Improvement on Thixocasting and Rehocasting Process: A Review

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Abstract:-In production technology Aluminium Casting can be produced by 33 different processes, but in modern days the most important process is high pressure die casting in rheocasting technologies for obtaining high performance in "Al" components. In fabrication technology rheocasting process is more desirable to produce high quality of Aluminum alloys. A lot of rheocasting processes are proposed, but for the final success it is necessary to choice a really feasible process and to maintain all the steps under a strict control. This review described the way of improving the performance of highly stressed parts, using simple rheocasting and thixocasting process, contributing to produced Aluminium and its alloys for automotive and aeronautical/aerospace applications. The main Semi Solid Metal (SSM) technologies and future trends has been presented and discussed. The properties of A356 and A357 Aluminium alloys were investigated to establish the influence of the adopted Rheocasting process on the final performances in terms of reliability of the produced parts.

Keywords:- Rheocasting and Thixocasting, Shrinkage, Lean Production, Productivity

I. INTRODUCTION

In the year 1825 Aluminium was discovered by a Denmark scientist Mr. Hans, by chemical process [1] and in 1876, the first Aluminium casting was produced by using sand moulds. By 2010, near about 33 plus different processes are available. From these processes most of the important commercially desirable process is "Conventional high pressure die-casting", but it has some major drawbacks such as "air" and "gas blow holes", "shrinkages", "swirl", "sink", severe surface defects like "cold shuts" and many more[2,3]. Due to these defects we are unable to weld and heat-treat to enhance the mechanical properties of the castings. To overcome these defects, use of SSM casting process, eliminate all defects and increases the casting strength. Thus minimum wall thickness has been achieved from 6 mm (sand casting) to 0.8 mm in the Vacuum die-castings and still upto 0.5 mm [4].

A. Basic Metal Forming Processes

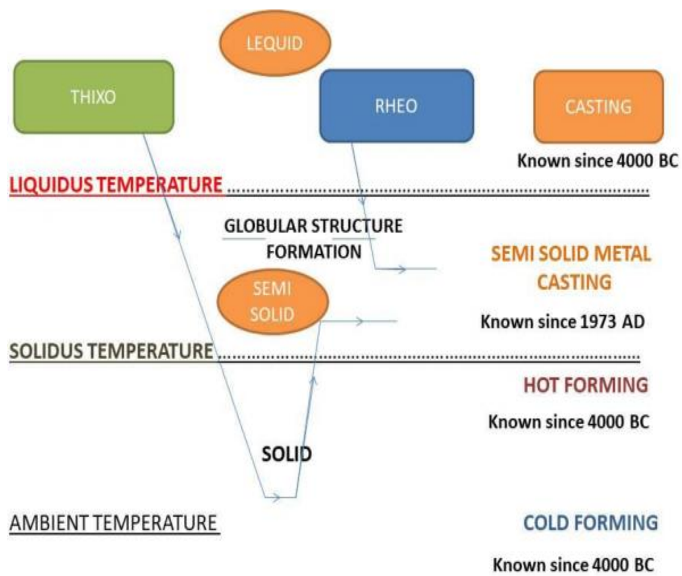

Figure 1.The Basic Metal Forming Processes Presented in A Schematic Diagram [4]

Semi-solid / semi-liquid state metal forming process was invented by Professor M. C. Flemings and his associates and they found many benefits of the product properties [5]. This forming process is formed when an alloy is at a temperature between the solidus and liquidus. Only the metallic alloy has solidification range, that's why they are formed the semi-solid state, but the process is called SemiSolid Metal (SSM) Technology for simplicity.

B. SSM Processes

Most of the forging process semi-solid metal (SSM) is used but in modern days SSM is used in casting process also. Thixotropy is a property of temporarily becoming liquid when sheared and turning to a gel when static, like margarine or toothpaste.

For a metal to be Thixotropic, it must:

1. Be heated to the semi-solid region of temperatures;

2. Have a globular microstructure at the processing temperature as shown Figure 2b, on dendrite one, Figure 2a. If these conditions are fulfilled, metal slurry can be formed in a die by a High Pressure Die Caster (HPDC) or a forging machine [3, 4, and 5].

