A cutting edge process

The Lost Foam casting process has grown from a state of infancy over the past 15 to 20 years to a modern, though steadily evolving, manufacturing process today. Though it was once thought of as a niche or specialty process, Lost Foam has come to the forefront as a process with widespread acceptance and a multitude of uses in different products. The process has found a long standing home in many different industries, products, and alloys because of the many advantages that it can offer to casting users.

The Lost Foam process begins with raw, unexpanded beads of polystyrene (EPS) or similar polymers. These beads are heated with steam, causing a blowing agent to expand the polymer beads until their volume expands to 30 or 40 times the original volume. These beads are then aged to equalise their internal pressure with the ambient pressure.

After ageing, the beads are then transported to the moulding machine. The moulding machine then injects the beads into the tool using specialised fill injectors which blow a mixture of air and beads into a well vented tool. Steam is then applied to the tool, where it permeates the beads and causes them to expand and fuse together inside the mould. After a cooling sequence, moulded shapes are extracted from the machine.

Complete parts can be assembled by gluing multiple segments together. These completed parts are assembled into a final 'cluster' in preparation for casting. The clusters are dipped into a refractory slurry that flows into the internal passages of the part and covers all exposed surfaces. The wet cluster is then air dried in a thermal oven before being transferred to the casting line.

At the casting line, the coated pattern cluster is placed into the flask, either by hand or with an automated placement device. Sand runs down around the part in a gentle distributed pattern. The flask is vibrated while the sand fills progress to cause sand to fill the internal cavities of the part.

The flask is indexed to the pouring station. At the pouring station, liquid metal is introduced into the pattern through a downsprue, and then melts out and replaces the foam as it fills the pattern cavity. The finished casting can be removed from the flask after enough time passes to ensure sufficient cooling.

The Lost Foam process offers a great number of advantages for casting users. Casting features and geometry that would be very difficult or impossible to make with other processes are routinely produced using Lost Foam.
The Lost Foam cylinder head and engine block are key components of the new family of engines from GM Powertrain (Photo courtesy of GM Powertrain, Detroit, Michigan)

achieved through component integration and reduction, as well as a dramatic reduction in machining, finishing, and assembly operations. The capital and in process inventory costs associated with these operations were also reduced by a large amount.

Another recent example of the benefits a manufacturer has realized from utilizing Lost Foam is the Vortec 4200 inline six cylinder engine produced by General Motors Powertrain. An aluminium engine block and cylinder head form the basis of the engine, the powertrain package of choice for General Motors' award winning sport utility vehicles. This inline six cylinder engine has a 4.2L displacement with a peak power of 270hp (202kW). The entire engine assembly consists of 593 components, as opposed to 686 for a DOHC V6 engine of similar size.

The new engine design takes full advantage of Lost Foam to impart value added features to the end product. In addition to the reduction in the number of parts required, far less machining is required on the casting. The net result of all of these advantages is that the engine is produced for a lower cost than a comparable V6 or V8 engine.

Both Mercury Marine and General Motors have made Lost Foam an integral part of their manufacturing success because of the benefits that the process offers them. However, even as the process has developed to a plateau of maturity, new technologies continue to be developed which allow Lost Foam castings with more complex geometry and tighter materials requirements to be made, all while improving on manufacturing productivity by reducing per piece manufacturing time and cost. The following section of this article describes some of the new technologies in depth.

Process enhancements for producing high performance aluminium castings in Lost Foam

Traditional aluminium Lost Foam castings have been limited in their material properties because of the long cooling times typical in Lost Foam aluminium. Because of these long cooling times, the high cycle fatigue strengths may not match those reached in a chilled type casting process. A new development in Lost Foam technology allows the foundry to produce castings with fatigue strengths comparable to or better than those produced by permanent or semi-permanent mould processes while still offering the design flexibility and component integration capabilities of Lost Foam.

