المجلة الإلكترونية الشاملة متعددة التخصصات
العدد الواحد والخمسون شهر (٩) ٢٠٢٢

Effects of aluminum casting process indicators on the mechanical properties of metal mold castings and a study of the variables that affect the weld joints of aluminum alloys

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Abstract

Aluminum alloys with various properties are used in engineering structures. Alloy systems are classified by the number system (ANSI) or by names that refer to the major alloying components (DIN and ISO). Choosing the right alloy for a particular application entails considerations of tensile strength, density, ductility, formability, workability, weldability, and corrosion resistance, to name a few. Aluminum ingots are considered the most important and the first ingots being strengthened at the present time due to their economic status and for the purpose of increasing efficiency and use area in various industrial applications and to achieve stability in properties. And because the design of metal plumbing molds remains a trial-and-error process in the design, where the element of human error is high, especially in the decision-making stages, and therefore the aim of this research is to investigate the effects of aluminum casting process indicators on the mechanical properties of metal molds and study the variables that effect On welding joints for aluminum alloy. Previous studies showed that aluminum alloys usually have high strength and elastic nature, a combination of good corrosion resistance and excellent corrosion resistance that aluminum alloys possess. The permanent welding and annealing of the aluminum alloy was carried out by welding process; in the normal welding process, the incorporation of aluminum alloys is a challenge.

Keywords: *Aluminum, casting process, weld joints, aluminum alloys*

1. Introduction

Currently, the demand for reinforced aluminum alloys has increased due to its effectiveness and distinctive properties that are compatible with the great industrial progress. Aluminum is a non-ferrous material, and it is widely used in engineering due to its good corrosion resistance properties and is lighter than ferrous metals. Many aluminum components are produced by casting technology. It is a Hypoeutectic Al-Si foundry commonly used in engine blocks, and most of this component is produced by the gravity casting method (Timelli, 2016). Other methods such as pressure casting are one of the many casting methods used to make aluminum molds. This process is done by changing pressure and temperature in order to obtain better mechanical properties and less porosity. The mechanical properties are usually affected by the type of mold in the casting process, as a metal mold, the ductility is higher than that of sand molding (Mae, 2008). Some types of sand such as chromite, quart and alumina are used in casting processes, among which chromite sand has the fastest cooling rate, so that good mechanical structure and fine structure of A356 cast aluminum alloy are obtained (Sun, 2012). The mechanical properties of A356 aluminum are influenced by the pattern types, and it is a consumable pattern housing that has better tensile strength, elongation and toughness than lost foam casting (Wenming, 2012). Moreover, the high pressure in the casting process reduced the porosity of the A356 alloy cylinder blocks. The mechanical properties of AlSi9Mg increased with increasing pressure in the semi-solid casting process (Dao, 2012). Compression casting is a more advantageous process for producing aluminum ingots than others. This process has superior mechanical properties with reduced porosity and purification of iron-rich and alpha (Al) mineral dendrites with different iron contents of Al5Cu0.6Mn-xFe than gravity die casting (Lin, 2014); (Suprianto, Tugiman, Tito Hadiguna, & Taher, 2016).

The use of cast aluminum alloys in automotive structural applications is rapidly increasing due to the need to reduce weight (Timelli, 2016). The service life of a cast aluminum component is determined by the size, shape, and distribution of microstructural features throughout the casting, particularly in those areas that are subjected to severe stresses. Grain size, secondary dendrite arm spacing (SDAS), phase distribution, presence of secondary phases or intermetallic compounds, morphology of silicon particles (size, shape and distribution) and finally, defects (i.e. porosity) play a major role in the behavior of aluminum alloys under static and dynamic loads. Essentially, finer microstructure features (low SDAS values) lead to better mechanical properties. Although SDAS is not only a factor affecting the mechanical properties of Al-Si alloys, in recent years researchers have paid special attention to this structural feature (Pavlovic-Krstic, 2010).