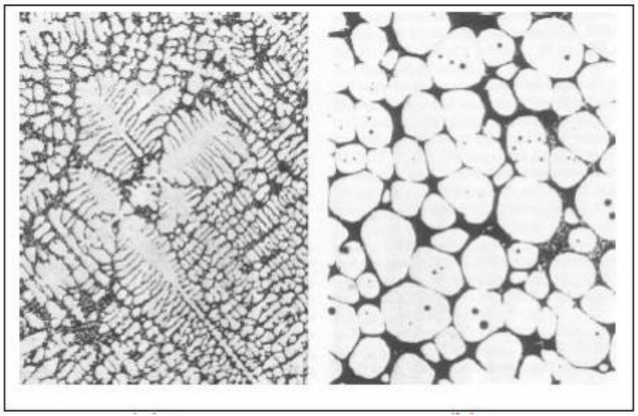

Figure 2.Dendrite Structure, Typical for Liquid Castings (A) Globular Structure, and (B) Typical of A Semisolid Casting [5].

Now a-days there are various process are developed for SSM tecnology but mainly two versions of SSM technology produce metal slurry with desirable globular structure in shape and size at a proper semisolid casting temperature. These are Thixocasting and Rheocasting processes.

Thixocasting process is done in two steps. In the first step, a stirring device is used to produce nondendritic structured solidified metal rods of diameter 3" to 6" through continuous casting process [6]. In the 2 nd step solidified rods are cut and heated upto the desired temperature in an induction machine 4 [7]. Only in the northern hemisphere companies are used this stirring technology in the world. In SSM forming globular structure billets are suitable i.e. by high pressure die casting (HPDC). Major disadvantage of thixo process is that the scrap cannot be recycled on site, shown in the figure 3 [4, 7].

Rheocasting is a one step process. The molten metal is treated by cooling or by cooling/stirring from liquid to semi solid temperature in order to produce slurry with globular shape of the solid phase particles, and hence, injected directly into the die, as illustrated in Figure 4 [8].The advantage of the rheo process in comparison with the thixo process is that the slurry with globular structure can be made on demand and "in house". The stock material can be any standard alloy cast by other methods like squeeze, gravity or HPD casting. The chemical composition of the cast metal can also be modified and tailored to meet the quality and various mechanical property specifications of the components. The rheo process does not need imported material with nondendritic structure. Scrap and runners can be directly re-melted in the rheocasting machine. These facts contribute to a lower production cost with high quality product (lean production) of the rheo castings.

Figure 3.SSM Thixo Process [17].

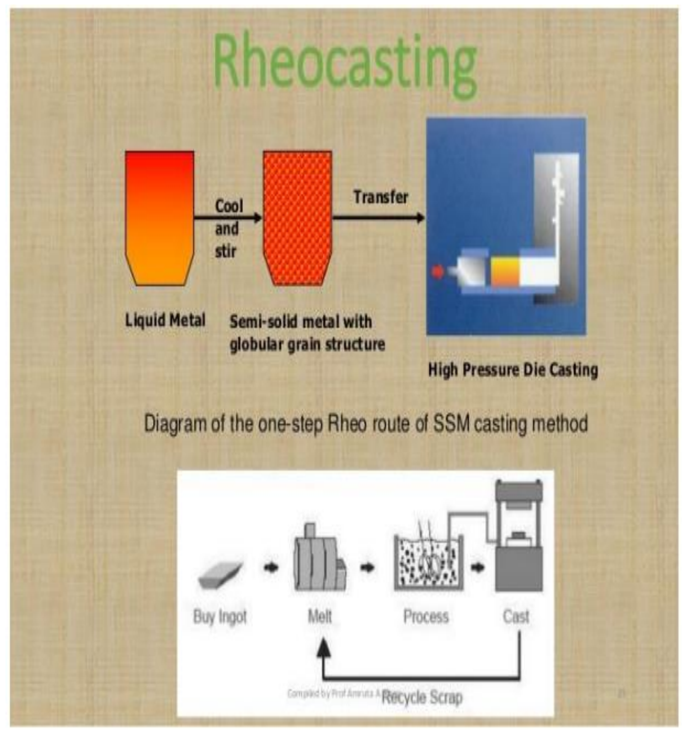

Figure 4.SSM Rheo Process [14].

