

IMPROVEMENT OF CASTING TECHNOLOGY USING A LOST METHOD

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Abstract

This article analyzes the industrial significance, technological advantages, and application areas of lost foam casting technology. Particular attention is paid to the effect of the refractory coating applied to the model surface on casting quality formation. The study examines the role of the coating as a thermal insulating layer and its influence on metal fluidity, heat transfer coefficient, and the removal of gaseous and liquid products formed during polystyrene decomposition. In addition, the necessity of a deeper investigation into the relationship between coating thickness and composition with other technological parameters, as well as their influence on casting properties, is substantiated. The results are important for optimizing the lost foam casting process, improving energy efficiency, ensuring environmental safety, and producing high-quality castings with complex geometry.

Keywords: Lost foam casting, refractory coating, coating thickness, casting quality, polystyrene pattern, heat transfer, gas evolution, molten metal, energy efficiency, environmental safety, complex castings, casting technology.

Introduction

The casting technology based on expendable (lost) patterns is widely used in developed countries such as the United States and Germany for casting cast iron, steel, and aluminum alloys. However, in China, this technology is mainly applied

to the casting of steel and cast iron, while its application in aluminum alloys remains relatively limited [1].

In the expendable pattern (lost foam) casting process, the filling of the mold with molten metal (where a polystyrene pattern is present inside the mold) is closely associated with the thermal decomposition of the pattern. The transition of the evaporative pattern (such as polystyrene) from a solid state to a liquid state, and then to a gaseous state, occurs under the influence of the heat of the molten metal. As a result, a number of physicochemical processes – still not fully understood – occur at the interface of the molten metal, pattern, and mold [2-5]. During the evaporation of the pattern, both solid and gaseous products are formed, such as CO, CO₂, H₂, N₂, and hydrocarbons (styrene, toluene, ethane, methane, benzene). The evaporation process of the polystyrene pattern under the influence of molten metal in the casting mold is highly complex, depends on many factors, and has not yet been fully studied [6]. The kinetics of pattern evaporation also depend on the technological properties of the casting mold, including:

- gas permeability;
- thermophysical properties;
- gating system parameters;
- pouring temperature;
- properties of the pattern material;
- contact surface area between the pattern and the molten metal.

ANALYSIS

Vighneshraj C.T. and co-authors, in their article titled “Innovative solutions and modern development trends in casting technology,” emphasize the following: Metal casting processes are widely used in the production of components. Over the years, various improvements and innovations have been introduced to increase the efficiency of these processes, enhance production capacity, and simultaneously reduce costs [7, 8]. The expendable pattern (lost foam) casting process is one of the advanced casting technologies and serves as an innovative alternative and complement to conventional casting methods. This technology enables the production of components with complex geometries and opens up new possibilities in the field of casting.

Shafeen P. and co-authors, in their article titled “Effect of polystyrene pattern coating on surface morphology and mechanical properties of Al–Si eutectic castings” emphasized the following: Polystyrene patterns are used to produce components with complex geometries. Among the various coatings applied to the pattern surface, graphite coating provided the best surface finish of the casting. In addition [9], it was determined that modification treatment using sodium salts improved the mechanical properties of the casting material, particularly increasing tensile strength and hardness.

Kandasamy Thiyagrajan and co-authors, in their article titled “Sand-clay mold casting and expendable pattern casting methods” emphasized the following: Compared to samples produced by sand-clay mold casting, cast components obtained using the expendable pattern (lost foam) casting method exhibit better results in terms of surface roughness and impact strength (i.e., these properties are lower in sand-clay mold casting). However, it was found that the hardness value is higher in sand-clay mold casting compared to the expendable pattern casting method [10-12]. In general, it was observed that the material properties vary depending on the selected casting method.

METHODOLOGY

Polystyrene does not harm the environment at low temperatures, as only a small amount of organic compounds are generated during the casting process, and these compounds can be easily collected [13]. These organic compounds can be treated using a negative-pressure suction-type combustion purifier. In addition, the reuse rate of used sand exceeds 95%.

Compared to conventional casting processes, the harmful effects of noise, CO (carbon monoxide), and silica dust are significantly reduced, resulting in a considerable improvement in environmental conditions.



Figure 1. Polystyrene pattern and the resulting casting



Models are produced from expanded polystyrene, methacrylate, polyalkylene, and polyalkylene carbonate materials. These materials are lightweight and require careful handling after production to prevent deformation.

Expanded polystyrene is mainly used in the casting of iron and its alloys. It is known that the density of these materials varies, which directly affects the quality of the cast products.

