that additively manufactured AlSi12 alloy have commendable mechanical properties over PDC manufactured aluminium alloy specimen.This superiority in mechanical strength is due to fine silicon particles uniformaly distributed over the each layers in direct energy deposition process.Fractured specimen exihibit finely dispersed particle as ductile behavior prevails.

Sr. no.	specimen	Strength (MPa)	% Elongation	Yield Strength (MPa)
1	AM- DED	420.19	4.21	315.20
2	PDC	165.08	1.10	132.35

Table 2. Variations of mechanical properties

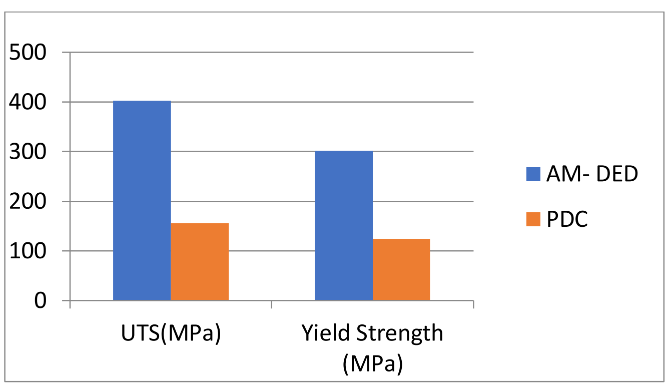

Fig 1. Comparison of UTS and yield strength of two specimen

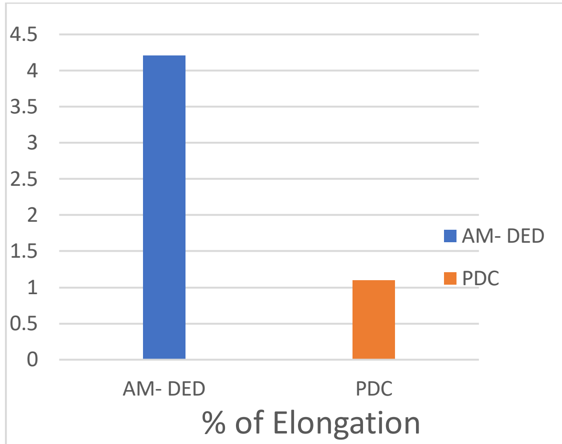

Fig 2. Comparison of % of elongation of two specimen

4.2 Hardness test

In most of the mechanical properties, hardness is well known and basic . In this experiment hardness is checked on rockwell hardness tsting machine. To test three separate areas of the top surface, both specimens are made using two completely different methods. Table 3 shows the average hardness value. The hardness value was determined using the B scale. A steel ball indenter with a resolution of 1/1600 was employed with a 150 kg main load. Due to the tiny grain microstructure created during the Permit and the quick powder solidification, the DED samples have a greater hardness than cast alloy, as shown by the results of the Hardness Test. The hardness (RB61) of the AM sample is much higher than that of the pressure die cast sample (RB19). Using these findings, it may be concluded that additively created specimens have the correct particle dispersion. As predicted, the hardness values match the strength results.

Sr. no.	Sample	Hardness (RB)
1	AM- DED	61
2	PDC	19

Table 3. Variations of mechanical properties

5. CONCLUSION

Specimens manufactured by direct energy deposition and pressure die casting were investigated under various mechanical tests. The specimens shows high level of variations in mechanical properties such as tensile strength, percentage of elongation and hardness. AM samples performed betted by all metrics: higher yield strength, higher ultimate tensile strength, more elongation at rupture, and higher hardness. Pressure die casting specimen, bonding between the particles are much lower than additively manufactured specimen. AM-DED specimen shows significantly improved mechanical properties due to inter layer bonding which results in better tensile strength, also fine grain structure, grain size and better cooling rate. In addition to residual stress, metallurgical flaws such as pores, fractures and surface roughness is a greater problem in additive manufacturing components. However, the underlying mechanisms for the creation of these abnormalities remain a mystery.

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