It has been recorded that research centers and industries are preferred to increase their productivity by the rheo process. The first rheocasting technology called New Rheo Casting-NRC, developed by Ube, Japan is already on the market and was implemented in mass production by a number of HPDC foundries in Europe and North America. The trend for application of the rheo process has become quite strong and few new technologies have been reported recently [1, 4, 7, 8].

II. REVIEW ON HIGH-PRESSURE DIE CASTING PROCESS

High-pressure die casting process (HPDC) named as rapid solidification process leading to formation of rapid solidified castings. The casting of a molten alloy into a mould can be complete within several milliseconds. Hence significant quenching effect and high production rates are possible [8]. Cooling rate at the die-melt interface is increase with the Application of high-pressure that enables good contact between molten alloy and die wall. Casting defects such as shrink holes which are generated by the shrinkage during solidification are reduced in HPDC. [8, 9]

An integrated virtual and rapid prototyping methodology was proposed by Ferreira et al for advanced die-casting manufacturing by using a hot-chamber process. This approach enabled optimization of diecasting manufacturing technology parameters and reduced lead-time of die-casting design process [3].

The physical, mechanical properties and aesthetic of the components are directly dependent on process conditions during casting, such as the die temperature, the metal velocity at the gate, the applied casting pressure, the cooling rate during die casting, the geometrical complexity of the component and the mould filling capacity. All these parameters influences are the integrity of cast components. If these parameters are not controlled properly, various defects within the finished component may be observed. Applied casting pressure is crucial during solidification of high integrity parts [5, 6, 8, 10, and 11]. Dargusch examined in 2006[9] that effect of process variable on the quality of cast components with incavity pressure sensors, delay time and casting velocity [9].He found the porosity decreases with increasing pressure and to increase with higher casting velocity. The latest development of rheocasting process is based on the principles of HPDC [9,5]. The material in semi-solid state is pressed into the tool cavity to enables faster solidification and for getting better productivity. Due to the narrow temperature range optimization of the new Rheocasting process requires control of process parameters. M. Tarkar et al observed that the different defects on microstructure of semi-solid slurry of Rheocast components which required to controlling of process parameters [4].

III. REVIEW ON THIXOCASTING AND RHEOCASTING

Samples have been machined from thixocasted bars where the raw material with perfect globular microstructure to be used for the final thixocasting process and in this way the materials is not affected by any casting defects. Specimen of A356 and A319 has been solution treated and tensile test for 6 different time at 540°Cand 500°C respectively. The solution treatment effects have been evaluated by the observation of the variation of the silicon particles diameter with solution time. On both alloys, solution treatment has involved coarsening and spheroidizing of eutectic silicon particles and dissolutions of inter metallic compounds in deferent process. It has been observed from tensile test that ductility is increases by Spheroidization of silicon particles and decreases ductility by thixo and rheo casting (RC) process compared to normal melt casting. (Table1.) [12, 13,14].

Alloys and condition	Ys,Mpa	Uts,Mpa	Elongation %
A356 as-thixo	104	241	12
A356 RC	226	277	14
A356 melting	106	231	18

Table1. Tensile test results in as-thixocasting, rheo-casting (RC) and melting of A356 alloys [12, 14].

The fracture surface analysis has confirmed that fracture of silicon particles is an important factor which influences the alloy failure under tensile stress. It is related to dislocations of metal and silicon particle interaction. In fact, failure levels of silicon particles decrease as ageing time increases, since other precipitate compounds become more effective to pin up dislocations during plastic deformation. Presence of Cu in the metal matrix with formation of $CuAl2$ precipitates causes the difference composition of metal forming. Components were manufactured using a Semi-Solid Rheocasting (SSR) process and heat treatment upto T6 tempareture line. The level of strength was satisfying, with YS = 319 MPa and UTS = 358 MPa, but the elongation was too low. For the A356 and A319 grades, the increase of strength is accompanied by a loss of ductility [13, 14].