2. Literature review

2.1 Aluminum alloys

Aluminum and aluminum alloy castings have dominated the automotive sector for decades (Mallick, 2010). Almost two thirds of aluminum castings are used in the automotive industries and continue to grow at the expense of iron castings. Although aluminum castings are much more expensive than iron castings, there are continuing market demands to reduce vehicle weight and increase fuel efficiency. It is this requirement that drives the replacement of iron parts with aluminum. LM25 is a common purpose aluminum alloy used in the food, chemical, marine, electrical, many other industries and above all in the automotive industry for the manufacture of cylinder blocks, heads and other engine and body castings (Suresh, 2013). Its potential uses are increased due to its availability in four heat treatment conditions in both sand and cold castings. It is suitable for fairly thin castings as well, and the production of castings in this alloy does not cause any problems due to hot rupture (Kabir, 2014).

It has good wear resistance, high strength and also provides good machinability. It is necessary to have knowledge about the phenomenon of hardening and its effect on mechanical properties during the design of die-cast auto parts (Zeren, 2006). Hardening of cast aluminum alloys begins with the separation of the initial alpha phase from the liquid. When the temperature decreases after nucleation, the initial phase grows as solid crystals that have a dendritic shape. It is well known that different cooling rates during solidification can lead to variation in the quantity and different morphological properties of the cast structures, which in turn can lead to different mechanical properties. Fine microstructured castings show better tensile and stress properties, especially for aluminum cast alloys. Studies on the effect of SDAS on tensile properties indicate that tensile strength and ductility decrease with increasing value of SDAS (Kabir, 2014). Because of the apparent importance of SDAS, many auto companies have included SDAS values in the engineering data of their aluminum castings. Increasing strict control over SDAS enables the production of castings with improved properties (Pavlović-Krstić, 2009).

2.2 Casting processes

Casting is considered a prehistoric process, but is thought to have been preceded by wrought metal, because the temperatures required to achieve molten metal are much higher than those required for agglomeration processes. Therefore, shape casting is a process by which metal is transformed from an alloy into another form that has an added value and is very close to the final shape of the object requested by the designer. Therefore shape castings can be used without any finishing or can be machined completely, which makes internal and surface integration very important. Moreover, shape casting is essentially a batch process, although modern engineering techniques are applied to many processes to automate these processes. Therefore, this is in direct contrast to the continuous casting of steel or the so-called continuous casting of aluminum and its alloys that was developed in the twentieth century. Continuous cast aluminum (DC cast) is actually a semi-continuous process. The largest ingots produced to date are “jumbo” plates 2,700 mm x 610 mm (Grealy, 2001)and round bars 1,050 mm (42 in) x 7 m in diameter with a weight of 20 tons. In both continuous processes, the end product is the raw material for some other forming process, such as rolling, forming or extrusion. Consequently simulation and modeling of casting processes is a technology that has been developed during the past five decades in order to give casting engineers a tool to control the quality of the final products they make (Benedyk, 2017).

Significant progress has been made in the past years in the field of hardening and casting, and this development has been well documented in 15 Advanced Casting, Welding Modeling Procedures and Conferences

Advanced Hardening (MCWASP) since (Cockcroft & Maijer, 2009). Furthermore, as computer and processor power increases, many aspects of physics, and associated phenomena including surface free flow, heat and fluid flow, and thermal pressure, are modeled (Olofsson, 2020). Nevertheless, implementing these computed results in real casting process windows and performance expectations is one of the major remaining challenges to make the molding process truly successful and become a useful tool for manufacturing companies (Yasuda, 2015). Currently a large part of the current modeling applications are used to prevent casting defects, for example the occurrence of porosity, thermal cracks and aggregate separation (Mark & Laurens, 2021).

The stress accumulation during casting, heat and fluid flow, and the solidification process were formulated to study the effect of all casting agents, thus arriving at several recommendations for improving casting practice (Smith & Jolly, 2007).

2.3 Aluminum casting process and mechanical properties

There are few studies on the effect of tool displacement, tilt angle and dive depth in the FSW process. Kumar et al. (2020) studied the effect of tilt angle on the mechanical properties of the FSW of AISI 316L. Three grades named 0, 1.5 and 3 were selected and it was found that at a score of 1.5, the highest value of UTS could be obtained. Moreover the angle of inclination affects the stirring area, the maximum temperature, and the shear layer under the tool shoulder. On the other hand, Rajendran et al. (2019) studied the effects of tilt angle on joint strength and stiffness in FSW of aluminum alloy AA2024 and realized that at 1 to 3 degrees a flawless joint is achieved. Also Zheng et al. (2017) studied the effects of dive depth on the mechanical properties and microstructure of FSW of dissimilar 2A70 aluminum alloy and Inconel 6000 nickel alloy. The range from 0 to 0.5 mm was chosen for the dive depth. It was found that immersion depth strongly influences joint strength. Ramachandran et al. (2015) found that tool displacement has a significant effect on the fine structures and mechanical properties of HSLA steel and AA5052-H13 aluminum alloy junction. Naghibi et al. (2016) studied the effect of tool displacement on the UTS of AISI 304 and AA5052 contrasting FSW joints. Based on the results, the maximum UTS occurs at 2 mm of offset.