Therefore, to ensure the stability of the mechanical properties and microstructure of cast products, the pattern material must be uniform and consistent. The pattern used in expendable (lost foam) casting differs fundamentally from those used in conventional sand mold casting [14]. In traditional methods, wooden, metal, or plastic patterns are used to create a cavity in the mold and are removed before pouring.

The density of polystyrene should typically be around 20 kg/m³. This is very important because the amount of metal poured into the mold is calculated based on the density ratio between polystyrene and the metal. If the density is below the required level, there may not be enough metal for casting, and the mold may not be completely filled, resulting in the loss of both the pattern and the casting. Conversely, if the density is too high, excess metal will be poured, and surplus metal will remain in the ladle.

In addition, low-density polystyrene is easily broken and damaged, which leads to poor surface quality after machining, and these defects are also transferred to the surface of the casting.

The pattern coating typically consists of a refractory material and a binder mixture (sometimes only a refractory material), which forms a solid layer after being applied to the pattern surface and dried. This coating must be porous (gas-permeable) to allow gases to escape. Otherwise, gases accumulate inside the mold and lead to casting defects.

Depending on the type of coating, the mold filling time with molten metal varies. The gases generated must continuously escape from the mold during the casting process to prevent the formation of defects. Pyrolysis products formed during the expendable (lost foam) casting process are one of the main causes of casting defects [15].

Gas products must be removed in a timely manner: if they escape too quickly, a pressure drop may occur, leading to mold collapse. In this case, the coating layer

loses its support and cannot withstand the weight of the sand. An ideal pattern coating should ensure the balanced and timely removal of both gaseous and liquid decomposition products of the foam.

Factors such as coating material, solid content, viscosity, liquid absorption capacity, coating thickness, and gas permeability directly affect the quality of the casting. The process of applying the coating to the pattern must be carried out very carefully, as uniformity is essential. If the coating is applied in a wet state, its wetting properties must also be consistent.

Polystyrene was discovered in 1839 in Germany by Edward Simon. It is a petroleum-based product obtained through the polymerization of styrene monomers. The chemical structure of polystyrene consists only of carbon and hydrogen atoms with an attached benzene ring, which classifies it as a hydrocarbon. Its general formula is $(C_8H_8)_n$. During the expendable (lost foam) casting process, polystyrene undergoes thermal decomposition under the influence of high temperature.

Advantages of expendable (lost foam) casting:

1. No draft angle is required for pattern removal from the mold;
2. No parting lines or additional waste are generated, which improves surface quality and reduces the need for additional machining;
3. Unbonded sand is used, making the process simpler and more cost-effective compared to conventional silica or resin-bonded sand;
4. Naturally directed solidification occurs, resulting in fewer defects;
4. Expendable patterns are easy to cut, glue, and machine;
5. Multiple components can be combined into a single complex casting;
7. The process is suitable for aluminum, nickel alloys, steel, and cast irons (also applicable to stainless steel and copper alloys);
8. Versatility: parts ranging from 0.5 kg to several tons can be produced;
9. The minimum wall thickness is 2.5 mm, with no upper limit.

Disadvantages:

1. The cost of pattern production can be high in low-volume manufacturing;
2. Although lightweight, patterns are easily damaged and deformed.



Application areas:

Expendable (lost foam) casting is widely used for the production of complex and large-volume components, including:

- automotive and marine engine blocks and cylinder heads;
- compressors (for heating and cooling systems);
- electric motor housings;
- counterweights for heavy machinery;
- hydraulic valves, hydrants, and pipe fittings;
- heat exchangers.

This technology is particularly attractive because it allows the simultaneous formation of holes, threaded connections, and internal fluid channels within the casting.

CONCLUSION

The expendable (lost foam) casting technology represents an advanced and efficient method for producing complex-shaped components with high dimensional accuracy and good surface quality. The process is characterized by the simultaneous interaction of molten metal and the pattern, which involves complex thermal decomposition and gas evolution phenomena. Therefore, controlling factors such as pattern material properties, coating characteristics, gas permeability, and pouring parameters is essential to ensure high-quality castings. The use of polystyrene patterns provides significant technological advantages, including design flexibility, reduced machining, and improved material utilization. At the same time, attention must be given to pattern density, coating uniformity, and gas removal to prevent defects. Despite certain limitations, such as sensitivity of patterns and higher costs in low-volume production, this technology offers broad application potential in industries such as automotive, machinery, and energy systems.

Overall, expendable pattern casting continues to evolve as a modern and innovative manufacturing technology, contributing to improved efficiency, reduced environmental impact, and expanded capabilities in metal casting.



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