Paper ID MD 11

LOST FOAM CASTING TECHNOLOGY – REVIEW PAPER

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Abstract — Lost foam casting (LFC) as a cost-effective and environmentally friendly casting process. The energy conservation and emission reduction in foundry industry should take casting quality and technology improvements as core mission. Lost foam casting is a casting method with the use of patterns, which are not removed from the mould but remain in it and are gasified under the action of the heat energy of a metal being poured into the mould. It has become one of the most important casting processes for ferrous and nonferrous metals, particularly for the automotive industry. LFC is regarded as the representative of the 21st century casting new technology.

Key words— lost foam casting (LFC); casting; defects in casting Defect Analysis, Defect Prevention, and Root Cause Analysis.

Introduction

The development of casting technology should be a strategic concern to planners of rapid industrialization of any nation. Major components of machine tool, power plants, industrial machinery & equipment's, automotive, agriculture, textile etc. are products of the foundry. Hardly can we think of any major machine or equipment which has no components that have been cast in a foundry. One can therefore rightly say that the acquisition of foundry technology is basic to economic development and self-reliance.

Lost foam casting (LFC) as a cost-effective and environmentally friendly casting process is widely used to produce complex engineering components. The layer of coating applied on the pattern foam is a crucial parameter for producing high quality castings. It was proposed that in lost foam casting process, refractory coating is developed on the pattern surface to provide support against the weight of the sand before the liquid metal solidifies as well as withstands the high temperature of molten metal. Recently, it was reported that the coating also provides an insulation barrier to keep the molten metal from losing too much heat, which may result in premature solidification. Thus, the coating may facilitate elimination of the degraded foam products including liquid and gases. In addition the coating layer decreases the heat transfer coefficient between the liquid metal and sand, resulting in the improvement of metal fluidity. Although, several studies have investigated the influence of coating in LFC , better understanding of the effect of coating on casting quality in LFC process is essential. Moreover, the effect of foam coating layer can be more complex due to the effect and interactions of several process factors. The composition and thickness of pattern coating are two critical factors governing the LFC. Limited studies have been carried out on the effect of coating thickness on other process parameters in LFC, but due to lack of knowledge on this area, it is therefore necessary to investigate how coating thickness would affect the casting characteristics. The LFC technology has been widely applied to cast iron, cast steel and Al alloys in the advanced LFC technology countries such as the USA and Germany. However, in China, the LFC is mainly applied to cast steel and cast iron and application of LFC to Al alloys are relatively low.

LITERATURE REVIEW

Z. Żółkiewicz et al. in the paper , "Pattern evaporation process" mentioned that In the technique of evaporative patterns, the process of mould filling with molten metal (the said mould holding inside a polystyrene pattern) is interrelated with the process of thermal decomposition of this pattern. The transformation of an evaporative pattern (e.g. made from foamed polystyrene) from the solid into liquid and then gaseous state occurs as a result of the thermal effect that the liquid metal exerts onto this pattern. Consequently, at the liquid metal-pattern-mould phase boundary some physico-chemical phenomena take place, which until now have not been fully explained. When the pattern is evaporating, some solid and gaseous products are evolved, e.g. CO, CO_2, H_2, N_2, and hydrocarbons, e.g. styrene, toluene, ethane, methane, benzene [16, 23]. The process of polystyrene pattern evaporation in foundry mould under the effect of molten metal is of a very complex nature and depends on many different factors, still not fully investigated. The kinetics of pattern evaporation is also affected by the technological properties of foundry mould, e.g. permeability, thermo physical properties, parameters of the gating system, temperature of pouring, properties of pattern material, and the size of pattern-liquid metal contact surface.

Majid Karimian et al.. in paper " Effect of casting parameter on shape replication and surface roughness of LM6 aluminium alloy cast using lost foam casting " mentioned although all investigated process parameters have strong influence on casting integrity and surface roughness, filling configuration and pouring temperature are more critical and should be designed carefully. ",Higher pouring temperature promoted better surface finish for all section thickness of the casting. Decreasing mould vibration time produced castings with smoother surface. Surface roughness increased with increasing casting thickness regardless of mould vibration time.

