Foseco Ferrous Foundryman's Handbook

Edited by

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Preface

The last edition of the *Foseco Foundryman's Handbook* was published in 1994 and like all the earlier editions, it aimed to provide a practical reference book for all those involved in making castings in any of the commonly used alloys by any of the usual moulding methods. In order to keep the *Handbook* to a reasonable size, it was not possible to deal with all the common casting alloys in detail. Since 1994 the technology of casting has continued to develop and has become more specialised so that it has been decided to publish the new edition of the *Handbook* in two volumes:

Ferrous	dealing with grey, ductile and special purpose cast irons together with carbon, low alloy and high alloy steels
Non-ferrous	dealing with aluminium, copper and magnesium casting alloys

Certain chapters (with slight modifications) are common to both volumes: these chapters include tables and general data, sands and sand bonding systems, resin bonded sand, sodium silicate bonded sand and feeding systems. The remaining chapters have been written specifically for each volume.

The *Handbook* refers to many Foseco products. Not all of the products are available in every country and in a few cases, product names may vary. Users should always contact their local Foseco company to check whether a particular product or its equivalent is available.

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John R. Brown

Chapter 15
Lost foam casting

Principle of the process

Unlike any other sand casting process, no binders are used. Pre-forms of the parts to be cast are moulded in expandable polystyrene or special expandable copolymers. Complex shapes can be formed by gluing mouldings together. The pre-forms are assembled into a cluster around a sprue then coated with a refractory paint. The cluster is invested in dry sand in a simple moulding box and the sand compacted by vibration. Metal is poured, vaporising the preform and replacing it to form the casting (Fig. 15.1).

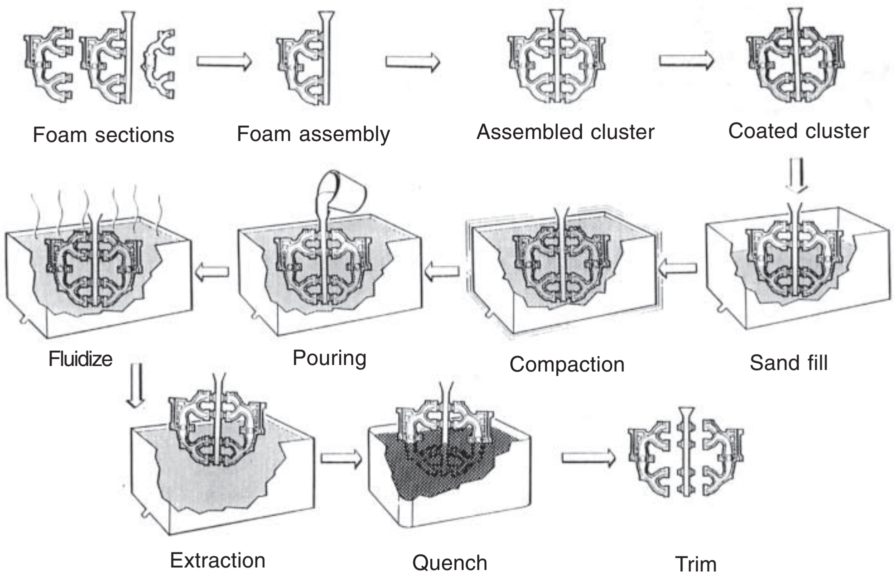

Figure 15.1 *The lost foam casting process.*

Many problems hindered the development of the lost foam casting process. By working closely together, designers, foundries, equipment engineers, polymer manufacturers and coating suppliers have now removed these barriers, making the process a cost effective way to manufacture quality castings. The casting of iron components was initially very difficult due to the formation of lustrous carbon defects on the surface and subsurface carbonaceous inclusions, which were only revealed on machining. Essential to the advancement of ferrous lost foam (LF) casting was the development of copolymers, such as the patented Foseco Low Carbon Bead, which helps to eliminate these defects and so make the process viable.

Patternmaking

The raw bead to be moulded is purchased from a chemical supplier. It consists of spherical beads of polystyrene (EPS) or copolymer of carefully graded size. The bead is impregnated during manufacture with a blowing agent, pentane. The first step is to pre-expand the bead to the required density by steam heating. It is then moulded in a press rather like a plastic injection moulding press. The moulding tool is made of aluminium, hollow-backed to have a wall thickness of around 8 mm. The pre-expanded bead is blown into the closed die, which is then steam heated causing the beads to expand further and fuse together. After fusing, the die is cooled with water sprays (often with vacuum assistance) so that the pattern is cooled sufficiently to be ejected without distortion.

