COMPARATIVE ANALYSIS ON MOULD FILLING OF A413 ALUMINIUM ALLOY IN SAND AND EVAPORATIVE PATTERN CASTING PROCESS USING VIRTUAL INSTRUMENTATION

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Abstract

This paper deals with the comparative study on the properties of Aluminium alloy (LM6-12%Si) castings in sand casting and Evaporative pattern casting (EPC) process. Thermocouples are used to measure the temperature of the casting during solidification. Signals from the thermocouples are connected to the DAQ (Data Acquisition Card) 6024E.The software development platform used for this application is LabVIEW. The signals acquired using DAQ card is given to the LabVIEW as an input. The acquired signals from the thermocouples are processed to obtain the mould filling and solidification time for both the process. Mechanical properties and micrographs of the castings were also considered. It is revealed that the properties of the evaporative pattern castings of A413 alloy are comparable to the castings.EPC is the viable alternate for conventional casting process to make intricate Al-Si Castings with energy efficient and environmental friendly way.

Keywords: *Evaporative pattern casting (EPC), A413 alloy, mould filling, solidification, Data Acquisition system, microstructure, tensile strength.*

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1. INTRODUCTION

The Evaporative pattern casting (EPC) process, first introduced by Flemmings in 1964[1], was modified from the full mould process originally developed by Shroyer in 1958[2]. The EPC process is distinguished from the full mould process by the use of unbounded sand as opposed to the bonded sand in the latter. This technique is referred to by several terms including Lost Form Casting (LFC), full mould process, Replicast and Policast process[3].EPC has been regarded as a cost effective ,environmental-friendly vital option to the conventional casting process for production of near-net shape castings with high quality, especially in forming components with thin-wall, complex geometry, tight tolerances and smooth as-cast surface[4].The advantages of the EPC process had not been fully realized due to lack of knowledge of the process needed to exercise proper control measures between 1950 and 1990, there was virtually no growth in the use of EPC. It is accounted for less than 1% of steel and iron castings and less than 5% of aluminum castings. The future for Evaporative pattern casting, however, is much brighter.

Since 1990,there has been a significant increase in the use of the process and the outlook is strong. BY 2020,about 29% of aluminium castings and 15% of total iron castings are expected.EPC has gained prominence as a casting process over the last decade. But it requires high degree of process control compared to sand casting[6-9].In this chapter an attempt has been made to investigate the solidification behavior of A413 alloy in sand casting and EPC using Virtual Instrumaentation.A413 alloy is widely used for making intricate castings of automobile components.A413 was considered for the entire study. The chemical composition of A413 alloy is 10-13% Si, 0.6% Fe,0.04% Mn,0.03% Cu,0.05% Mg and remainder of Al.Equivalent designations of A413 are LM6(BS) 4600 (IS617-94),Al-Si 12 (ISO 3522-85),AC3A.1(Japan) and G-AlSi12 (DINI725(5)-86).A413 is a corrosion resistant aluminium casting alloy with average durability and strength, and also posses high impact strength and ductility[10].

2. EXPERIMENTAL PROCEDURE

2.1 Evaporative Pattern Casting

Rectangular shaped foam pattern of size (110mm long and 80mm wide and 20mm thickness was cut from a standard EPS (Expanded Polystyrene) Board by using a hot wire cutter. The required gating system with sprue (W20×T20×L140mm), runner (W20×T20×L60mm), and pouring basin (W40×T20×L40mm), were also cut from the same foam board. Pattern was attached to the gating system with a glue to form pattern assembly. The bottom gating system was adopted. The pattern assembly was then coated with a water-based Zircon coating by dipping method and dried. The thin dried layer of refractory coating is acting as barrier between sand and metal during mould filling. The refractory slurry consists of fine Zircon flour,bentonite and water. The pattern assembly was then placed in a steel flask and filled with unbounded dry silica sand. Silica sand of single sieve AFS grain fineness number 55 was used. In order to get sufficient strength of the sand mould for withstanding the metallostatic pressure of molten metal, the sand gets compacted by a vibration table. The flask was ready for pouring molten metal.