M.Khodai et al ,in paper "Behaviour Of Generated Gas In Lost Foam Casting ",, mentioned that melting point temperature of metal, as well as volume and rate of the foam degradation have significant effect on the mold filling pattern. Therefore, gas generation capacity and gas gap length are two important parameters for modeling of mold filling time of the lost foam casting processes.

Yazad N.Doctor et al ,in paper "Review Of optimization Aspects Of Casting Processes " ,mentioned that , in today's global competitive environment there is a need for the casting set ups and foundries to develop the components in short lead time. Defect free castings with minimum production cost have become the need of this indispensable industry. Rejection of casting is caused due to defective components. These defects depend on various process parameters which need to be improved using various methods in optimization.

Jimoh, S. 0,et al.in paper " Casting Technology And Development Nigeria As A Case Study" mentioned It is acceptable fact that foundry technology is essential for industrial development Funds are required to acquire both the hardware and software. Deliberate and special allocation of funds must be made to set up foundries focused on specific national needs e.g. automobile, machine tools, etc. Working capital should be provided as and when required so that the foundries could be run as commercial and profitable enterprises

.Li Yuanyuan et al in paper "Energy Conservation And Emission Reduction Stategies In Foundry mentioned that Casting is the basis of manufacturing industry, but it is a polluting industry with big energy consumption. As major sectors of energy consumption and pollutants (especially CO_2), energy saving issue has rose concerns. Energy conservation and emission reduction is related tightly with the survival and development of the industry, and it is also a key point of sustainable development of local economy

Zongade Shan et al in paper "Key Manufacturing Technolog And Equipment For Energy Saving And Emission Reduction In Mechanical Equipment Industry", mentioned that It is important to promote sustainable development in the equipment manufacturing industry in order to develop and promote energy saving and emission reduction technologies. This can be achieved during the processes of designing, manufacturing, using and remanufacturing, using such things as digital technology, new material, near-net shape forming technology, clean production technology, short production process technology, waste-free manufacturing technology, automatic control technology, and remanufacturing and reusing technology. The goals of energy saving and emission reduction can be achieved with the research and application of these new green technologies and equipment. By reducing raw materials consumption, energy consumption and environmental pollution, this will promote sustainable development in the mechanical equipment industry.

Vighneshraj C T et al in paper "Innovation And Recent Development In Casting "mentioned that : Metal casting processes are being adopted for manufacture of parts. Over the years improvements and innovations have been deployed to make the processes more productive to increase output and at the same time making them cost effective. The Lost Foam Casting (LFC) process is a pioneering casting technique and an innovative alternative and addition to conventional foundry methods. It permits the production of complex components, and opens up new scope for casting.

Shafeen P et al in paper "Effect Of Surface Coating Of Polysterene Pattern On Surface Morphology And Mechanical Properties Of Al-Si Eutectic casting " mentioned that , polystyrene pattern is used to produce complicated profiles. Graphite coating on the pattern gives the best surface finish in the casting among the coating materials used. Modification treatment using sodium salts found increase in mechanical properties such as ultimate tensile and hardness.

Kandasamy Thiyagrajan et al in paper" Study Of Aluminium Alloy 7075 : Sand Casting & Lost Foam Methods", mentioned that that the surface roughness and impact strength values are low in the sand casting method compared with lost foam casting. The Hardness value is high in the sand casting compared with lost foam casting. It is observed that the properties of the materials are varying according to the method of casting.

