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MIDTERM PROJECT

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Absract

In this research we will talk about definition of semi-solid metal casting, its importance industry,interpretations based on the cost-performance ratio graphic,chararacteristics of semi-solid cast components,microstructural assesment and interpretations based on the radius change of globules depending on sturring and temperature graphics, types of semi-solid metal casting and finally we will make various interpretation and inferences based on the supporting article depending on subtopics(“Purpose, “Theory and Methods” etc..)

1.INTRODUCTION

1.1 Definition and Development of Semi-Solid Metal Casting

In ordinary casting techniques, molten metal is poured into the mold and it is allowed to solidify by standing here. In this casting techniques, unwanted shrinkage, collapses and dendritic microstructures are observed. In order to get rid of these undesirable conditions, researchers conducted researches for a long time. Then, a procedure with a spherical microstructure resulting in much better properties was obtained. In this procedure, shear stresses were applied to transform the dendritic structure into globules, it was observed that these shear stresses bend the dendritic arms and reduced their surface energies and these dendritic arms were broken. The materials produced by this technique have low viscosity as desired. It was brought by sturring with the desired equilibrium state. Aluminum and magnesium alloys produced by this method have superior properties. Also mechanical mixing or electromagnetic sturring can be preferred as sturring method.

1.2 Importance in Industry of Semi-Solid Metal Casting

Despite its many superior features, semi-solid metal casting is not known enough in the industry, which is exactly why manufacturers must have a deep knowledge infrastructure to help buyers benefit from semi-solid metal casting.This infrastructure includes design guidelines, topology optimisation tools, available material data,prototype manufacturing and casting simulations. The points of the casting simulation are to identify potential defects such as gas compression, underfilling and to calculate criteria such as isolated solidification hotspots, part adjustment, filling speed, tool temperature, solidification pressure.

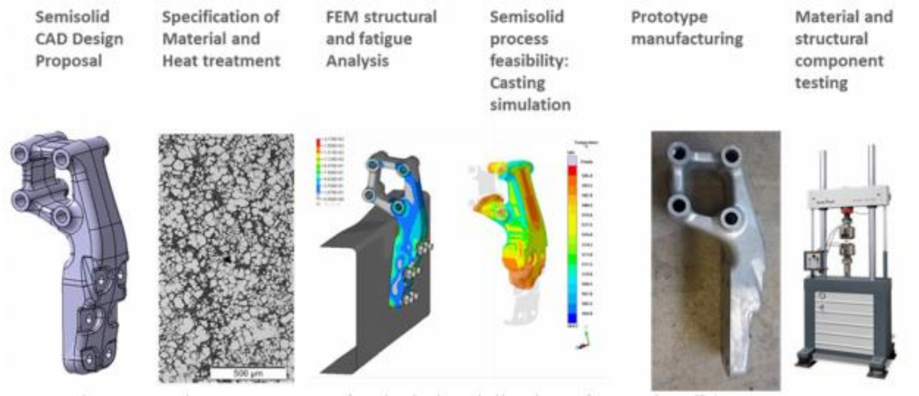
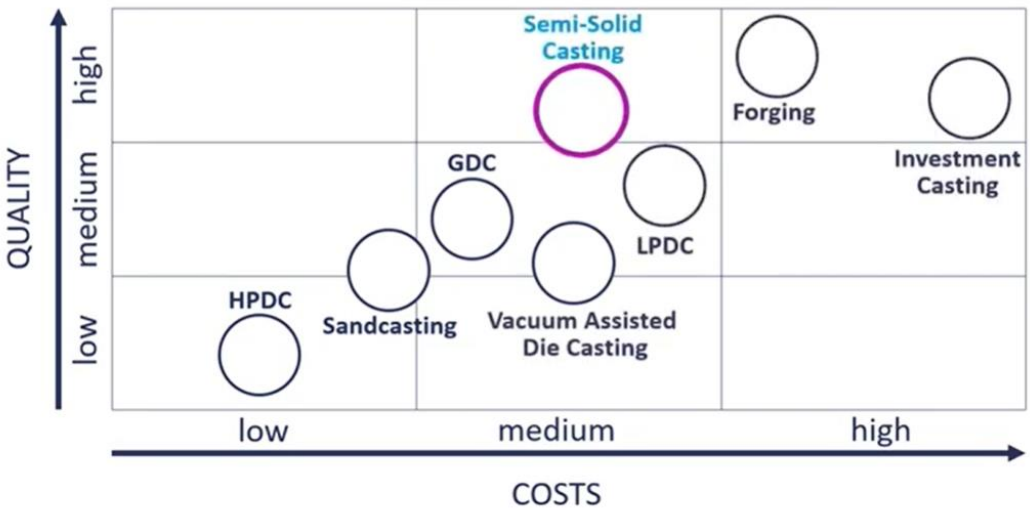