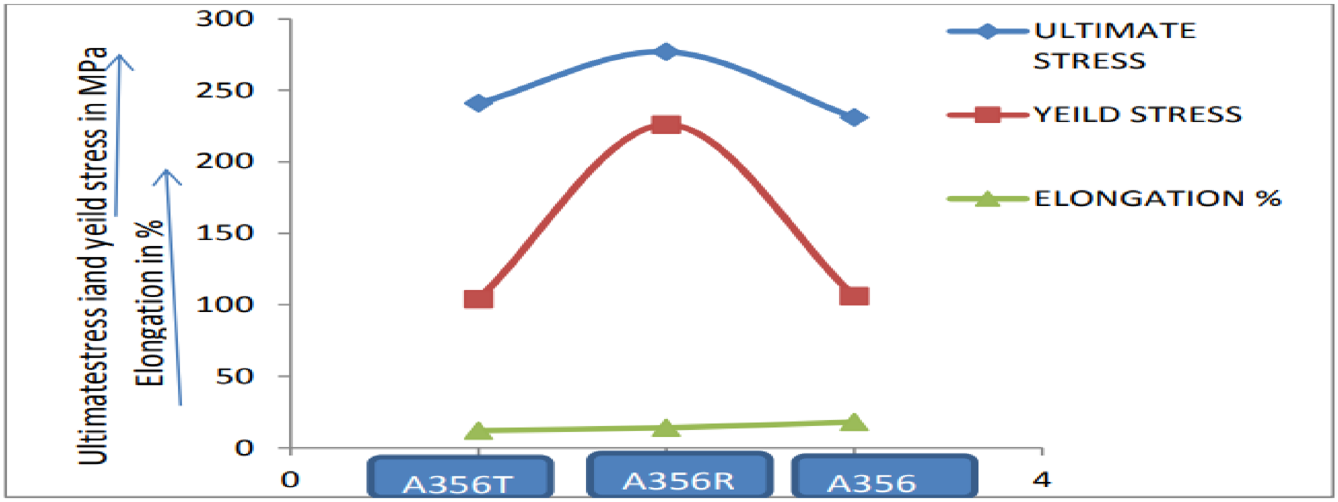

Figure 5: Ultimate Stress, Yield Stress, and Percentage of Elongation Curve of A356 Alloy Under Thixocasting, Rehocasting, and Meliting Condition

Figure 5 indicates that in case of thixo process when we are applying heat and followed by slowly cooling upto 540°C for SSM condition there by achieved high ultimate stress of A356 alloy which can be used for the application of thin product casting such as knuckle housing component, engine block, and four way valve etc.