The cycle time is dependent on the heating and cooling of the die, a process which is necessarily rather slow, taking 1–2 minutes for a cycle. The moulding machines are large with pattern plate dimensions typically 800 × 600 mm or 1000 × 700 mm so that multiple impression dies can be used to increase the production rate.

Some lost foam foundries purchase foam patterns from a specialist supplier, such as Foseco–Morval (in the USA and Canada). Others make their own patterns. The casting reproduces in astonishing detail the surface appearance of the foam pattern. A great deal of effort has been put into improving surface quality and special moulding techniques such as Foseco–Morval's 'Ventless Moulding Process' have been developed to minimise bead-trace. EPS mouldings for casting have now reached levels of quality and complexity far beyond that expected from a material designed originally for packaging.

Joining patterns

Where possible, patterns are moulded in one piece using the techniques developed for plastic injection moulding such as metal 'pull-backs' and collapsible cores, but many of the complex shapes needed to make castings cannot be moulded in one piece. Sections of patterns are glued together quickly and precisely using hot melt adhesives using special glue-printing machines (Fig. 15.2). The adhesive is reproduced in the finished casting so that it is important to lay down a controlled amount of glue to avoid an unsightly glue line.

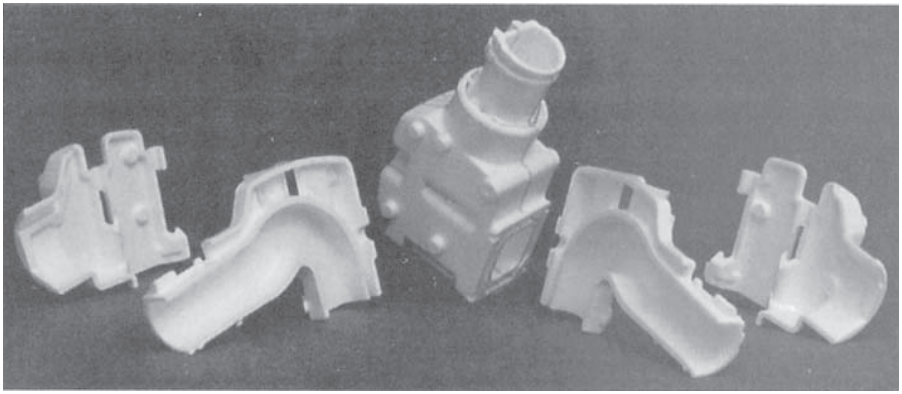

Figure 15.2 *Sections of patterns are glued together to form complex shapes.*

Assembling clusters

Some large castings are made singly, the EPS pattern being attached to a down-sprue of EPS or, in the case of ferrous castings, usually of hollow ceramic fibre refractory. Smaller castings are made in clusters, the patterns being assembled around the sprue with the ingates acting also as supports for the cluster.

Coating the patterns

The foam pattern must be covered with a refractory coating before casting. If no coating is used, sand erosion occurs which can lead to mould collapse during casting. The coatings are applied by dipping and must be thoroughly dried in a low temperature oven before casting.

Investing in sand

The coated pattern clusters are placed in a steel box and dry silica sand poured around. As the box is filled, it is vibrated to compact the sand and cause it to flow into the cavities of the pattern. It was the failure to vibrate correctly that led to so many problems in the early days of lost foam. Following much research by equipment suppliers, good vibration techniques have been developed and patterns with complex internal form can now be reliably invested. It is not possible to persuade sand to flow uphill by vibration so patterns must be oriented in such a way that internal cavities are filled horizontally or downwards.

The mechanism of casting into foam patterns

When low melting point metals such as aluminium alloys are cast into EPS foam, the advancing metal melts and degrades the polystyrene to lower molecular weight polymers and monomers. These residues are then transported through the coating as both liquids and gases into the sand. This process is illustrated in Fig. 15.3. Failure to remove the gaseous residues quickly enough results in slow mould filling and misrun castings, Fig.15.4. If the gases escape too quickly, however, then the metal will fill the cavity in an uncontrolled turbulent manner giving rise to oxide film defects and even mould collapse (Fig. 15.5). If the liquid residues are not absorbed by the coating, a thin carbon film may form on the liquid metal front which, if trapped, may cause a 'carbon-fold' defect (Fig. 15.6).