Fig. 1. Development support for the industrialization of a semi-solid cast component

1.3 Interpretations Based on Cost-Performance Graphic

Tab. 1. Price-Quality ratio of semi-solid casting



This table shows us that semi-solid metal casting is very profitable in terms of price performance when compared to other casting techniques. If we look at it from the industrial point of view, which is the previous subtopic, it meets what is desired according to other casting techniques according to the demands of the buyers. If we briefly mention the desired criteria; High production power, lightweight components (especially its use in the construction of vehicle parts reduces CO2 emission and therefore cost).

2. RELEASED TOPIC

2.1 Characteristics of Semi-Solid Metal Cast Components

2.1.1 Superior weldability and pressure tightness: Some of the components shown below are only possible in semi-solid casting. This specifically refers to air pressure vessels that require helium leak tests. No casting type complex-walled thin-walled castings other than semi-solid casting technique can pass pressure tightness and welding pressure tests.The reason is that the casting part which is formed by semi solid metal casting has a laminar filling behaviour that prevents turbulance and gas leakage.

Fig. 2. Components which can product only with semi-solid metal casting suscessfully.(In order of figures;”Air Pressure vessel cap”,”Air pressure vessel with nozzle on top”,”Air pressure compartment end caps”)

2.1.2 Near net shape casting: Using a melt which is containing globular solid particles at semi solid state(slurry), can minimize shrinkage, which provides high dimensional accuracy and small draft angles. Also, this globular granular structure can be achieved without additional cost, such as high surface quality welding joint geometries.

Fig. 3. Components with high dimensinal accuracy.(In order of figures;”Subframe casting node”,”Exhaust brackes I and II”)

2.1.3 Enhanced surface quality: Compared to other casting processes, the smooth surface of the die ensures that the resulting product has a very good surface quality thanks to its high solidification and low gas content. This property is a unique property compared to other casting types.Through to this property can make powder coating and chrome plating. Some of the components shown below were put into semi-solid casting from high pressure die casting. Because the high demands on surface quality could not be met by high pressure die casting. The main reason for this was the gas porosity on the surface with heat entering inside during the coatings.

Fig. 4. Components with enhanced surface quality with semi-solid casting(In order of figures;”Cylinder head cover”,”Cooler top frame”,”Convertible roof hinge cover”)

2.1.4 Increased die life: The thermal shock of the mold decreases while low heat input occurs during filling from the slurry metal used in semi-solid casting. Consequently, the heat of the die is kept under control by reducing the thermal cooling shock while spraying. Higher die life compared to high pressure die casting.

2.1.5 Higher thermal and electrical conductivity: Using a relatively low Si content as a semi-solid casting component reduces the pore amount and ensures that the resulting metal product has high thermal conductivity. By using the advantage of high electrical conductivity, it provides the desired level of quality for parts such as radio filters, electronic or internal cooling systems, engine cooling devices.

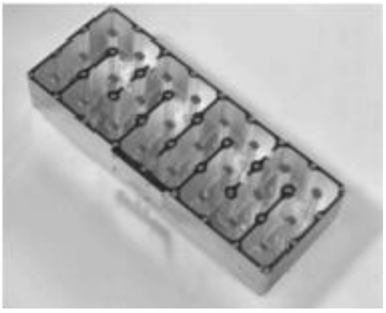


Fig. 5. A “filter housing” with thermal conductivity produced with semi-solid casting.

