The Evaporative Pattern Casting process

The Evaporative Pattern Casting (EPC) process – also called the expanded polystyrene moulding process, the evaporative foam process, the lost foam process and by various trade names – has been known to the foundry industry since 1958. It is now established in the production of castings for certain niche applications that include, for example, the production of aluminium alloy cylinder head castings. It has been predicted that by 2007, 29% of aluminium castings will be produced by the EPC process.

In the EPC process, foamed patterns coated with a refractory are embedded in a dry, unbonded sand that is compacted by vibration to provide sufficient rigidity to the mould to enable it to withstand the pressures associated with the pouring of metal.

The pattern remains in-situ during the pouring stage and is vaporised by the incoming metal that replicates the pattern shape to produce the casting. After cooling the casting and unbonded sand are easily removed from the moulding flask, the casting is retrieved for finishing and the sand recovered for reuse.

Advantages of the process

The expendable pattern eliminates the requirement for a joint line in the mould and provides flexibility for both the designer and foundryman. The need for mould taper is eliminated and the castings consequently weigh less than their sand cast counterparts and require less machining. One of the many advantages of the EPC process is the low finishing cost because of the absence of cores, the need for corebox and flash due to core clearance or mould joint lines. Holes as small as 1.5mm in diameter and slots with a width of 1.0mm can be routinely cast. Accurate tolerances can be held and the requirement for machining is reduced.

A further advantage of the EPC process is that inserts, such as bolts etc. can be glued into the pattern or the pattern can be moulded around the insert, and when the metal is poured the insert remains in-situ in the metal.

Process characteristics

The EPC process is unique, and as such, requires specialist skills and practices that are simply not transferable from conventional sand casting processes. The foam pattern requires special handling, especially when composed of multiple parts that must first be assembled. The disposable pattern eliminates the requirement for a joint line in the mould so that the pattern can be orientated to suit sand flow during mould production and metal flow during filling. Sand flow is especially important in the production of castings with complex internal features that in any other process would be produced by separate sand cores.

Pattern quality

Pattern quality is a function of bead size and density and is normally determined by the type of bead and the size of the preexpanded bead, which in turn is controlled by the vacuum and steam conditions. A high density produces a better pattern surface finish. However, a high density will impair mould filling and produce excessive decomposition products. This problem can be exacerbated by a number of process variables that include:

- Low permeability in the sand
- Low vacuum level applied to the mould during casting
- Excessive coating on the pattern
- Too many patterns on one gating system

A pattern density of between 19g and 23g/l is recommended to provide the required pattern strength and surface finish and avoid unacceptable problems. The surface quality of the pattern is also affected by the need for vents and the finer the die vents the less chance of them being reproduced on the pattern.

Pattern joining

If pattern joining is necessary, a synthetic rubber or EVA adhesive is recommended. Ideally, the glue should be printed onto the pattern or the pattern dipped into the glue using automated systems. This minimises the amount of glue used and, therefore, the amount of gas evolved by the join. If the pattern has no internal cavity the glue need only be applied to the outer edges to provide the join and prevent ingress of the coating medium. If a hot plate is used to melt the edges of the pattern, prior to pressing the joining surfaces together, the need for an adhesive is eliminated. However, care must be exercised to avoid pattern material being squeezed out.

Pattern coating

Coatings can vary from country to country even when they have the same reference number. This is due to the use of local materials, even though the proportions of such materials as molochite, mullite, silica flour, talc, mica, zircon, etc may be the same. The main consideration is coating thickness and permeability. Generally, the denser the pattern the thinner should be the coating to improve permeability. However, the danger is that this thinner coating may result in metal penetration. Alternatively, using coarser sand and/or a higher vacuum level can enhance the removal of the products of pattern decomposition.

Metal flow

The flow of metal in the EPC process is quite different from that in other sand casting processes. The presence of a pattern that decomposes to a liquid and then gaseous phase retards the rate of metal flow. Consequently, the application of conventional fluid mechanics calculations for gating is inappropriate.

