Journal of Mechanical Engineering Research and Developments
ISSN: 1024-1752
CODEN: JERDFO
Vol. 44, No. 8, pp. 204-217
Published Year 2021

A Review on Properties and Casting Technologies of Aluminum Alloy in The Machinery Manufacturing

Bao Quoc Doan[†], Dinh Tuyen Nguyen[‡,*], Minh Nhat Nguyen[‡†,*], Tri Hieu Le[‡], Thi Minh Hao Dong[‡], Le Hung Duong[‡]

[†] Faculty of Mechanical Technology, Industrial University of Ho Chi Minh City, Ho Chi Minh city, Vietnam
[‡] Institute of Mechanical Engineering, Ho Chi Minh City University of Transport, Ho Chi Minh city, Vietnam
[‡†] Institute of Engineering, Ho Chi Minh City University of Technology (HUTECH), Ho Chi Minh city, Vietnam

*Corresponding author email: nguyendinhtuyen8899@gmail.com; nm.nhat@hutech.edu.vn

ABSTRACT

The technology of manufacturing engineering and metallurgy are fields that cannot be left out of the development trend of the industrial revolution 4.0. Breakthrough technologies in metallurgy and metalworking, respectively, along with history, have marked great strides in metal technology, especially aluminum alloys. With outstanding properties in durability and versatile applicability in green manufacturing and lightweight materials, aluminum alloys have made miraculous leaps in the machine-building industry, especially in automotive and aeronautical engineering. The role of aluminum alloy is more important in the development of advanced metal technologies, especially the emergence of new and high-precision casting technologies. This work aims to focus on evaluating the typical properties of aluminum alloys as a basis for discussion of the casting technologies currently being developed for this lightweight material. The article also gave an overview of the development status and applicability of aluminum alloy casting technologies in the industry that is changing according to the current technological revolution.

KEYWORDS

casting technologies, aluminum alloys, manufacturing engineering, metallurgy.

INTRODUCTION

Non-ferrous metals play an increasingly important role in manufacturing in industrialized and modernized production nowadays. In manufactured applications, only steel is a non-ferrous metal that is popular than aluminum. It's strengthened because of the popularity of aluminum, which in the Earth's crust ranks third in metal ingredients. In fact, aluminum has been gradually replacing the function of steel in production and processing in the aviation and automotive sectors [1]. In particular, aluminum is utilized in the aerospace and automotive fields for replacing steel components. According to the report, it is claimed that 13–20 kg of GHG emissions are avoided for every kilogram of aluminum used which substitutes mild steel, steel, and cast iron [2-4]. It is considered one of the most recycled products thanks to its widespread usage of construction, packing, automotive, aerospace, and the electrical distribution sectors and its relative value. The aluminum sector has undoubtedly expanded together with the aviation and aerospace industries due to the extraordinary strength of the ratio of the weight of aluminum alloys and to their natural resistance to corrosion. However, amazing advancements have also happened in building, packaging, and electronics, as well in everyday home goods, all at the same time. Aluminum and its alloys are widespread, and their existence on the planet has enriched civilization in numerous ways. According to the report released by Aluminium Association, that 90 percent of aluminum used in construction and automotive parts is recycled at the end of its useful life [5]. Furthermore, 75% of all aluminum produced in the past is still in use today [6]. Primary and secondary aluminum are created respectively about 343 kt and 260 kt in the United Kingdom in 2010 [7]. With the latest production of about 40 kt of primary aluminum a year, two in three largest principal aluminum smelters in the UK have ceased to operate [8].

Aluminum can be found in its pure form or as alloys with other chemical components after manufacturing. Electrolysis of aluminum oxide (alumina) temperatures ranging from 950 to 980°C is the way to produce the primary aluminum (the Hall-Héroult process) [9]. Alloys may be created by combining chemical components including copper, zinc, manganese, silicon, magnesium, iron, etc., and it will create primary aluminum with new mechanical properties [10-11]. Following the introduction of the Hall-Heroult electrolytic reduction method, castings became the first significant market for aluminum. In the early years, uses have been restricted to attractions like house numbers, hand mirrors, combs, brushes, tie clasps, hat pins, and ornamental lamps that accentuate the lightweight, silver shape and the new metal's novelty. Cast cookware from aluminum was a welcome choice for iron cast and brass pots, pots, cans, and sludge. Aluminum costs have gradually dropped and major technical applications became financially feasible around the end of the nineteenth century [12]. Due largely to the low density, good casting ability, high special strength, and so on, the usage of casted aluminum alloys has increased in recent years.