2.1.6 High productivity: When semi-solid casting is made using high pressure casting machine, the production of thick-walled components can be brought to a higher level thanks to fast solidification, high automation and low production times. Thanks to these properties semi-solid casting; It can easily be preferred to sand casting, gravity casting or low pressure casting.

2.2 Microstructural Assesment

As we mentioned in the introduction section, by mixing the slurry with electromagnetic or mechanical mixers, unwanted dendrites are broken and replaced by spherical structures. So, when the dendrites are replaced by the mentioned spherical formations, the viscosity decreases, zero or low porosity, high strength castings occur in this section. We will interpret this globular’s radius depends to temperature and mixing time.

Table 2. Average globules' diameter vs. temperatures, at constant stirring time, 20 min

Temperature (°C)	570	580	590	600	610
Average globules' diameter (μm)	58.39	35.31	35.15	39.13	52.96
Shaping factor	0.73	0.70	0.69	0.67	0.65

Table 3. Average globules' diameter vs. stirring time at constant temperature, 590 °C

Stirring time (min)	10	15	20	25	30
Average globules' diameter (μm)	48.02	47.23	35.15	36.94	46.54
Shaping factor	0.66	0.67	0.69	0.71	0.73

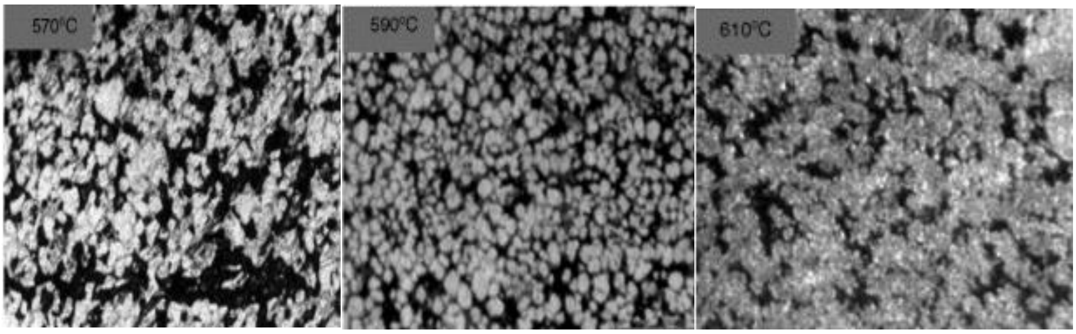


Fig. 6. Optical micrographs at various temperatures in constant stirring time, 20 min

Different microstructures obtained between 570-610 temperatures are shown at a constant mixing time (20 min) in the table. Depending on the tables and figure, a homogeneous dispersion and globular radius range is observed at the temperature of 590 degrees. As the viscosity increase at low temperatures, lumps may occur.As a result, there is a possibility that the mixer may not perform its duty properly. On the other hand, if the temperature rises too much, agglomeration may occur in solid particles.

On the other hand, depending on the temperature, the smallest globule radius value was observed at the mixing time of 20 minutes.When the mixing time exceeds 20 minutes, the globules start to clump again due to the thermomechanical laws and the Coalescence effect.

As a result, the components used in all semi-solid casting processes have an optimum temperature and mixing time. More efficient products can be obtained by observing the microstructures of the components and using a suitable mixing time and temperature accordingly.

2.3 Types of Semi-Solid Casting

There are several types of semi-solid metal casting processes. When metal is poured into aluminum, thixocasting and rheocasting processes can be used. In thixocasting, the starting metal is used as billets without dendritic structures. After these billets are semi-solid by heating, they are poured into the mold cavity and cast. In rheocasting, the semi-solid slurry is injected into the mold cavity as in conventional die casting and casting is obtained.Speaking of the differences, the thixocasting process has advantages such as advanced mechanical properties, near to net shape, good surface quality. However, there are also some disadvantages due to the need for special feedstock materials and special billet needs. The lack of need for billets and using molten metal directly provides a great financial advantage to rheocasting.Two different rheocasting processes have been designed since the development of rheocasting.A process using a cooling slope and a process using low superheating casting. The cooling slope was in the form of slurry when poured into the metal mold in the process used. In the other process, the globular particles were not yet formed and were in the form of crystal seeds. The formation of globular particles will take place during casting and the desired microstructure will be obtained.