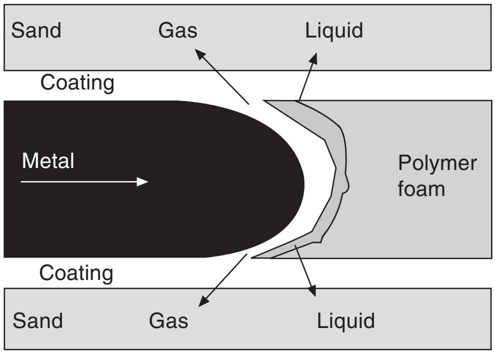

Figure 15.3 *An illustration of the transport of gas and liquid polymer degradation residues through STYROMOL and SEMCO PERM lost foam coatings.*

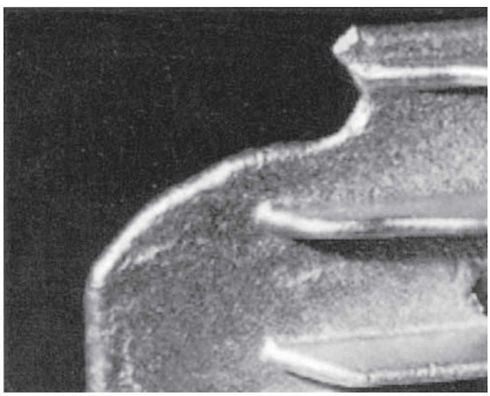

Figure 15.4 *A mis-run defect caused by the use of a coating with insufficient permeability.*

When iron is cast, the higher temperature causes rapid breakdown of the EPS with much gas formation. Vacuum may be applied to the casting flask to aid the removal of the gas. High temperature pyrolysis of EPS results in tar-like carbonaceous products which are not always able to escape from the mould. They break down further to a form of carbon called 'lustrous carbon' which causes a defect characterised by pitting and wrinkling of the

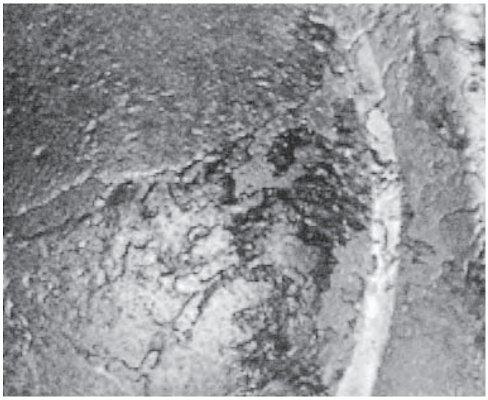

Figure 15.5 *An oxide film defect (on aluminium) caused by turbulent mould filling through use of a coating with too high permeability.*

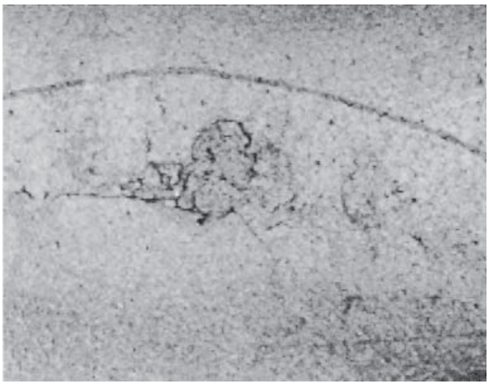

Figure 15.6 *A cold fold defect (on aluminium) caused by poor liquid residue removal.*

upper surface of the casting. High carbon irons, such as ductile iron, are most prone to the defect. In the early 1980s it seemed as though the use of the lost foam process would be seriously restricted by this problem. It was then found that the polymer PMMA (polymethyl methacrylate) depolymerises completely under heat to gaseous monomer leaving no residues in the casting. PMMA is not easy to make in an expandable form and not easy to mould either. Foseco has developed 'Low Carbon Bead', a copolymer of EPS-PMMA which has moulding properties similar to EPS and eliminates lustrous carbon in all but the heaviest section castings (Fig. 15.7).