Cast aluminum alloy to have significant economic advantages in comparison with wrought aluminum alloys, such as mass manufacturing of components, shorter processing cycle and assembly cost lower. The manufacture of casting components of aluminum, therefore, occupies roughly 60% of the yearly output of aluminum [13,14]. In this work, the enormous variety of applications for which aluminum has competed requires the creation of unique compositions and material conditions to meet specific technical demands. Physical and mechanical characterization and performance test findings provided the basis on which new aluminum alloy innovations and composition control refinements could be continuously improved. The introduction of permanent molds and pressure die casting as a choice to casting sand promoted the development of novel alloys that were not only suitable for applications but also for casting processes. Increased competition and development in the aluminum casting markets have been improved by ongoing technological advancements in the alloy, casting, and recovery technologies.

PROPERTIES OF ALUMINUM ALLOY

The hardness properties of aluminum alloy are affected by alloying elements basing on they can be found in solutions or in the second phase of a reaction. The elastic constant is defined by the essence of the interactive atomic and the potential energy between the atoms when alloying elements are attendant in a solid solution. Young's modulus belongs to solid solution aluminum alloy is defined by the difference in atomic size and electronic structure [15]. Although utilizing composites more and more, Al alloys remain a material of basic importance for structural applications due to their lightweight, flexible, relatively low cost, and colligated improvements have been acquired especially for alloys 2XXX, 7XXX, and Al-Li. As a whole, the 2XXX series alloys are utilized for applications of fatigue critical because they are extremely resistant to damage; when the main requests are sustainabilities, the 7000 series alloy will be mentioned, when the ingredients that need high stiffness and very short density, the Al-Li alloys are recommended [16]. Inside, the main criteria for structural applications is force-resistance, and the type of materials most utilized are Al-Cu alloys (2XXX series) [17]. In comparison to other series of Al alloys, the alloys of the 2XXX series including Mg have: (i) stronger strength due to the deposition of the Al_2Cu and Al_2CuMg phases; (ii) better anti-damage to damage; and (iii) better resistance for cracking fatigue development.

By forming (precipitating) the second phase in the aluminum matrix, which is implemented by phase transition, will help the hardness and strength of some alloy of aluminum can be increased significantly. By suitable heat treatment, this process (called precipitation hardening or age hardening) is solved. (1) the significant solubility (a few percent) of one ingredient in the other, and (2) a solubility limit that drops dramatically as the temperature drops are two prerequisites required for the hardening of the precipitate. Al-Cu phase diagram can be satisfied for both of these conditions, shown in Figure 1 [2]. This type of alloy is prone to solidification cracking and interdendritic shrinkage. For avoiding these conditions, precise casting techniques are required. Excellent regeneration granulation and selective cooling are necessary for permanent mold methods or any other methods. Alloys containing silicon and copper are alloys utilized widely in the number of aluminum casting alloys. Because the quantities of both additions vary so much, copper predominates in certain alloys while silicon predominates in others. Copper enhances strength and machinability, and silicon ameliorates castability and decreases hot short. Higher hypoeutectic silicon concentrations are often better suitable for more complicated castings as well as permanent mold and die casting processes [18].

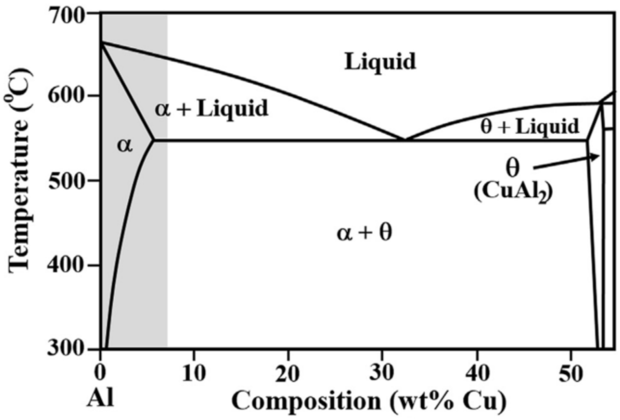

Figure 1. The general Al-Cu phase diagram [19]