3.LITERATURE

Development of a semi-solid metal processing technique for aluminium casting applications, Jessada Wannasin and Sangop Thanabumrungkul, Mar. - Apr. 2008, Songklanakarin J. Sci. Technol., Department of Mining and Materials Engineering, Faculty of Engineering, Prince of Songkla University, Hat Yai, Songkhla, 90112 Thailand.

3.1 Purpose

Although conventional die casting allows the production of high quality parts in the selected article in the introduction section, it allows the mold life to be extended, the cycle time to be reduced and the cost of the produced parts to be reduced thanks to the fact that the casting can operate at lower temperatures when done with semi-solid casting. Despite the emergence, it was aimed to mention the advantages in terms of economics and labor. In the continuation of the introduction part, it purposed to mention the advantages of rheocasting economically by comparing thixocasting and rheocasting, which are 2 types of semi-solid casting processes. Using the different aluminum alloys in the Experiment section, the microstructures of the alloys and their suitability for semi-solid casting were tested based on temperature values.

3.2 Theory and Methods

In the theory part of the article, it has been suggested that the convection formed by the effect of stirring during solidification breaks the dendrite structure.In the experiment section, three different aluminum alloys were left to cool with the injection of argon gas and porous graphite. When the solid fraction at the desired value was obtained, the additions were removed. By using cooling curves and thermal analysis, semi-solid temperatures and eutectic temperatures of alloys are determined. These values and cooling curve will be given in the tables below.

Table 4. Results from the thermal analysis and values used for the Scheil Equation, with TL = liquidus temperature, TE = eutectic temperature, TM = melting point of pure aluminum, and k = partition coefficient.

Alloy	T_L (°C)	T_E (°C)	T_M (°C)	k
A356	612	574	660	0.13
Al-4.4%Cu	646	530	660	0.18
ADC12	-	569	-	-

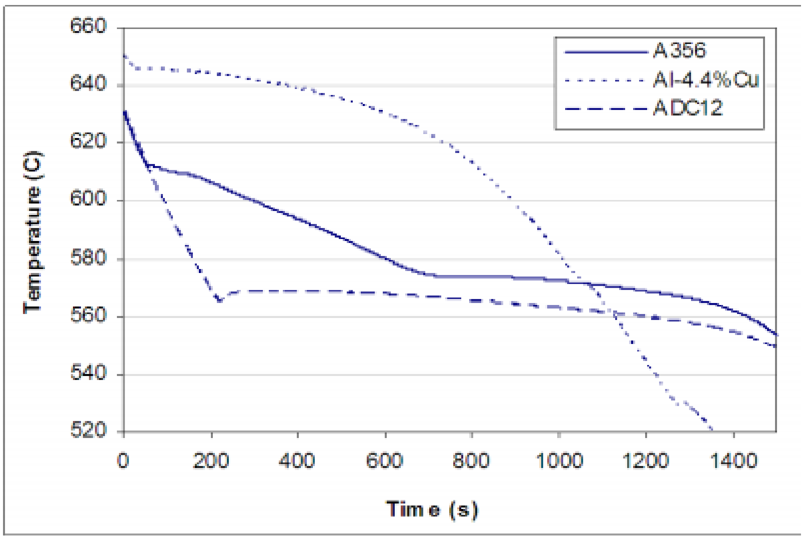


Fig. 7. Cooling curves of the three aluminum alloys used in this study.

In the article, it is said that the solid fraction increases until the eutectic reaction takes place with the decrease of the temperature of A356 and Al-4.4% Cu alloys, it is supported by the solid fraction-temperature curve. However, since ADC12 alloy undergoes eutectic reaction before the globular structures begin to form during solidification, no solid fraction can be found.