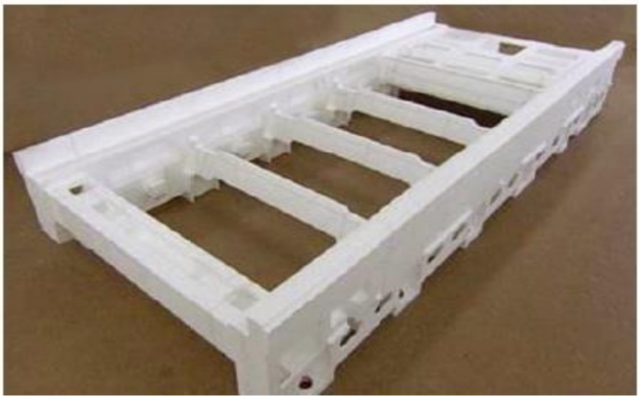

Fig 1 : Lost foam pattern

METHODOLOGY

LFC is a near net shape and precision forming process; and it is regarded as the representative of the 21st century casting new technology. Firstly, the solid die is fabricated using the foam pattern material based on the structure and size of the casting part, and then the foam pattern is coated with refractory slurry. After drying the coated foam pattern and modeling, as well as vibration compacting, the molten metal is poured into the foam pattern. As a result, the foam pattern is subjected to gasification disappearance; and finally the metal casting with the shape of the foam pattern is obtained. Compared with other casting processes, this new casting process has the following technical characteristics and advantages

The structure design of LFC casting is flexible. Because the foam material is used as the pattern, the foam pattern has no drawing pattern inclination. During the LFC process, a mono-block foam pattern can be fabricated using slicing manufacturing and adhesion method; and thus a casting can be obtained whole.

As a consequence the core can be omitted and the pore structure can also be directly manufactured, resulting in a great decrease in time and cost of processing and assembling as well as the investment of processing equipment. Loose-sand compact modeling is adopted in the LFC process, and the sand has no binder. Therefore, the production process of castings is simplified, resulting in high labor productivity.

Additionally, the sand can be fully reused, so the production cost is greatly decreased. Meanwhile, the traditional sand mixing, compacting, combined box and sand preparation processes can be omitted. The foam pattern can be freely assembled, and several castings can be simultaneously poured using one box. As a result, the LFC process is beneficial for mass and automated production. The LFC process is likely to realize cleaner production.

Fig 2: Casting

The polystyrene (EPS) does no harm to the environment at low temperature because the EPS gives rise to fewer organic compounds during pouring and the organic compounds are easily collected. The organic compounds can be treated using the negative pressure aspiration type combustion purifier, and the reuse rate of old sand is higher than 95%. Compared with the traditional casting process, the harm of noise, CO and silica dust are significantly decreased, resulting in a significant improvement of the environment.

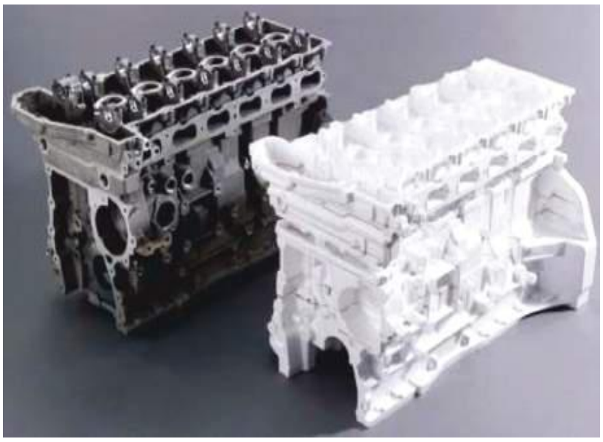

Fig 3 : Cylinder Block

Fig 4 : Electric Casing

Patterns are made of expanded polystyrene foam; methacrylate and poly alkylene and polyalkylene carbonate. The materials are light in weight. They must be carefully handled after production to avoid distortion. The expanded polystyrene is used for aluminum and its alloys; it is not used in iron founding because of the defects that it causes for the casting. It is known that the materials have different density values and this has effects on the quality of castings produced. It is then required that there must be consistency in the material used as pattern for consistent quality in terms of the mechanical properties and the microstructures of the castings. It is observed that the pattern used in EPC is in sharp contrast to the ones employed in the traditional sand casting methods where wooden, metallic and plastic materials are used to create cavity in the molds and then removed before pouring casting material into the molds. It is fundamental that the polystyrene's density be as normally used in patterns manufacturing, that is, 20 Kg/m3. It is essential because the amount of iron to be poured into the mould is calculated on the basis of ratio between the polystyrene and iron density. If the density is less than standard, the casting is carried out with less iron, with the risk that the mould is not filled, losing both the pattern and the casting. If the density is greater, the casting will be carried out with an excessive amount of iron, and there may be several tonnes of excess in the ladle, with nowhere to pour it. Additionally, low-density polystyrene is easily ruined and broken, with inferior surface quality after machining, which is transmitted to the casting. Pattern coating which is a mixture of refractory material and binder or many a times only the refractory material, when applied on patterns, forms a solid layer on the pattern when it is dry. The coating must be permeable to allow gas to escape into the surrounding; otherwise the gas would be trapped, causing defects in the castings.