For these reasons, the kind of alloys is utilized widely in fuselage manufacturing still 2024-T3. The strength and hardness in the molded and heat-treated conditions are improved significantly by copper. If the alloys accommodate from 4 to 5.5 wt.% Cu, it will react strongly to heat treatment and the casting properties are improved. The impact of atomic Cu in the solid solution of Al on Young's modulus is positive. When Cu is increased, the divalent Al/Cu atomic species rise the modulus of aluminum alloys, according to Amirkhanlou and Ji [20]. Cu may be an effective alloying element in unusual cast aluminum alloys containing Si, Mg, Zn, Zr, Ni, Mn, and Ti in addition to alloys of Al-Cu. By Combining other alloying elements, Cu can create a variety of tertiary phases. Under heat-treated circumstances, Mn in Al-Cu alloys can produce $Al_{20}Cu_3Mn_2$ dispersoids in the microstructure. In the Al-Cu-Mg system, Mg may be in a balanced state with the Al_8Mg_5 binary phase as well as the Al_2CuMg and Al_6CuMg_4 ternary phases [21,22]. By changing the composition accordingly and strictly controlling the impurities can help the improvements achieves effectively.

Adding alloying elements like Sn, In, Cd, and Ag, especially, can help refine the microstructure and therefore improve mechanical characteristics. For example, increasing Sn concentration up to 0.06 wt percent has been improved hardness found by YS, and UTS [23]. Exceptionally low gravity and low thermal expansion are shown by the aluminum silicon. The reconstruction of the eutectic silicon phase in hyper eutectic aluminum-silicon alloys is necessary by adding phosphorus to the molding process and the product performance. Because excellent castability and mechanical properties of aluminum-silicon alloys, it is considered that the common cast aluminum alloys. Silicon can replace aluminum atom 74 in the equilibrium phase diagram of Al-Si alloy 72,73 for creating a-Al(Si) solid solution from 0 to1.65% Si. Low weight, good mechanical characteristics, good castability, weldability, strong heat connectivity, and excellent corrosion resistance are specialties of Al-Si alloys (Figure 2) [24]. The domestic applications, automotive and aerospace fields are all in the presence of Al-Si alloys. The adding of magnesium to aluminum-silicon alloys creates an exceptionally significant and valuable family of compositions that combine great casting qualities with good after-heat properties.

The alloys are still kept excellent corrosion resistance and a low degree of thermal expansion. The deposition of Mg_2Si will reinforce the aluminum matrix by adding magnesium to the alloy of Al-Si. The $AlSi_{10}Mg$ alloy, which generally includes from 0.4 to 0.6 wt percent Mg, is widely utilized in three-dimensional (3D) printing using selective laser melting (SLM) [25,26]. The linked Si lamellar structure often raises Young's module up to the expected mixture model upper limit, whereas the isolated and spheroidized Si particles generated by thermal processing are well represented by the predicted lower limit for Al-Si alloys in mixture modes. Controlling the level of impurities as Fe and Si will increase the mechanical properties. For instance, the 2024-T39 alloy, which is 0.22 wt/percent of Fe+Si, far below 2024 alloy (0.50 wt%) has an ultimate tensile strength (UTS) of 476 MPa, whereas a typical 202024 alloy has an ultimate tensile strength of 428 MPa [20,27-29]. Many of these alloys naturally age, reaching maximum strength within 20 to 30 days after casting at room temperature.

In order to develop the property, solution heat treatment is not a good solution. Microseparation of magnesium-zinc phases reduces hardening due to fast solidifications in these alloys. When natural aging fails to provide enough property development, usual solution heat treatments can be applied. Because Zn is the most soluble metal in Al, to improve the strength, Zn content has increased [30]. The 7XXX series alloys are the strongest alloys of

Al and they are employed in high-stress aeronautical components, for instance, with upper-wing skins, stringers, and stabilizers produced by the alloy 7075 (YS = 510 MPa). When the Zn/Mg and Zn/Cu ratios are approx respectively equal to 3 and 4, the results collected are optimal natures of the sequence 7XXX series [31]. Because of excellent mechanical properties (YS = 504 MPa, elongation = 14%) and greater suffer damage, the alloy 7075 is replaced by alloy 7085 in aerospace applications. When they refine the grain and therefore enhance mechanical characteristics, Zr and Mn may be added up to 1%. Fatigue behavior is another essential topic connected to the specific uses of 7XXX series alloys, and much research has been done on it, taking into account various factors [32,33].