In another work, Kar et al. (2019) examined the effect of tool compensation on material flow in FSW for aluminum and titanium and found that by increasing tool displacement, material flow increased. In addition, Tamjidi et al. (2017), by studying the effect of travel speed, rotation speed and tool displacement, the FSW process was optimized for AA6061 and AA7075 aluminum alloys. They found that by compensating with the AA7075, the mechanical properties are improved. In another work, Savin et al. (2016) studied the effect of parameters on FSW of AA6061-T6 has been studied statistically. They found that pin shape, rotational speed, travel speed, and tilt angle had the largest effects on UTS and joint stiffness, respectively.

Furthermore, Periyasami et al. [24] also studied the effect of parameters on the FSW of aluminum alloy AA6061 and AA7075-T651. Based on the results, it is observed that the pin diameter, tool displacement, and tilt angle have the largest effects on the UTS of the joint, respectively.

On the other hand Dirazkola et al. (2019) studied the effect of rotational speed, travel speed, dive depth and angle of inclination on the UTS of heterogeneous FSW of AA5754 and Polymethyl methacrylate (PMMA) and found the optimal values for the mentioned parameters. Said papers used single factor tests, which mean keeping one variable and keeping the other constant. Due to the high costs and time consuming of beta testing, the researchers decided to use artificial intelligence (AI) to reduce the risk of co-production with voids and wasted money. For this reason, they used different approaches in relation to artificial intelligence (Kumar, 2019). In the first step, FSW process parameter optimization is used for similar joints, and at the same time, it is used for dissimilar joints.

Couplings are various aluminum alloy joints widely used in the automotive industries.. On the other hand, CCD and ANOVA are commonly used to improve parameters of the FSW process. It can be concluded that all research outputs found the highest final tensile strength after FSW for dissimilar aluminum junctions (Ghiasvand, 2022).

Before begin to test the mechanical properties of castings, it should be noted that the final casting quality check is only the last inspection point to prevent unqualified castings from leaving the factory. The key to ensuring the quality of castings lies in enhancing the quality awareness of all employees within the enterprise, strengthening quality control and management over the entire production process of castings, stabilizing the production process, organizing civilized production, adopting as advanced production technology and equipment as possible, equipped with sufficient effective inspection methods for process quality and quality Final casting (Timelli, 2016).

Conventional mechanical performance testing Conventional mechanical performance testing is performed at room temperature. Test items typically include tensile strength, yield strength, elongation after fracture, area reduction, deflection, shock absorption (or impact toughness) and hardness. Tensile strength, yield strength, elongation after fracture and area reduction are measured on a tensile testing machine; Shock absorption or shock hardness is measured on an impact testing machine; Bending and bending resistance is measured by transverse bending test methods; Hardness is measured by types of hardness testers (Mark & Laurens, 2021).

1. **Tensile test**

Tensile samples of gray cast iron are manufactured by single-cast cylindrical test rods or connected die-cast test rods. The diameter of the single casting test rod is 30 mm, and it is poured in the same batch as the casting in the vertical cast dry sand mold. The diameter of the parallel section is 20 mm ± 0.5 mm. When The use of bending strength and deflection as an acceptance condition for the mechanical properties of the casting, bending test can be carried out, the bending sample directly adopts the cast blank test strip with a diameter of 30 mm ± 1 mm.The shape, size and surface quality of tensile test specimens, bending test specimens, cast blank test rods, tensile testing and methods shall conform to Bending test and technical requirements of the test machine, calculation and processing of measurement results with industry standards (Lin, 2014).

Tensile testing methods for metals and other cast alloys (including tensile specimen size measurement, stabilization methods, test rates, performance measurement methods, test results approximation and processing, etc.), types of tensile specimens and their cross-sections.