Foseco and SMC have developed STYROMOL and SEMCO PERM lost foam coatings, designed to remove both the liquid and gaseous residues at the rate required to give controlled mould filling and defect-free castings (see p. 239). These coatings include:

Insulating STYROMOL 169 series coatings for aluminium.
Non insulating STYROMOL and SEMCO PERM coatings for grey and ductile iron.

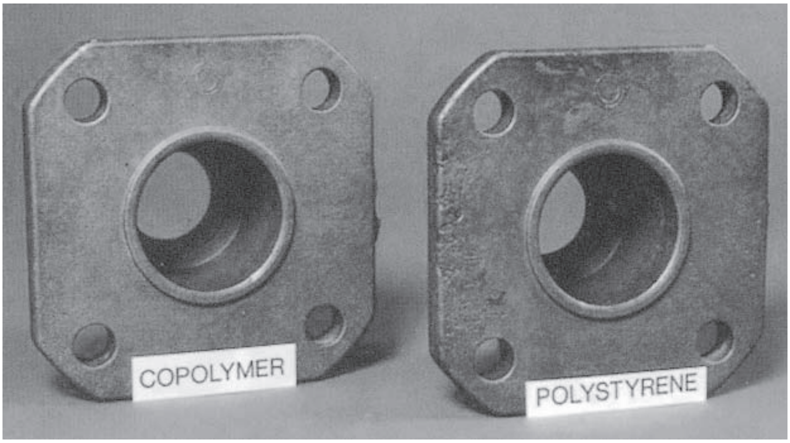

Figure 15.7 *The use of Foseco Low Carbon Copolymer Bead eliminates lustrous carbon defects on grey and ductile iron castings.*

High refractoriness STYROMOL and SEMCO PERM coatings for chrome irons, manganese and carbon steels.

Methoding

Patterns must be orientated to allow complete filling with sand. Ingates must fulfil the dual role of supporting the fragile pattern cluster and controlling the metal flow. In aluminium casting, it is mainly the permeability of the coating that controls the filling of the casting and very gentle, turbulence free filling is possible with direct pouring. Iron castings, having higher density and heat content, are usually bottom gated to allow controlled mould filling.

Advantages of lost foam casting

1. Low capital cost: The capital cost of a lost foam foundry is as little as 50% of a green sand plant of similar capacity.
2. Low tooling cost: Though tools are expensive, their life is long, so for long-running, high volume parts like aluminium manifolds, cylinder heads and other automotive parts, tool costs are much lower than for gravity or low pressure dies which have a shorter life and require multiple tool sets because of the long cycle time needed for each casting. For shorter running parts the advantage is less and may even be a disadvantage.
3. Reduced grinding and finishing: There is a major advantage on most castings since grinding is restricted only to removing ingates.
4. Reduced machining: On many applications, machining is greatly reduced and in some cases eliminated completely.

5. Ability to make complex castings: For suitable applications, the ability to glue patterns together to make complex parts is a major advantage.
6. Reduced environmental problems: Lost foam is fume free in the foundry and the sand, which contains the EPS residues, is easily reclaimed using a simple thermal process.

Disadvantages

1. The process is difficult to automate completely; cluster assembly and coating involves manual labour unless a complete casting plant is dedicated to one casting type so that specialised mechanical handling can be developed.
2. Methoding the casting is still largely hit and miss and a good deal of experimentation is needed before a good casting is achieved.
3. Cast-to-size can be achieved but only after several tool modifications because the contractions of foam and casting cannot yet be accurately predicted.
4. Because of 2 and 3, long lead times are inevitable for all new castings.

Applications

The successful foundries have been extremely selective in choosing casting applications. In general, lost foam is not regarded as a low-cost method of casting. It is the final cost of the finished component that must be considered.

Aluminium castings

By far the largest proportion of Al castings are used in the automotive industry so this has proved the biggest market for LF.

Inlet manifolds: This was the first successful application and is still being used. The usual process for manifolds is gravity diecasting, a slow process with high tooling cost. Lost foam is used to best advantage in water-jacketted carburettor manifolds.