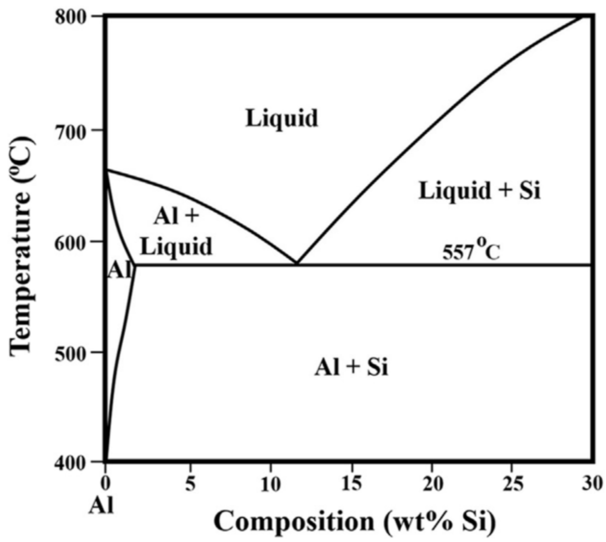

Figure 2. The Al-Si phase diagram [24]

Because Li has a low density (0.54 g/cm^3), it decreases the density of Al alloys (by 3% for every 1% of Li added). Furthermore, the significant increase of the elastic modulus depends heavily on Li the unique alloying element (by 6% for every 1% of added Li). With the lower density and greater specific mechanical natures than the 2XXX and 7XXX series, the Al-Li alloys are considered that the fabulous material for aeronautical applications [34]. When compared to the traditional 2524 and 2014 alloys, using the 2060-T8 Al-Li alloy for fuselage panels and wing upper skin resulted in weight savings of 7% and 14%, respectively. Cu, Mg, Ag, Zr, Sc, Mn, and Zn are the primary extra elements in Al-Li alloys that activate strengthening processes by an association of grain refinement and precipitation [35]. Strong anisotropic mechanical properties due to texture, grain shape, particle size, and precipitation are thought to be caused by Li concentration is more than 1.8% by weight [36]. This was a significant disadvantage in the first ages of Al-Li alloys (GEN1 and GEN2), which also had low hardness and corrosion resistance.

Al-Li alloys were initially developed in the 1920s, and the 2020 alloy (GEN1) was first manufactured in 1958 for the Northrop RA-5C Vigilante's wing skins and empennage. The third generation (GEN3), a family of alloys with an excellent mix of features for aviation applications, was developed considerably later in the 1990s, thanks to a profound knowledge of the connection between the microstructure and mechanical characteristics of materials. Previous generations of Al-Li alloys had a larger Li concentration and lower density than GEN3 alloys, but they suffered from significant anisotropy due to the deposition of coarse Li phases, such as T2 [37,38]. Al-Li alloys have improved significantly in recent years, owing mostly to compositional tailoring and knowledge/control of the deposition concatenation of steady and metastable phases [39]. Cu content is approximately 3 wt percent in the alloy ingredients of considerable importance, Li content is usually below 1.8 wt percent (in most modern alloys it does not passes 1.5 wt percent), Mg content fluctuates across a wide range, and other elements, particularly Ag and Zn, may be added. Specific ingredients have an important influence on the precipitation sequence [40].

For instance, the sustainable δ’ phase is formed by a high Li content [41], while Mg leads to deposition found commonly in Al-Cu-Mg alloys, specifically Guinier–Preston–Bagaryatsky (GPB) zones, S’/S [42]. Despite the increased strength, the appearance of the δ 'phase is typically undesirable since it is susceptible to mow localization, resulting in poor toughness and ductility. Generally, there is currently a dearth of comprehensive research on the influence of extra elements on Young's modulus of Al-Li alloys. However, because the inherent modulus of second phases and the volume fraction of depositions in Al-Li alloys are both low, adding a small amount of Mg, Ag, Zr, Sc, Mn, and Zn components are unlikely to have a negligible influence on modulus improvement. In order to mass-produce and applications in industrial sectors, the ability of these materials to make castings of complex shapes is important. Treatment method, volumetric fraction, size, and distribution of elevated modulus phases are the main factors for improving castability. Compare to the solid solution, the second phase of Al alloys is more effective in stiffness improvement in most cases [43]. Be, Li, Si, Cu, Mn, and Ni are among the most popular components for improving the cast aluminum alloys modulus. However, Al-Li and Al-Be alloys are crisp, costly, and poisonous, and shaped castings with complicated geometry are difficult to produce.