This development is the use of pressurised Lost Foam casting, which uses the application of isostatic pressure during solidification to reduce the amount of internal porosity formed to near negligible levels. The basic premise of the process is simple — aluminium that solidifies under pressure will not have the degree of distributed microporosity and interdendritic porosity as an aluminium alloy allowed to solidify at ambient pressure.

A reduction of internal porosity will result in an increase in fatigue strength and elongation properties of the casting metal. The patented pressurised Lost Foam process was developed by the French company Aluminium Pechiney and is licensed worldwide under the trade name Castyal. The process is currently in use at Albert Handtmann GmbH in Biebergach, Germany as well as Mercury Marine's new state of the art facility in Fond du Lac, Wisconsin, USA.

Mercury Marine's three cylinder aluminium engine block consolidated eight separate parts into one component (Photo courtesy of Mercury Marine, Inc, Fond du Lac, Wisconsin, USA)
The new patented multiple direction compaction system increases the capabilities of the process.

In concept, pressurised Lost Foam is very similar to the conventional Lost Foam casting process. After the foam is compacted in the sand, the flask is indexed to another section of the flask conveying loop. Here, an overhead gantry crane travels to the flask, lowers down, and picks up the flask automatically. The gantry crane then carries the flask over to one of six pressure vessels and positions the flask inside of it.

A pouring robot dips a ladle of molten aluminium from a holding furnace, brings it to the casting flask, and then pours the aluminium into the downsprue. Once the robot finishes the pouring process, it moves out of the way and a hinged lid on the pouring vessel comes down and seals against the top of the pressure vessel.

A pressure ramping system builds pressure in the vessel until it reaches approximately 150psi (10bars). The vessel remains pressurised for approximately 15min while the metal solidifies.

Mercury Castings, a division of Mercury Marine, plans to use the pressurised Lost Foam process to produce key cast components of the Mercury product line. In addition, Mercury Castings plans to expand its customer base by growing from being a captive foundry supplying internal parts to being a source of Lost Foam castings to outside customers as well. Dave Dickinson, director of Mercury Castings said, "OEMs are looking for Lost Foam casters with our skill in design and casting of complex small engine components.

There was a niche that needed to be filled, and we had already developed the expertise to do it.”

The pressurised Lost Foam process produces castings with material properties unachievable in a conventional Lost Foam casting process. The application of pressure reduces internal porosity to nearly undetectable levels as well as increasing elongation properties. Most significant, however, is the increase in high cycle fatigue strength that the process creates.

**Process equipment enhancements for the Lost Foam process**

Several other significant technologies have been developed in the area of process equipment used in the sand fill and compaction process. As with the new advances in pressurised Lost Foam technology, the net result of these developments is that the practising Lost Foam foundry can offer a better product to its customers, whether that means more salient features, lower cost, or other desirable product enhancements.

In the sand fill and compaction portion of the process, loose sand is 'rained' down around a foam pattern cluster while the flask is being vibrated. The vibrations cause the sand to flow into pattern cavities and fill them with sand. During this process, sequential layers of sand are added to the flask. Successful filling of sand into pattern cavities depends on the ability of process equipment to accurately drop the correct amount of sand into the system and around the foam pattern. A pattern will not be filled if rainfall sand levels fall below the pattern opening, or if so much sand is raised into the flask that the overburden prevents the cavity from filling. Traditional systems have used timed open and closed intervals of the sand rain gate to accomplish this task. However, changes in the fluidity of sand or media used for the process can lead to inconsistency in deposited sand levels.

A patented new system from Vulcan Engineering Co. of the USA, uses a closed loop measuring and dosing system to repeatedly measure out the same amount of sand in every flask. The system consists of a batch hopper with a transparent window on the front, a linear positioning system, and a sensor that can detect the presence of sand or no sand behind the sensing window. This set of components works together as a system to repeatedly measure out and deposit the same amount of sand into a casting flask during the sand fill and compaction process.