2.2 Sand Casting

A rectangular wooden pattern of size 110mm×80mm×20mm was used for the green sand moulding. The mould cavity was in the drag and the gating system with riser was formed in the cope. The silica sand with AFS was used with optimum quantity of bentonite and water.

2.3 Virtual Instrumentation

Virtual instrumentation is a new type of computer based system for acquisition, storage, processing and presentation of measured data of various sensors.Chromel-alumel k type thermocouples are used for measuring temperature of metals during solidification process which are surrounded by ceramic tubes. The thermocouples are connected to the Data Acquisition Card (DAQ) 6025E through a signal condition unit, which converts the signal from the range of mV into the range of 0.5V-10V.Then the signals are sent to the pc through serial port(fig 1).The software platform used for this application is Lab VIEW (Laboratory Virtual Instrument Engineering Workbench) is a development environment for computer-based data acquisition and instrument control programs based on graphical programming. The signals acquired using DAQ card are given as an input to the Lab VIEW (fig1).The thermocouple wires were inserted into the coated pattern in the evaporative pattern casting process. In the case of sand casting, the wires were placed in the mould cavity. The middle portion of the rectangular pattern was selected as the location for measurement of temperature in both the processes.

2.4 Melting and Pouring

The melting was carried out in a gas crucible furnace. A total of 10 Kg of pre-cut ingot slabs of the A413 alloy were melted in a graphite crucible. Upon reaching a liquid metal temperature around 770°C, flux was added into the molten metal and stirred well in the crucible. Then the slag was removed. After that degassing tablet (hexachloroethane) was submerged into the melt using a preheated plunger until there was no evolution gas. Then the molten metal was poured into the mould cavity in sand casting and also poured over the foam pattern in EPC.Five castings were made in each process for the investigation.

3. RESULTS

3.1 Solidification of Curves of A413 Alloy

Data acquired from Lab VIEW software during solidification are stored as spreadsheet which contains temperature and time. The solidification curves were plotted using the data.Fig4 shows the solidification curves for the A413 alloy castings of sand casting and EPC .The thermocouples are subsequently increased to the temperature of the molten metal. In the case of EPC ,the thermocouple initially registered the temperature and subsequently increased to the temperature of the gaseous degradation products ahead of the metal front[11,12]. Subsequently the metal established contact with the thermocouple junction, the measured value rapidly increased to the temperature of the metal front. The temperature range for the solidification of A413 alloy is 565°C which is normally short range. In sand casting, it reaches the pouring temperature when it contacts the molten metal. The solidification time of EPC is slower than sand casting. Also it is found that the solidification rate of the EPC is lower than the sand casting. From the analysis of the solidification curves of EPC process and sand casting, there is difference in temperature gradient after the mould filling and solidification which reflects the heat transfer characteristics of EPC process of A413 alloy during solidification.

3.2 Measurement of Mould Filling Time

After pouring the molten metal, the foam degrades and releases gaseous and liquid residue. It will be allowed to pass through coating and mold material media. By knowing the temperature of two thermocouples, it is possible to find out the mould filling time accurately. The tabulation table 1.shows the recorded values of temperature of two thermocouples and its time intervals.

Table -1: Measurement of mould filling time

Fillingtime (sec)	**Thermocouple 1 (Temp°C)**	**Thermocouple 2 (Temp°C)**
0.00	38.00	38.00
1.00	390.09	38.00
1.10	680.00	38.00
1.20	716.00	38.00
1.30	716.00	38.00
1.40	716.00	38.00
1.45	716.00	38.00
1.98	716.00	38.00
2.40	716.00	38.00
2.75	716.00	41.00
3.05	716.00	78.00
3.69	716.00	78.00
3.95	716.00	78.00
4.05	716.00	712.00

3.3 Microstructure Study

Samples were cut from each casting near the thermocouple location. The samples were prepared using the following steps: first, coarse grinding with a belt sander using 80 grit paper; second, fine grinding with 600,1000 and 1500 grit papers: third, polishing with diamond paste and finally, etching of the samples using Keller's for 15 seconds. The samples were studied using optical microscope with Image Analyzer(CLEMEX) at a magnification of 100X and 500X.The micrograph of cast LM6 alloy consists of eutectic acicular Si particles(dark grey) in primary α-aluminium matrix(white).When compared to the micrograph of cast LM6 alloy, lost foam castings are having coarsening of Si particles. More over it is observed that the size of the needles of Si particles is lengthier in evaporative sand castings, than sand castings as shown in fig5.