STATE OF THE ART CASTING TECHNOLOGIES

Casting Process Technology

Sand Casting

One of the oldest engineerings for manufacturing metal parts is sand casting. Its capacity to handle high corresponding temperature metals (e.g. titanium and nickel alloys), manufacture of bespoke and complicated components, and production numbers ranging from tiny to large are some of the features that set it apart from other casting processes [44]. Some disadvantages can arise during metal sufficing and condensation like shrinkage, improperly filling, porosity, blowhole, and pinhole, etc besides the advantages [45,46]. The benefit of sand casting is that nearly any metal may be poured into the sand mold, and the size, form, and weight of the item are almost limitless. The most direct way from sample to casting is sand casting. Some limitations related to sand casting such as machining needs for finishing castings, especially large castings with rough surfaces. According to Kaufman and Rooy [47], because of their excellent castability, effective corrosion resistance, and, in particular, the high strength-to-weight ratio in heat-treating conditions, aluminum sand cast alloys have been applied widely for construction elements in the automotive, aerospace, and general technological industries.

There are several 3D printing methods available, each with its own set of advantages and disadvantages. Binder jetting technique for fast casting 3D printing of sand pattern plays a critical role in delivering a better value for the over 5000-year-old casting sector by creating quality and cost-effective sand molds [48]. By accurately regulating process parameters and material producible with gas inside of the printed mold, the mold components may be produced. With the appropriate gas permeability, resistance, and heat absorption properties, a functional mold can be constructed, which provides a high success rate of excellent castings with an optimized weight reduction design. A very limited number of parts in the mold assembly is one of the disadvantages fixed in traditional mold design. The thermal and physical identities of the mold may be changed using a variety of powders, various particle sizes or shapes, and bonding materials, thereby providing opportunities for casting a large range of alloys. Limited investigations were conducted to investigate the link between the properties of the printed mold, the materials, and the machining parameters of processing for the mold. The numerical modeling of a developed part, the optimization of the success rate, and financial and ecological reasons must address these shortfalls. These shortcomings are necessary to solve. Adhesives are commonly utilized in this process such as furan resins, which is a carcinogen and very dangerous, thus, the improvement, development, or finding the new source material is important [49].

Shell Mold Casting

The melted metal will pour into the mold with a crust of resin-bonded sand from 0.4 to 0.8 in. (10 to 20 mm) thick. By introducing chemically rinsed sand into a heated mold to heat the bond, the mold was come from there. The curing depth may be checked to desirable thickness by temperature and cycle control of core mold. Cured mold portions, generally supported by unbonded or green sand are detached and arranged for pouring. Shell mold castings exceed regular sand castings at the marginally greater surface finish and cooled at a slightly higher speed; nevertheless, equipment and manufacturing costs are higher and The size and complexity of the casting which may be manufactured are small [50]. The shell molding process is done through 5 stages, shown in Fig. 3. Sand molding and core printing have both been done by using 3D printing technology, however, they merely replace conventional molding and core-making methods without altering the form or size of the sand mold (core) or its thick structure.

Base on 3D printing techniques, a new blank mold type has been presented in this study. The rib-reinforced variable thickness shell mold is a feature of the new type. This mold design allows for regulated cooling of castings, i.e., varied cooling speeds in various regions, and improved temperature homogeneity following solidification. The residual stress and variation may be reduced, which leads to the casting's performance may be enhanced. A356 aluminum alloy bearing frame will apply for the new type of mold. There is a comparison between 2 types of mold, the new type which is various thickness variable shell molds reinforced with 3D printed ribs and the rest is the conventional dens mold, the castings collected with these two molds are also compared. Experimental findings indicated that the cooling rate for the cast was improved by 30% by the rib-stärked shell mold, tensile by 17%, yield strength by 11%, elongation by 67%, and deformation reduction by 43%, while consumption of sand was significantly lowered by 90% [52,53].

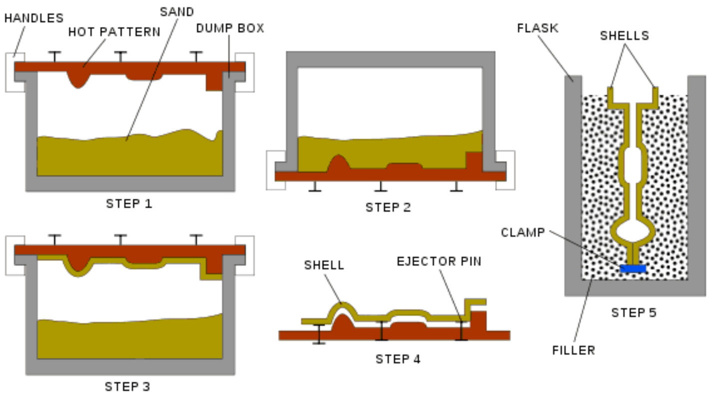

Figure 3. The production process of shell mold casting [51]