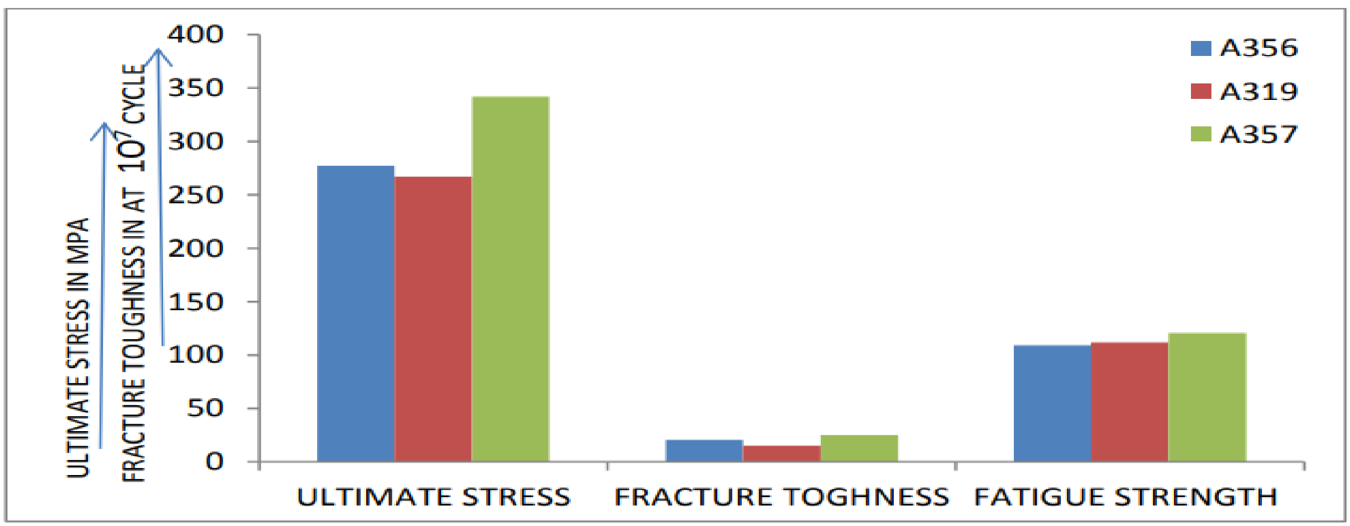

Figure 6: Result of Ultimate Stress, Fracture Toughness, Fatigue Strength of A356, A357 And A319 Alloy

To achieve low weight high strength ratio, for various application in the aerospace industry selection of material is much important. From figure 6 it is clear that in this comparative study along with different 0 50 100 150 200 250 300 0 1 2 3 4 ultimate stress yeild stress elongation % A356T A356R A356 M Ultimatestress iand yeild stress in mpa Elongation in % 0 50 100 150 200 250 300 350 400 ultimate stress fracture toughness fatigue strength A356 A319 A357 ultimate stress in mpa fracture toughness in at 1o7 cycle 8 “al” alloy, the best alloy is A357 because of acquiring ultimate stress, fracture strength as well as fatigue strength is higher form A356 and A319 alloy.

Material	A319		A356		A357	
	Min..	Max..	Min...	Max.	Min..	Max..
Si	5	7	6.5	7.5	6.5	7.5
Fe	-	.9	-	.15	-	.15
Cu	3	5	-	.03	-	.03
Mn	.2	.5	-	.1	-	.1
Mg	-	.55	.3	.45	.5	.7
Cr	-	.15	-	.15	-	-
Ni	-	.45	-	.45	-	-
Zn	-	2	-	.07	-	.07
Ti	-	.2	-	.1	-	.18
Others	-	.35	-	.1	-	.1

Table 2 Chemical composition range (wt. %, Al = balance) of A319, A356 and A357 alloy [12,15,16,19].

The literature related to Thixocasting and Rheocasting processes is quite specific and the major part of studies and researchers are dedicated to A356, A357 and A 319 alloys, in the SSM processes. A356, A357 and A319 alloys having good characteristics of castability, weldability with wide range of semisolid temperature. In fact fracture and/or de-cohesion of silicon particles, in these alloys, have been mainly correlated to the alloy failure by stress application. Ultimate stress, fracture toughness, and fatigue strength of A356, A357 is affected by the presence of Cr, Ti, Ni percentage [15,16,17,18,19].

IV. CONCLUSIONS

This paper represents a review of the evolution of SSM processes, with modern developments of products in reliability in terms of quality with high productivity. The attainable properties of aluminiumsilicon alloys of the type A356 and A357 have been illustrated and discussed as a comparison to the low thixo-casting and reho casting processes, demonstrating the superior quality and performance in terms of various mechanical properties such as ultimate stress, fatigue strength and fracture toughness of parts produced using rheo-casting technology. This study deals with the production of heavily stressed 9 structural parts as well as components for automotive application of A356 and A357 alloys. The mechanical strength, measured by tensile tests, is consequently very satisfying and promising for excellent performances of components. Moreover, the reliability of the process has been verified through the tensile test. Preliminary results indicate that the Produced parts are easily joinable by welding, opening new ways and perspectives to designers.

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