3.4 Mechanical Properties

The castings were machined and samples were cut from the traverse direction of the rectangular castings. The tensile specimens were prepared according to the ASTM E8-00 with good surface finish for chuck gripping at the tensile test machine. The tensile tests were carried out with computerized Universal Testing Machine capacity of 100 kN(Model:UNITEK-94100).Samples were also prepared for hardness test and Vickers Hardness number (VKN) was measured using Zwick micro hardness testing machine with a load of 500g.Samples were cut from the middle portion of the castings and polished o all sides to form smooth, slightly rounded surfaces having no cracks or sharp edges. The ASTM standard test method was used to determine density of each sample based on the fundamental Archimedes' principle. Then the percent porosity was calculated from the measured density and theoretical density[13].Table 2. shows the ultimate tensile strength, micro hardness and percentage porosity values for the casting and EPC.The mechanical properties of sand casting are slightly higher than the EPC.The percentage porosity is also higher in EPC.

Table -2: Mechanical properties

Properties	**EPC**
UltimateTensile Strength (MPA)	140-150
Micro Hardness(Vickers) VHN	58-62
% porosity	1.54

4. DISCUSSIONS

Generally the mechanical properties of Aluminium-silicon alloys are related to the grain size, and the shape, size and distribution phase. Coarse grain, eutectic silicon, and cavities all reduce the tensile strength, the ductility and the impact strength of the alloys. If the macro and micro structures are controlled, they should have excellent mechanical properties. From the analysis of micrographs of EPC and sand casting of A413 alloy, it is revealed that the eutectic acicular Si particles of EPC are coarser than the sand casting which in turn reflects that the slower solidification rate of EPC .Hence the tensile strength and micro hardness of EPC are slightly lower than the sand castings. Even though the foam decomposition is an endothermic reaction, the under cooling effect is compensated by the thermal insulation of ceramic coating in EPC. The good fluidity, pressure tightness, resistance to hot tearing and shrinkage of the Al-Si alloy make them a good choice for EPC Moreover, the gaseous products escape through the coating and into the sand during mould filling in EPC. The liquid products of low molecular weight species get absorbed into the coating and, when sufficient heat from the metal accumulates in the coating, the absorbed organics decompose into smaller fragments and volatilize[14].This condensation-volatilization process continues in the sand until the liquid metal loses heat and solidifies. This in turn reduces the thermal conductivity of ceramic layer which is attributed for the slower solidification rate in EPC[15-18].Though the mechanical properties of castings by EPC are slightly lower than sand castings, the values of UTS and micro hardness are within the prescribed limits of A413 aluminium alloy. The mechanical properties of EPC are improved by controlling various process parameters of such as permeability of coating, coating materials, applying vacuum in the mould, grain size of foam pattern,etc[19-20].

5. CONCLUSIONS

Experiments were carried out on the A413 aluminium alloy using sand casting and Evaporative pattern casting process. Virtual Instrumentation system was used for recording the temperature during solidification and plotting solidification curve.VI system is bested suited for recording the temperature in casting environment. Further the foam plays the important role in determining the mold filling and metal velocity. The comparative examination was performed and it is concluded that there is no significant change in mechanical properties. It is possible to assure the viability of adopting the EPC process to an existing conventional acting process to produce Al-Si alloys. The EPC process has advantages with respect to other casting methods, for high production of complex sharp parts he patterns are cheap and easy to manufacture. These are free of lines and extra angled. It is possible to reuse the sand nature.

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