Investment Casting

The pottery molds and usable patterns of wax, resin, or other low-temperature molten materials are utilized commonly in investment casting (Figure 4). The ceramic sheath method involves repeatedly immersing and air drying constructed designs in a ceramic slurry until the required shell thickness is achieved. The completed design is dipped in a large enough container for ceramic mud to enclose and solidify around it in the solid mold investment process. In any instance, the mold is autoclaved to remove the pattern before being fired at high temperatures to eliminate all free water and organic elements and processing according to the binding method used. The mold is usually preheated and spilled under partial vacuum conditions [54,55]. Aluminum alloys, bronze alloys, magnesium alloys, cast iron, stainless steel, and tool steel are the most popular alloys that used in investment casting. This process is considered that have beneficial for casting high-melting metals that cannot be cast with plaster or metal. Parts having complicated geometry like turbine blades or handgun ingredients are generally produced through investment casting.

Parts for the automobile, aerospace, ship building and military sectors are also prevalent in elevated temperatures [57,58]. Clear grid shape, significant dimensional exactly and complicated design are salient elements of the investment casting process. Various scholars have undertaken consistent study efforts to explore the realm of investment casting. A review of the literature demonstrated the influence of processing factors on cast specimen output parameters. This article focuses on the advances made and planned at each stage of investment casting and their hybridization with other processes. Furthermore, from 3000 BC, investment casting has been utilized for creating items like weapons, jewelry, idols, and sculptures of gods and goddesses; this paper examines the current uses and developments in medical research using a mix of fast prototyping and gathered investment casting. Advances in sheath molding with fiber and polymer gathering, as well as the creation of alternate feedstock filaments to unify precipitation modeling, all have been discussed thoroughly [59,60].

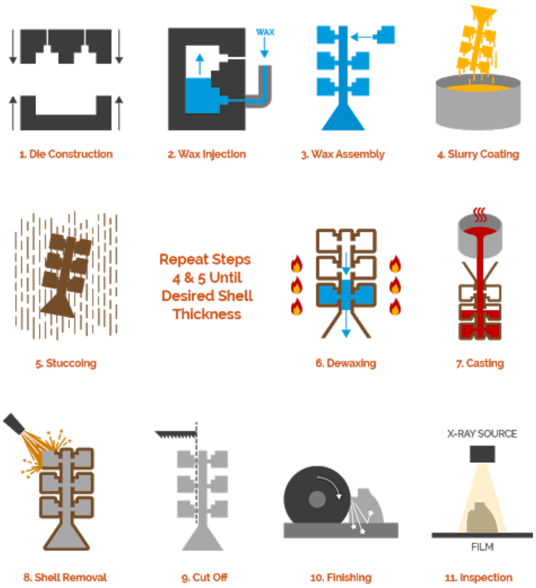

Figure 4. Investment casting process steps [56]

Rapid investment casting, a variation of traditional investment casting, has become a prominent area of research in the disciplines of aerospace, dentistry, and biomedical engineering with the development of new metal additive manufacturing technologies. The additive properties of 3D printing are used by rapid investment casting to pattern making, as a result, more complicated castings are possible than with conventional investment casting. Rapid investment casting is considered as a production process that relatively new additive manufacturing science has combined casting knowledge stored up over 5,000 years. As a consequence, the technique can compete with newer metal AM technologies while also providing outstanding surface quality, fatigue strength, and the capacity to manufacture components from nearly any metal or metal alloy [61,62].

In the process of the investment casting a ring-shaped ZL101 alloy, a survey is proposed base on PROCAST software, which is the alloy phase diagram and the thermophysical natures are analyzed. Besides, the early casting temperature and casting process have been determined. The following are the findings of the analysis of the geometry model and temperature sector model in the process of the casting solidification process: 1) In the early casting process, shrinkage and porosity are created on the two sides and bottom end of casting parts, while slag inclusion is fulled at the top. For avoiding these two types of disability, optimization and simulation are applied in the casting process. Testing has been given consistent results, this indicates the improvement process is reasonable. 3) The better casting process is eventually created, and the simulation reveals that the experiment and simulation results are in excellent agreement, providing actual guidance for the design of other casting samples as well [63-65].