Cylinder heads: The fastest growing automotive application. Heads are conventionally cast by gravity die with a complex package of cores set into an iron die. Use of LF gives the designer rather more freedom to cool the working face effectively, the combustion chambers can be formed 'as-cast', avoiding an expensive machining operation and bolt holes can be cast.

Cylinder blocks: Automotive companies are moving away from grey iron towards Al blocks. LF offers substantial design advantages; features can be cast in, such as the water pump cavity, alternator bracket, oil filter mounting pad. Oil feed and drain line and coolant lines can also be cast more effectively.

A variety of other automotive parts are being made, water pump housings, brackets, heat exchangers, fuel pumps, brake cylinders. Applications will increase as designers become aware of the design potential. High strength parts such as suspension arms have proved difficult because of metallurgical differences between LF and conventional castings. New developments such as the Castyral Process in which pressure is applied to the solidifying casting are being adopted to improve strength.

Grey iron

Modern automated green sand is such a fast and efficient process that LF cannot compete on cost of the casting alone. Foundries must look for castings where the precision of LF gives savings in machining costs.

Stator cases: This has proved one of the most successful applications. There are weight savings of up to 40% to be made through thinner cooling fins, machining of the bore can be reduced, though not eliminated, mounting feet can be cast complete with bolt holes.

Valves: Grey iron valve bodies, caps and gates are being cast in large numbers. Flange faces are flat so by casting-in bolt holes etc. machining can be eliminated completely in many cases.

Ductile iron

Pipe fittings: One of the most successful applications, the precision of LF is so great that flanges can be cast flat complete with cast bolt holes so that machining can be eliminated altogether. Bends, tees, spigots etc. up to at least 300 mm diameter are being cast in large volume, replacing resin sand moulding. Achieving success has not been easy because of distortion problems both on foam patterns and castings, but the potential benefits are so great that foundries in Europe and Japan have persisted and finally achieved success.

Valves: Machining can be eliminated completely in many cases, particularly with redesign of the part. LF is becoming the accepted way of making water valves up to about 150 mm pipe diameter.

Hubs: Lower weight and reduced machining is possible.

Differential cases: Several automotive companies have persisted with this difficult casting. The advantages are reduced machining (on the internal surfaces) and better balance.

Manifolds: Weight savings are achieved through control of wall thickness and clear passages improve performance.

Brackets: Bolt holes can be cast so that machining can be eliminated completely in some cases.

Other alloys

Steel: The process is not suitable for most steel castings because of the danger of carbon pick-up from the foam pattern. The carbon pick-up is not uniform, but carbon-rich 'inclusions' are found in carbon steel castings made using the process. Residues from the pyrolysis of the EPS become trapped in the liquid steel giving rise to areas of high carbon, up to 0.7%C, often under the upper surfaces of the casting where the EPS residue has been unable to float out of the steel. Such defects are unacceptable in most steel castings. Even the use of foam patterns made from PMMA does not entirely eliminate the problem. Some high carbon steels, such as austenitic manganese steel which has around 1.25%C content, can be successfully cast using lost foam.

Wear resistant castings: Elimination of flash and dimensional precision give LF a major advantage over other casting methods. Grinding balls can be made in enormous clusters. Shot blast parts are made in large numbers. Slurry pump bodies can be cast with minimum machining saving many hours of machining time. Wherever the rather high tooling costs can be justified, LF has become the standard method of manufacture.

Duplex castings: The process lends itself to making castings containing inserts, such as tungsten carbide or ceramic. The inserts are fitted into the foam pattern before casting.

The future

LF casting has now passed through the critical development stage to become a mature foundry process. While many of the early technical problems have been overcome there are still some to be solved:

Cluster assembly, still requires too much manual work.
Methoding, still a matter of trial and error, though the current work on modelling is helping.
Distortion of foam patterns can be a problem, but more and more the coating is seen as a way of stiffening fragile patterns.
Glueing, expensive and not easy on non-flat joint lines.
Automation, better methods of mechanically handling foam patterns for cluster assembly and coating are needed.

Lost foam will not replace conventional casting processes. It is seen as a clean process, all the used sand can be easily reclaimed and chemical residues burnt off so that it is probably the most environmentally acceptable foundry process at present available. This will prove to be a growing asset in the future. But that is not the main reason. For the major automotive groups the reason is the design flexibility offered.