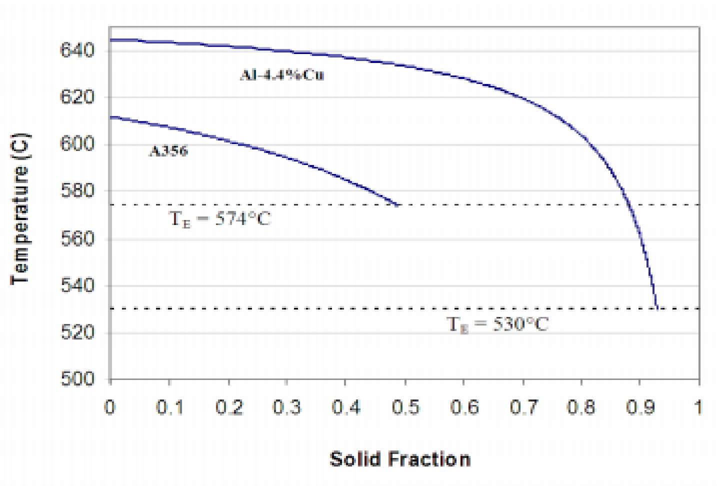


Fig. 8. Solid fraction curves of the A356 and Al-4.4%Cu alloy. Dashed lines indicate the eutectic temperatures.

In other words, different alloys are used in the article, values and curves depending on time and solid fraction during cooling are used as experimental conditions. We will make inferences about this section detaily in the next title.

3.3 Results

In this section,first of all it can be concluded that a casting product with much superior properties will be obtained by preventing the formation of dendrite by the globular structure of the semi-solid metal obtained with the help of mixers and optimum required slurry temperature.

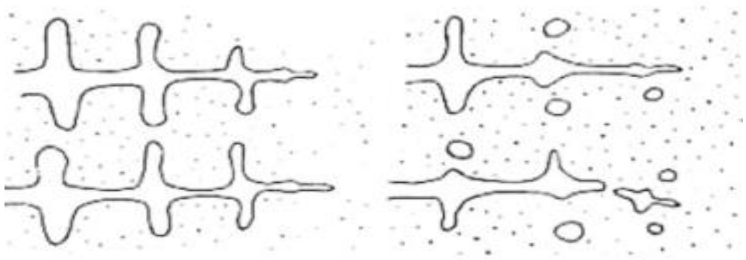


Fig. 9. Schematic of dendrite multiplication

Secondly, based on the cooling graphs of 3 different alloys used in the experimental part of the article based on time and solid fraction, we can say that the A356 and Al-4.4% Cu alloys are suitable for semi-solid casting. ADC12 alloy, on the other hand, cannot be used in semi-solid casting since it reaches the eutectic temperature value without forming globular structures during cooling, because semi-solid casting cannot reach the globular structure required for the production of high quality parts.

Finally, the semi-solid and liquid microstructures of the 3 alloys tested in the supporting article were examined and the desired globular structures were observed in the microstructures when the A356 and Al-4.4% Cu alloys changed from the liquid state to the semi-solid.

However, it is clear from the figures given below that the globular structures are not observed due to the occurrence of the eutectic reaction in the alloy ADC12.

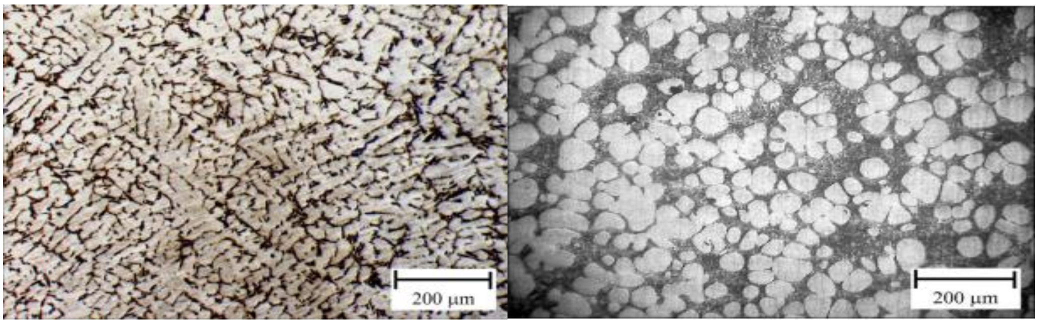


Fig. 10. Microstructure of liquid A356 and semi-solid A356.