Permanent Mold Casting

The sand mold casting equipment as well as other usable mold processes and depend on production volume is usually cheaper than permanent mold tooling. The degree of process automation is determined by the volume of production. Molds may be operated manually or fully automated. Automated multi mold processes provide high production rates, and components have constant dimensional features and qualities. The rules and mechanics of gravity casting are considered as alike, solid cation ratio higher is recreated by the metallurgical structure of permanent castings. The usable mechanical properties are shorter than the ductility that is included in minimum mechanical characteristics that are normal and particular. Permanent mold castings have better mechanical characteristics than gravity castings, which is one of the reasons for choosing this method over others. The prominent products of permanent mold casting technology are automobile engine pistons, with components as shown in Figure 5.

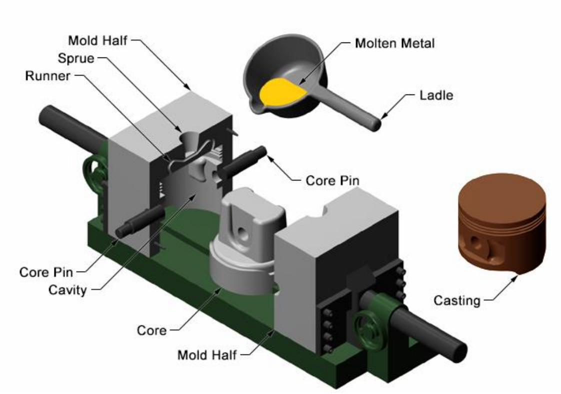

Figure 5. The permanent mold casting process for automotive aluminum alloy piston [66]

The most of available mold process is more alloy tolerant than the permanent mold process. The most common permanent mold alloys, like those from the Al-Si, Al-Si-Mg, and Al-Si-Cu (Mg) groups, have excellent castability. In the casting of hot-short alloys, where the liquidus-solidus range and high-temperature strength combine to enhance the tendency for cracking before and after solidification, mold stiffness is a problem. Even the most challenging foundry alloys, like low-iron aluminum-copper alloys, have been cast successfully, and alloys with restricted castability are frequently cast in permanent molds[67]. Die coating at the casting-mold theme is the most significant single factor influencing heat transmission in permanent mold casting or gravity die casting (GDC) of aluminum alloys, and thus has the largest impact on the rate of solidification and microstructure development. The affection of coating thickness, coating ingredient, and alloy ingredient on the thermal transfer at the casting mold surface are investigated in this research. The research investigates both plumbago and TiO_2-based coatings. Al-7Si-0.3Mg and Al-9Si-3Cu are aluminum alloys that have been studied.

The good type K- thermocouple has been recorded the thermal histories throughout the mold wall [68]. By utilizing an inverse method, mold surface temperature and heat flux density have been calculated from these observations. The infrared thermometer was used to estimate the temperature of the face of the casting, and the heat transfer coefficient (HTC) between the face was calculated by using this information. When the alloy is considered as liquid, the coating material has only a little impact on the heat stream, and the thermal contact resistance appears to be regulated more by the porosity and thickness of the coating. When the thickness of the coating growing up, the HTC will fall. Even so, when the solidification is taking place and the HTC decreasing, HTC of ceramic coating of alike thickness are shorter than the HTC of graphite coating. The coating material effect will disappear immediately after the air gap at the separation face is formed. The values reach a peak of HTC and the heat flux density of Al-9Si-3Cu smaller than that of Al-7Si-0.3Mg. Thus, the solidification time of Al-7Si-0.3Mg less than that of Al-9Si-3Cu, and it grows up with coating thickness [69].

Squeeze Casting

Squeeze casting is a result of the combination between low-pressure casting and high-pressure casting, and completely removing the gas defects associated with HPDC and allowing heat treatment of the casting are advantages of the squeeze casting method. In squeeze casting, to sustain laminar flow, metal is filled in the mold [70]. Once the chamber is full, the melt pressure is risen to above 100 MPa and sustained to provide the casting until it has solidified, compensating for shrinkage. Mold design for squeeze molding is different from mold design, it includes dense gates and a big shot end biscuit for guaranteeing that the gates are not frozen before the casting in the chamber has solidified, and for ensuring providing for shrinkage during solidification [71,72]. It has a cheap operating cost, a low shrinking porosity, a high metal yield, and a good surface finish. Because of the intimate connection between mold and liquid metal, it leads to high-quality castings and higher heat dissipation rates across metal mold boundaries. The diagram demonstrates the squeeze casting process. The method is divided basically into two kinds: indirect and direct methods.