Shape, gauge, length, size and quality shall meet Surface requirements of GBT228 "Method of tensile testing of metallic materials at room temperature". The specimen is not allowed to have mechanical damage, cracks, large transverse knife marks, obvious deformation and other visible defects. Sticky sand, fins, burrs and other defects and weft adhesions should be removed (Ghiasvand, 2022).

2. Impact test

The impact tester is used to determine the shock absorption energy when the impact sample breaks under secondary shock load. The impact testing machine must meet the requirements of GB/T3808-2002 “Inspection of Pendulum Impact Testing Machines” and should be checked periodically by the national measurement department. The impacting samples are divided into V-shaped impingement samples, U-shaped impact samples, and non-notch impact samples. Gray cast iron adopts cylindrical non-grooved impact samples, which are machined from 30mm diameter die-cast blank test bars. Nominal gauge 420mm x 120mm. Must that the casting method of the blank test strip, the technical requirements of the impact sample, the technical standards of the impact testing machine, the test conditions and methods meet the requirements of GB6296-1986 "Impact test method for gray cast iron". As blank castings, or non-bent specimens that have been annealed, machining and heat treated in the same furnace with casting. The shape, size and technical requirements of the specimen are determined by supply and demand. Other cast metals and alloys are p U-shaped impact yens (usually used for metals and alloys cast with large sensitivity of the degree) or V-shaped impact samples are used as the striking sample (Suprianto, Tugiman, Tito Hadiguna, & Taher, 2016).

U- or V-shape impact samples may be taken from single test blocks (rods), molded test blocks (rods) or casting bodies. Sampling location and direction, type, shape, size and casting method of the single casting test block (rod) and the attached casting test block (rod), the connection method and connection location of the attached casting test block (rod) and casting body shall depend on the supply and demand terminals. Corresponding casting standards are selected or agreed upon. For castings that require heat treatment, the attached test block must be cut after heat treatment, and the single cast test die (rod) must be heat treated in the same casting furnace (Ghiasvand, 2022).

3. Hardness test

There are two common methods for determining the hardness of castings: the Brinell hardness (HB) method and the Rockwell hardness (HRC) method. Hard and brittle castings are usually measured by the Rockwell hardness method, and other castings are generally measured by the Brinell hardness method. For cast alloys with a uniform metal structure such as Cast steels, there is a certain conversion relationship between Rockwell hardness, Brinell hardness and tensile strength. Refer to GB/T112-199 "Hardness and strength conversion value of ferrous metals" and GB/T3771-1983 "Conversion value of hardness and strength of copper alloys" (Dao, 2012).

The Brinell hardness method uses a carbide ball set in a certain diameter to press it into the sample surface with the corresponding test force. After the specified holding time, remove the test force, measure the diameter of the indentation on the sample surface, and divide the test force by the test force. The quotient of the spherical surface area is the distance The prefix Brinell hardness value, the symbol is HBW, it is suitable for materials with a Brinell hardness value less than or equal to 650. Instruments, samples, test methods and test results The Brinell hardness tester shall comply with GBT231.1-2002 "Part One of the mineral Brinell hardness:" method Test”. Brinell hardness testing may be performed on tensile specimens, impact specimens, castings or specially cast hardness test blocks. Testing surface shall be smooth, flat, and free from scales and foreign dirt (Ghiasvand, 2022).

Rockwell hardness varies according to the scale used. The most commonly used scales are HRA, HRB and HRC. HRB adopts steel ball indenter with hardness value = 130-c; HRA and HRC adopt diamond cone shape with hardness value = 100-e. The main load of HRA is 490.3 N, the measuring range is 60 ~ 85 HRA; the main load of HRC is 1373 N, and the measurement range is 20 ~ 67 HRC. Instruments, samples, test conditions and test methods used in the Rockwell hardness tester, as well as the processing of test results must comply with GB/T 230.1-2004 “Part I of Mineral Rockwell Hardness: Test Method (A, B, C, D, E, F, G, H, K, N, T Scale).” Specimen selection, test site and technical requirements for the test surface of the Rockwell hardness tester it are the same as those of the Brinell hardness test (Suprianto, Tugiman, Tito Hadiguna, & Taher, 2016).