This system works with an overhead sand valve to fill a batch hopper with sand. The system then uses a search algorithm to move the sensor up and down and detect the upper edge of the sand in the batch hopper. For each fill zone in a fill and compaction recipe, the system will move the sensor down a certain distance. The sand gate then opens, and sand is allowed to flow out of the batch hopper until the sensor detects the upper edge again. This system automatically corrects for changes in sand flowability, resulting in a more robust and controllable process. A patented new sand gate design also makes the process more robust and repeatable with the ability to produce two distinct sand rainfall patterns and still create an even, level sand fill in the flask. One of these rainfall patterns can be used to fill around the part in a gentle, controlled manner while the other one could be used for tapping off the flask after the bulk of the filling was done, resulting in improved cycle time and productivity.

New equipment innovations have also improved the process of vibrating the flask to move sand within. A patented new system marketed under the trade name Vector-Flo™ by Vulcan Engineering Co offers unseen flexibility for vibration control for Lost Foam. Traditional systems for sand fill and compaction use horizontal or vertical vibrations to move sand around within a flask. The only thing that can be adjusted while the system is running is the speed of the drive system. With the new sand fill and compaction system, vibration frequency, amplitude, and direction are all user selectable and can be changed 'on the fly' during a fill and compaction cycle.
The construction of the new system is inherently simple. A structural steel frame surrounds the flask on all sides. The structure of the frame is large enough to allow rails to pass through as well as a gondola (carriage) and a flask to be indexed in and out of the system. Four individual eccentric weight motors are mounted to the outside frame to provide vibration energy to shake the flask.

In operation, a flask is indexed into the system and the frame lifts up around flask, lifting the flask clear of the gondola. An upper set of clamp pads comes down and clamps the flask once it is clear of the gondola. Once the flask has cleared the gondola, an upper set of clamp pads moves down and clamps the flask tightly on diagonals through the centre of the flask.

Forces for vibrating the flask are generated by four different motors with eccentric weights on them. These motors are custom engineered with a special integral sensor that monitors the speed and position of the eccentric weight. A central motor control system monitors and controls all four motors simultaneously. This control system can run all four motors at identical speeds with any combination of relative phase angles between the motors. This phasing ability gives the system the ability to actively add or subtract the forces created by the rotating motors. By using different combinations of motor phase angles, many different vibrations can be generated. This gives the user of the equipment more flexibility to apply toward the process.

The system is designed to be mass symmetric about the centreline of the flask. This creates vibration patterns and a system vibration pattern which is uniform from one side of the flask to another. In addition, the system includes a height control system that maintains an even height of the flask regardless of the level of sand fill. This active height control system eliminates the use of linkage bars and positive stops, and prevents any vibration from being transmitted to the base and foundation of the system.

The new system also gives the user the ability to preferentially move sand into pattern cavities. With the new fill and compaction system, sand can even be made to climb uphill to fill a pattern cavity with this new technology. This improvement in process capability will allow product designers more flexibility in Lost Foam part design and will improve manufacturing productivity.

The Lost Foam casting process has already established itself as an important process in the manufacture of high value added casting applications. As process technology for the process continues to grow, so too will commercial usage of castings made using the process. All of these process and equipment improvements are some of the tools that will help keep the Lost Foam process on the cutting edge of foundry technology.

Reader Reply No.15

**Gemco capability**

Gemco Engineers, located in Eindhoven, The Netherlands, is an independent engineering and contracting firm in the foundry industry.

During the last decade Gemco has developed an in depth knowledge of the Lost Foam process. Since the establishment of the Gemco Lost Foam Center in 1996, Gemco has had in house possibilities for Lost Foam product development and prototyping for customers.

The Lost Foam Center also manufactures foam patterns for several iron, aluminium and steel foundries in Europe. This wide experience has recently led to the development, design and realisation of a modular aluminium Lost Foam Foundry. This new, innovative foundry concept, consists of specialist Lost Foam equipment, designed by Lost Foam specialists. Gemco can really help foundries from the first step in Lost Foam to the realisation of a complete foundry.

Reader Reply No.16

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