Squeeze pressure is delivered via the die-closing punch, which is a direct process; however, squeeze pressure is applied after the secondary ram closes the mold, which is an indirect process. This is a unique characteristic of squeeze casting over the predicted mold casting method [73-75]. In Figure 6, the diagram has shown the squeeze casting technique. The pressure will be applied until the composite has completely solidified. Utilizing pressure to push liquid metal into microscopic holes in the fibrous preform, this technique provides high wettability of the pattern by the melt. Free of common casting defects such as shrinkage holes and porosity and also minimal reaction between melting metal and reinforcement because of the short residence time at high temperatures are advantages of this technique. Squeeze casting is considered an old method, it is utilized for producing aluminum alloy ingredients without pores and fine grains, if there is a comparison between the squeeze casting and other castings, the squeeze casting has more outstanding characteristics. This casting process has been used to make aluminum alloys like silicon-free alloys, for use in diesel engine pistons. This is very difficult for collecting these alloys by traditional methods [76,77].

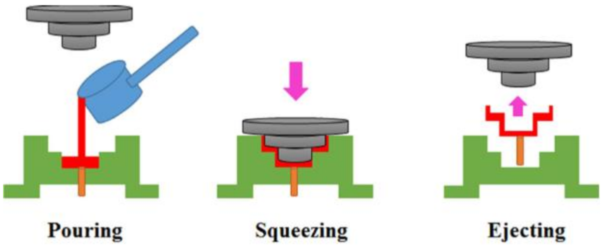

Figure 6. The diagram of the squeeze casting technique [76]

The squeeze casting technology may remove effectively gas and shrinkage porosity, it has been suggested that the complicated ingredients that should be produced of aluminum alloys and aluminum metal–matrix composites [78]. One of the techniques of semisolid metal-forming (SSMF) used widely is the semisolid squeeze casting (SSSC) process, the process combines good filling up the performance of semi-solid metal and the features of squeeze casting technology [79]. It combines the ease of liquid casting with the outstanding mechanical characteristics of solid-state plastic forming to create one of the most intriguing metal processing technologies of the twenty-first century. A semisolid slurry is first inflated into the mold chamber in the SSSC process. After that, under the pressure, rheological filling up, crystallization solidification, rheological feeding, and a small number of plastic deformation are performed. After the SSSC process, a high-strength product with a dense inner layer, precise size, and few macro-and micro defects may be produced [80].

Akbari, Baharvandi, and Shirvanimoghaddam were the first to apply and analyze the technique and composites systematically generated in this way [81,45]. In testing with Saffil δ-alumina-fibre/ aluminium-alloy matrix composites, they registered the ram shift, the temperature at the upper and bottom faces of the preform, and pressure in the melt vs time and found the capitulations for good infiltration without basic deformation of the preform. Comparison of mechanical properties and microstructure, chill casting, sand casting, and squeeze casting are methods for creating Al-8% SiC particles [82]. The size of grain has increased in microstructure by chill and sand casting products, thus, to request engineering and non-engineering applications, cooling and sand casting are utilized in fewer quality parts, although squeeze cast yields may be employed in their as-cast form in industry demands for high-quality components. In traditional casting and forging preparations, ferrous alloys and other metals have been cast successfully by the squeeze casting method. Reciprocating engine pistons, car and truck wheels, brake rotors, and automotive chassis structural components are the productions of squeeze-cast aluminum alloys. Squeeze casting is simple and economic, using materials efficiently and it has great potential for automatic operation at high production speeds [83].

CONCLUSION

This review has revealed many of the essential and typical roles of aluminum alloys in critical applications such as the aerospace, automotive, marine, electrical, packaging, and food industries. The properties of aluminum have been discussed and it has been shown that aluminum alloys can provide many environmental and economic benefits in terms of recycling. To support the applications of aluminum alloys, aluminum alloy ingot processing, and fabrication technologies were born, in which typical casting technologies such as sand casting, shell mold casting, investment casting, permanent mold casting, and squeeze casting. Aluminum alloy is one of the very few metals that can be cast by many methods such as pressure casting, metal dies casting, sand casting, gypsum molding, melt casting, and continuous casting. Some new advanced casting methods, such as fire casting, are also available. In terms of feasibility, a wide variety of aluminum alloys can be cast by different methods, however, based on size and design, a casting method will be selected that is most suitable. Furthermore, quality is an important factor determining the choice of casting method. Finally, the casting engineer tries to promote the advantages, overcome the disadvantages of each method, to meet the complex needs of the market - fast, many, good, cheap.

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