In addition to Brinell hardness and Rockwell hardness, the hardness of minerals can also be represented by Shore hardness (HS) and Vickers hardness (HV). The measurement of shore hardness of minerals must meet the requirements of GB/T4341-2001 "Method of Testing of Mineral Shore Hardness". The determination of the hardness must meet the requirements of GB/T4341-2001. Metal Vickers with the requirements of GB/T4340.1-1999 "Vickers metal hardness tester part one: test method". Various types of hardness testers should be periodically checked by the national metrology administration in accordance with relevant standards (Lin, 2014).

2.4 Weldability and Optimization of Process Variables for aluminum alloys

In recent trends, aluminum alloys have been widely applied in various business fields, being simple in construction, transportation, and advanced marine and aerospace applications such as wing partitions, etc. Aluminum alloy is usually at the same time as the light; it will be of high strength and flexible nature, the combination of good wear resistance and excellent wear resistance possessed by aluminum alloy. Permanent and annealing welding of aluminum alloy was carried out by welding process; in the normal welding process, the incorporation of aluminum alloys is a challenge (Sathish, 2021).

Currently, aluminum alloys are simply welded using TIG welding to different thicknesses of the sample. In comparison, the TIG welding process produces higher quality weld joints (fewer defects), easier and faster than arc welding. The strength of the micro-grain is improved in the TIG welding process, and it is observed in the mechanical strength analysis. How much higher quality welding is obtained compared to other welding process, it is an added advantage of TIG welding process. Aluminum has a combination of properties that are hard to find in our world: lightweight, very strong, highly malleable and non-reactive. It is the lightest metal on earth, exceptionally bendable and resistant to rust due to the presence of a thin layer of chromium on its surface, and is equally strong. It does not magnetize all types of metals (with the exception of some less magnetic ones), which makes it ineffective as a superb conductor of electricity (Varshney & Kumar, 2021). Friction welding, also because welding generates low heat means residual stresses are kept low. The transverse force in the wench (also known as the transverse or transverse friction force) is used to measure stress (Mehdi & Mishra, 2020).

Dengkui et al. exposed that the mechanical properties of the material change through applications of different geometric shapes. The authors studied and reported that characterization of weld joints such as weld width, depth of penetration and features of the reinforcing process can achieve this. The mechanical properties were changed, and the strength was also obtained. From this study, the values of WZ and PMZ stiffness and weakening of joints and mechanical properties were reduced (Denykui, 2018).

Furthermore, Aravind and Daniel Das suggested that the maximum welding strength was achieved by using process parameters (current, welding speed and welding time) to achieve the optimum tensile strength of 130.27 MPa. The S/N ratio also states that to ensure maximum weld strength (Aravind. & Daniel Das, 2020). In addition, Ramandeep et al. It was revealed that the welding current increased the stiffness of the weld joint. For their study, the properties of welded samples are affected by welding defects such as porosity, which reduces the tensile strength (Ramandeep, 2019). Gurmeet et al. analyzed empirical comparison analysis of TIG welding and the FSW process to understand the metallic properties of the core material and the welded area. Furthermore, their study found the stiffness of a TIG weld joint and compared it to other weld joints (Gurmeet, 2017).

In addition, Ji Kun et al. (2014) TIG welding was performed on aluminum alloy 2219. It demonstrated the enhanced hardness and tensile properties that occur in the post-weld heat treatment process. They also concluded that the highest elongation and impact toughness could be obtained by carrying out post-weld heat treatment. Furthermore, Tamar et al. (2011) reported that the tensile strength of AA7075 welded joints was increased by applying post-weld aging behavior. In AA7075 welded joints, significant impact reduces impact energy.

Adalarasan et al. (2014) stated that 6061 aluminum alloy should be welded by a TIG welding process, optimum process parameters such as 24 V, 180 A, welding speed of 110 mm/min, and gas flow at a rate of 12 L/min. They also evaluated the significant contribution of welding current by ANOVA and considered the baseline controllable parameter. Sethuraman et al. (2018) studied optimization parameters for peak current (130, 150, and 170 amperes), core voltage (20, 25, 30 amperes), and gas pressure (4, 5, 6 kgf/cm2) for TIG welding on the AA6063. The effect of each individual variable was found, which is best suited with the help of

ANOVA and regression analysis. Shanavas et al. (2017) performed an analysis to get the most appropriate parameters such as 180 amperes, welding speed 100 mm/min, and buoyancy of the inert gas 11 L/m. They also concluded that superior tensile strength was obtained over other joints. With the best of research, TIG method weldability studies for aluminum alloy AA8006 have not been reported in the literature. Joints are becoming more susceptible to fatigue, making 2219 aluminum more difficult to weld than originally thought.