Fig 5: Trunk body casting and Foam pattern

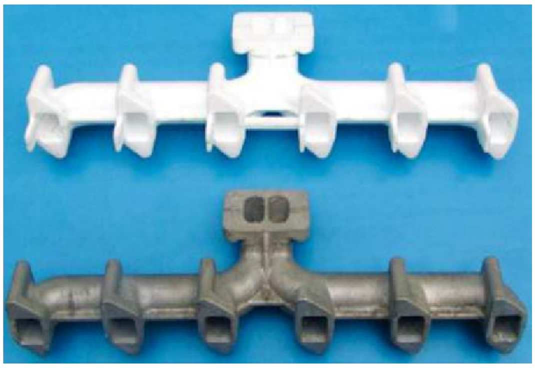

Fig.6 Exhaust manifold

Depending on the type of coating, the time to fill the mould with the liquid metal is affected. The gas generated must escape continuously from the mould to avoid defects. The pyrolysis products are the main causes of defects in EPC Process. The release of the gas products should be in a timely manner; if they are too fast, it leads to mould collapse because of pressure drops such that the coating layer is no longer supported and could not therefore bear the weight of the sand. An ideal pattern coating must allow gaseous and liquid foam degradation products to be transported out of the casting in a timely and balanced manner. Variables such as coating material, percent solid, viscosity, liquid absorption capability, coating thickness and gas per-meability affect the quality of casting" .The application of the pattern coating must be carefully done on the pattern to ensure that it is consistent . If the coating is applied wet, the wetability must be consistent. If it is applied Polystyrene was discovered in Germany in 1839 by Edward Simon and is a derivative of petroleum produced by polymerization of monomer styrene. The chemical structure of the polystyrene contains only carbon and hydrogen atoms with benzene ring attached to it and it is then classified as hydrocarbon. The chemical formula is $(C_8H_8)_n$. In EPC Process, thermal degradation of the polystyrene occurs at elevated temperature.

Lost Foam Casting delivers many benefits, including:

1) Requires no draft to aid removal from the mould
2) Has no parting lines and no flash is formed providing a better, more consistent surface finish without the need for further machining
3) Unbonded sand is used which is simpler and cheaper than greensand or resin bonded sand
4) Natural directional solidification takes place, so casting is more predictable with fewer defects
5) Foam patterns are easy to manipulate, carve, glue and handle
6) Multiple parts can be consolidated in a single complex casting, reducing the need for post casting assembly
7) Process is suitable for Aluminium and Nickel alloys, Steels and Cast Irons. It can also be used for casting Stainless Steels and Copper alloys.
8) Versatility: Cast parts can range from 0.5kg to several tones
9) Minimum wall thicknesses are just 2.5mm with no upper limit.

Limitations of Lost Foam Casting:

1) Pattern costs can be high for low-volume applications.
2) Patterns are light and easy to handle but are easily damaged or distorted.

Applications of Lost Foam Casting:

The lost foam process is accepted as the process of choice for complex high volume components such as automotive and marine blocks and heads; compressors for the heating and air conditioning industry; electric motor housings; counterweights for heavy equipment; hydraulic valves, hydrants, and pipe fittings for the water distribution industry heat exchangers for various industries. The value added features such cast-in holes, threaded fasteners and internal fluid passages have made the LFC attractive to many casting buyers.

CONCLUSION

LFC technology which is attracting global interest provides both product designer and foundry technicians with new possibilities and benefits. This is because the lost foam mould allows virtually limitless complexity with respect to the moulded foam. It also makes it possible for the final casting to be exact as possible to the component required so that subsequent machining is reduced to the barest minimum. Using lost foam technology, highly complex products can be produced with utmost precision. This means that it is now possible to integrate various components into one casting, which would previously have required many castings, machining, gaskets and assembling. This initiative brings higher technology into the foundry industry and is generating new interest for the industry in world.

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