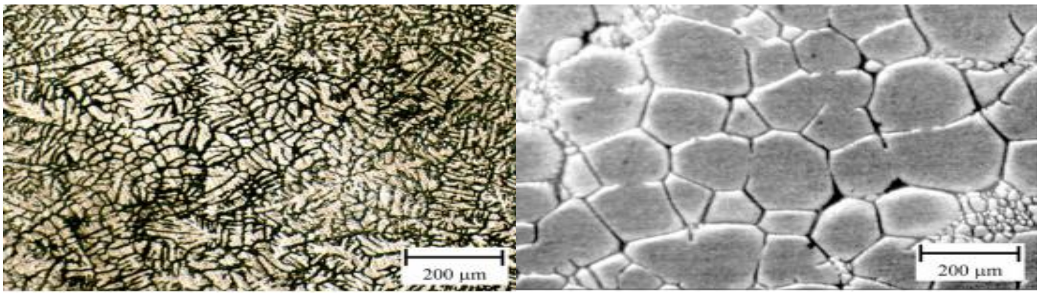


Fig. 11.Microstructe of liquid Al-4.4%Cu and semi-solid Al-%4.4Cu

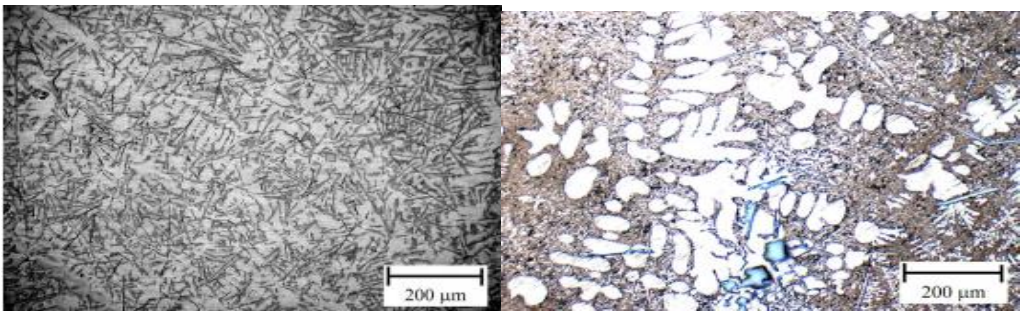


Fig 12. Microstructure of liquid ADC12 and semi-solid ADC12

From these microstructure assesments, it can be observed which of these 3 alloys are suitable for semi-solid casting.

3.4 Conclusions

In the supporting article, it is seen that semi-solid casting has more suitable production processes and costs in all respects when considering economic and process advantages compared to conventional die casting. For this reason, semi-solid casting process meets the demands of buyers such as cost, high quality parts production, low cycle times much better than other casting processes. In other words, more use and encouragement of this casting technique will be more efficient for all buyers and sellers.

Based on the experimental part in the supporting article, whichever alloy is used when making semi-solid casting, the thermomechanical properties and microstructure of the alloy should be determined and observed under various tests and conditions before the casting is used. If these tests indicate that the alloy is suitable for semi-solid casting, the alloy can be easily used for semi-solid casting.

References

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2. Winklhofer J.,”Semi-Solid Casting of Aluminium from an Industrial Point of View”, ***Solid State Phenomena***,285:24-30(2018)

3.Haga T.,”Simple rheocasting processes”,***Journal of Materials Processing Technology***,130-131:594-598(2002)

Questions

1)What are the advantages of semi-solid metal casting over other casting methods?

In the semi-solid casting, in the slurry of molten metal and mixing with mechanical or electromagnetic mixers, globular particles are formed in the solid-liquid mixture. Thanks to this globular structure, products with superior mechanical properties are created.

2) How to understand the suitability of an alloy for semi-solid casting?

With various thermomechanical tests, cooling graphics are made depending on the mixing time and solid fraction,whether the temperature required for the formation of globular structures is above the eutectic temperature is examined.Correspondence is tested by making microstructural observation in liquid and semi-solid form.

3) What are the differences between thixocasting and rheocasting?

In thixocasting, before the metal is injected, it must be turned into suitable billets. It is extra cost to produce or import these billets. There is no such requirement in rheocasting, the semi-solid slurry metal can be injected directly.