Researchers have developed a number of mechanisms to try to deal with these limitations which include AC TIG (Treat Everything Weld), VPT (Validation of Every Parameter), and Plasma solutions to develop VPT (Solve all treatability problems). However, there has been no solution to the instability/inconsistency and welding procedure cycle of the AC technique, to the point that it is no longer a problem. In order to use a variable polarity plasma welder, a successful welding joint must be created. High perforation seams must be used for the job of welding large aluminum sheets, and a large amount of heat is required. Although smaller than normal for AC TIG process, the current used is still high (Mehdi. & Mishra, 2019). For AA6061 and AA7075, comparison of the TIG and FSW residual stresses revealed that the longitudinal residual stress is greater than the transient residual stress in the welded joint (Sun & Gong, 2019). Comparative investigations in terms of heat transfer and residual pressure have not been properly analyzed in the literature. Residual stresses and heat transfer affect the quality of the weld at the beginning and end of the joints. In thin plate welding, in the cases analyzed, it was found that an increase in spindle rotation in stirrup welding increases the tensile strength on the joints initially and decreases after a certain limit (Sathish, 2021).

2.5 Effect of Welding Variables on Aluminum Alloy Weldments

When welds are made in cold-treated or heat-treated aluminum alloys, the welding heat reduces the mechanical properties in a narrow area, known as the heat-affected zone, which surrounds the weld. It is generally accepted that the amount of heat introduced into the metal during the welding process and the rate at which this heat is removed has an effect on the extent of this heat affected area. Input and thermal removal rates also affect weld strength, especially in heat-treated alloy plates if they are not reheated after welding. The aim of the research described in this paper is to study the relationship between the variables that determine the rate of heat input, the output force, and the extent of the heat affected area (Gurmeet, 2017).

The effect of welding variables on the strength of welds and the extent of heat affected area in aluminum alloys have been studied. The following conclusions were made on the basis of this investigation: the effect of welding heat on strength and over the heat-affected zone is a function of the parameters El/Vt, where E and I are the welding voltage and current, respectively, and where V is the speed at which the welding is performed. , and t is the thickness of the material. The relationship between the extent of the heat affected area and the modulus El/Vt is approximately given by Eq 4 and 5 for 6061-T6 and 6063-T6 and by eqs 6 and 7 for non-heat treatable alloys. The span of the heat affected area shall not exceed 1.5 inches from the center line of the weld if recommended procedures are followed (Sathish, 2021).

With the increase in the use of cast aluminum, the requirements for mechanical properties have also increased (El-Sayed, 2015; Youssef and El-Sayed, 2016). Since the mechanical properties of Al castings are greatly influenced by their embedded content, it is important to study these inclusions, their types, causes and adverse effects. One of the most important inclusions is the defect of the double oxide film, which has been reported to have very adverse effects on the reliability and reproducibility of castings (Campbell, 2003).

Raiszadeh and Griffiths (2006) established a methodology for studying the history of oxide films at Al melt. Their results showed that due to the high free energy of forming Al2O3, the oxygen in the air trapped inside the double oxide film defect would be consumed, first to form Al2O3, and then nitrogen reacted to form AIN. These interactions will reduce the size of the trapped air bubble. Also, if the initial hydrogen content of the melt is above the equilibrium associated with the surrounding atmosphere, the hydrogen will diffuse into the trapped air bubble and increase in size (El-Sayed & & Ghazy, 2017). The reaction rates of air trapped within the defect were used to build a quasi-experimental mathematical model to predict the duration of the atmosphere within the defect of a double oxide film. The results indicated that the consumption of oxygen and nitrogen within the defect would take no more than three minutes (Raiszadeh and Griffiths, 2008).