The organic adhesive compounds used to join the pattern and/or gating segments together also produce decomposition products. One of the secrets to successful exploitation of the process is managing the metal flow into the mould and the gaseous
flow out of the mould. The type and amount of adhesive, the thickness and permeability of the coating, the heat content and density of the metal being cast, the gating system design and the use of vacuum all influence metal and gas flow. One of the first things to be considered is the pattern thickness and the distance the metal must run. For a casting with a thin section, anything below 5mm, it is advisable to top gate. This applies to the casting at ferrous or non-ferrous materials. Sufficient down sprue must be provided to allow the castings to be positioned in the bottom two thirds of the box. Most foundries have developed their own gating systems using round hollow or solid bars of various diameter depending on size and number of casting being cast per sprue. Hollow gating components support filling because they reduce the resistance to metal flow caused by the build up of pressure from pattern decomposition.

Current research at Loughborough

The EPC processing of a hypereutectic aluminium silicon alloy, originally developed for diecasting, is being evaluated. The alloy is suitable for the production of automotive cylinder blocks and other applications where resistance to wear is important. The research has evaluated the effect of processing variables on the structure and integrity of castings. The integrity is defined as freedom from shrinkage, gas porosity and non-metallic inclusions and the structure is defined as the form of the primary silicon and the eutectic matrix. The principal process variables that have been evaluated include foam density, adhesive, pattern coating, casting conditions, vacuum level, pouring temperature and melt additives.

Comparative tests were conducted for metal poured using the EPC process, the CO₂ silicate process and gravity die casting. The comparisons were taken from cast test bars sections of 15mm diameter. The metallographic samples were taken 20mm away from the ingate. The structures shown are for material that has not been treated to refine the primary silicon. Figure 1 shows (i-t) the as cast structure for castings produced in a CO₂ silicate process mould, an EPC process mould and a gravity die. The structure of the EPC sample shows the advantage obtained by creating airflow past the casting using vacuum suction.

The mechanical properties obtained from the EPC process material are also encouraging with a UTS of 152N/mm² compared to 116 N/mm² for the CO₂ silicate process and 159.6 N/mm² for the gravity die cast material. The final stage in the research will consider the use of primary silicon refining agents, such as phosphor-copper, to optimise the structure and properties.

Reader Reply No.17

References
1 Shroyer, H F (1958), US Patent 2830343
2 Fiseco, Shaping the future with the lost foam casting process, Foundry practice 232, June 1999, p12-16

USA EPS Lost Foam Market

Since the late 1990s, the Lost Foam market in the USA has seen rapid growth, write Dr Fred Sonnenberg, Technical Advisor – Lost Foam at StyroChem.

The technology was introduced in 1958 and had been growing sluggishly.

Commercial products

There are two producers of lost foam EPS beads in the USA, NOVA Chemical and StyroChem. NOVA offers one grade, F271TF while StyroChem offers a similar grade, T170B. StyroChem also offers second generation EPS lost foam beads, that utilise a mixture of pentane blowing agents. The triblend mixture of pentanes offers easier expandability during the preexpansion step to achieve lower density potential of the moulded EPS patterns.

While StyroChem’s T170B can generally be expanded at densities and moulded as low as 20.8g/l (1.3pcf), the ‘180’ series EPS lost foam beads can be expanded at 17.6g/l (1.1pcf). For thicker patterns, D180B is recommended because it has a larger average bead size of 450µm compared to 350µm for T170B and the T180D products.

Small ‘X’ bead

StyroChem has developed a small ‘X’ bead containing triblend blowing agent which results in a product that can be expanded to a low density. The smaller average bead size of 250µm can be used to fill thin wall sections more easily than a ‘T’ grade having an average bead size of 350µm.

Shown above is a typical bead size distribution of lost foam EPS grades as determined by particle size analysis.

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Commercial USA EPS lost foam grades