Therefore, due to its unique properties, the use of aluminum alloys in various industrial sectors has grown significantly in the past decades. Their high electrical and thermal conductivity, high flexibility, and high strength-to-weight ratio allowed them to be widely adopted in the aerospace and automotive industries (El-Sayed, 2015). It was found that the mechanical properties of Al castings are affected by the presence of double oxide film (or double membrane) defects which have been reported to not only reduce tensile strength and reduce fatigue of castings but also increase their versatility (Fawzia Hamed Basuny, 2016).

In general, most mechanical and structural components are subject to different ranges of temperature difference in service conditions. Thus, thermal gradients induced in these fractions lead to internal stresses and strains and these thermal cycles originate from the low cycle stress process, which begins with the process of crack nucleation and propagation. An automobile part, such as a cylinder head, is an example of a parts subject to thermal cycles, and thus to the thermomechanical fatigue (TMF) process. In such a component, fatigue fractures occur due to shutdown initiation cycles, which involve temperature changes of up to 300 ° C. Aluminum alloys used for this application exhibit mechanical behavior that includes plasticity at low temperatures and large viscosity at high temperatures. These alloys also undergo an aging process, especially at temperatures above 150 °C, so different stress mechanisms operate during the thermomechanical cycle applied to the material, making understanding the entire fatigue process very complex. Efforts will be made to improve the performance of these materials by controlling the properties of the microstructure, for example, the cooling rate, with the aim of reducing the spacing of secondary and porous dendritic arms (Ratke, 2006).

On the other hand, there are also authors who believe that the positive effect of low SDAS values is intensified at low cycles, while porosity (especially its size) plays a major role at high cycles. The small SDAS also reduces the time required for the homogenization heat treatment because the propagation distances are shorter. Because of the obvious importance of SDAS, more and more auto companies have so far set the limit of SDAS in their engineering specifications, especially for SDAS in the area of the combustion chamber surface which is the most subjected to thermal and mechanical stress in cylinder heads. In general, the required values for SDAS vary from model to model of cylinder heads (BMW, Porsche, VW, Fiat, etc.). In addition, the SDAS value ranges from 20 to 40 µm and is measured at a distance of 3-5 mm from the surface of the combustion chamber. It should be noted that in some cylinder heads more stringent requirements must be met as SDAS at 4 mm from the surface of the combustion chamber must be less than 20 µm (Pavlovic, 2007). In industrial production, it is very difficult to achieve control of the solidification rate (and thus SDAS values), due to the complex casting geometry including the presence of many cavities and also different wall thicknesses (Pavlovic-Krstic, 2010).

3. Conclusion

The mechanical properties of cast aluminum alloys largely depend on the microstructure of the alloy's hardening. The service life of a cast component is determined by the microscopic distribution throughout the casting, especially in those areas that are subjected to severe stresses. In the trend towards the production of lightweight composites, the description and prediction of the microstructure in shape castings has become important. This is because microstructure length scales are required in the mechanical property models used to improve the design.

The use of predictive property models is critical due to the need to replace heavy iron parts with aluminum alloy castings and the limited experience with aluminum alloy castings and their long-term performance. Secondary dendrite arm spacing (SDAS), which is defined as the distance between prominent adjacent secondary arms of the dendrite, has been used in recent years to describe the metallic structure of casting materials. Castings with microstructures show better static and fatigue properties, especially for aluminum cast alloys, and this improvement correlates with a lower SDAS value.

The influence of foundry variables such as mold materials and casting temperature on the microstructure, secondary dendrite arm spacing (SDAS) and mechanical properties of the cast LM25 Al alloys was determined. Metal die castings have refined the microstructure compared to sand die castings due to the increased cooling rate/hardening rate. Hence, the LM25 Al alloy has a good dendrite structure when cast into a metal die and also has better mechanical properties. Using thermodynamic modeling, the presence of the metallic CuAl2 and Al-Cu-Mg-Si phases was confirmed. These phases between the metals are responsible for the better mechanical properties of the LM25 alloy. Metal die castings also have a lower porosity which results in sound casting. This paper clarifies the relationships between mechanical properties and SDAS with casting temperature. It is clear that pouring temperature has a noticeable effect on SDAS and mechanical properties. The higher casting temperature results in the arms of the secondary dendrites being spaced more precisely and as a result the hardness of the alloy increases with a decrease in the elongation%.

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