Mould Related Defects

DEFECTS PRINCIPALLY RELATED TO THE PRODUCTION OF POOR QUALITY MOULDS

Introduction

In addition to those problems resulting from the use of poor quality sand, there are also a number caused by unsatisfactory moulding techniques, lack of maintenance, the use of unsuitable moulding boxes or poor pattern equipment. These aspects adversely affect the quality of the moulds produced, resulting in the following defects:

- Shrinkage porosity
- Cross joint/mismatch
- Ram-off
- Flashes and Crushes

Shrinkage Porosity

Shrinkage defects can result from inadequate control over metallurgy and pouring temperature. The most common reason for shrinkage is, however, mould wall movement, due to the production of soft moulds.

Mould wall movement as a cause of shrinkage defects

How shrinkage occurs

The solidification of graphitic cast iron involves stages in which the volume of the metal decreases, for example due to liquid contraction or to primary austenite separation, and a subsequent stage at which expansion occurs owing to the precipitation of graphite during eutectic solidification. In commercially produced grey and ductile cast irons, the expansion which occurs during eutectic solidification is due to graphite formation and more than offsets the decreases in volume in other stages of solidification.

In principle, it should be possible to produce completely sound castings without any feeding.

In practice, the extent to which this can be achieved depends upon whether the mould has sufficient strength or rigidity to resist the forces which result from ferrostatic pressure and the expansion occurring during eutectic solidification.

Thus the concept of mould rigidity has become closely related to casting soundness. Moulds of low rigidity are least able to resist the expansion forces acting upon them, dilation of the mould cavity occurs, oversize castings result, and if unfed, the cast-
Mould Related Defects

ings contain surface and/or internal shrinkage defects. Fig 1 shows how mould rigidity affects both casting dimensions and the size of external 'pipes'.

The effects of mould rigidity upon soundness are shown schematically in Figs 2 & 3. In the first case (Fig 2) with a mould of low rigidity, the mould cavity enlarges under the action of heat and extra liquid iron is drawn from the feeding or gating systems to compensate for the mould wall movement. If the feeding and gating systems freeze prematurely while mould wall movement is still occurring, porosity and cavities will be formed.

On the other hand, with a rigid mould (Fig 3), when metal is cast the mould cavity tends to decrease in volume and, in some circumstances, surplus metal can be expelled via the gating and feeding system. This is known as purging. The result is smaller, lighter and sounder castings.

Assessing mould wall movement

The extent of mould wall movement - which can be either expansion to increase the volume of the casting with low rigidity moulds, or contraction with those of high rigidity - can be easily assessed by weighing or measuring the castings produced. When a series of castings from a production line are examined, and the dimensions or weights are checked, it is very common to find variations in size and weight. This is illustrated by the data in Fig 4 which relates to weights of grey iron brake drums, for castings taken in random order from a production line. The weights ranged from 73.5-78.5 kg - a variation of 5 kg. The moulds for these castings were all made in greensand on jolt-squeeze moulding machines.

Softer moulds produce heavier swollen castings. Well-rammed moulds produce lighter and more accurate castings.

Thus weighing or measuring castings provides a simple quality control measure which enables foundries to eliminate potentially unsound castings before any machining is undertaken. Heavier oversize castings are almost certain to contain porosity or shrinkage cavities. Sometimes, as shown in Fig 5, castings may be so badly swollen that weighing or measuring is unnecessary.

With greensand moulds, enlargement of the mould cavity begins soon after pouring the casting and subsequently becomes more pronounced during eutectic solidification. This effect is worse if the mould has insufficient rigidity to resist ferrostatic pressure and the forces arising from the expansion of the metal during eutectic solidification. A factor contributing to the enlargement of greensand moulds is the occurrence of a low strength zone formed by moisture condensation behind the heated mould surface.

Although moulds made on high pressure squeeze machines are more rigid than those produced on jolt/squeeze or simultaneous jolt/squeeze machines, they are still substantially weaker than chemically bonded moulds. Whereas the weight of castings made in chemically bonded sand is practically unlimited and castings have been made in excess of 200 tonnes, the same cannot be said for greensand moulds. The relative lack of rigidity of greensand limits the maximum weight that can be poured, the limit that can be achieved being dependent upon the type of moulding machine.
Mould Related Defects

Once this is exceeded, mould movement and the resultant enlargement of the mould cavity creates an additional feed demand. A common problem in this respect is the placement of larger and larger feeders in an attempt to produce a sound casting. Each increase in feeder size increases the ferrostatic pressure on the mould, further enlarging the mould cavity, such that a sound casting is never produced.

The effect of squeeze pressure

Most moulding machines ultimately squeeze the sand around the pattern. This force is provided either by a single squeeze head somewhat larger than the moulding box size, or individual squeeze heads that fit inside the moulding box area.

Single Squeeze Heads

In practice, single squeeze heads produce the weakest moulds, even when simultaneous jolt/squeeze is available. This is because, although the squeeze pressure is distributed over the area of the moulding box, it is principally concentrated on top of the tallest flat area of the pattern. A good example of this is a brake drum where the top of the pattern is close to the top of the box. All the squeeze pressure is concentrated on the top of the pattern and once the sand between the top of the pattern and the underside of the squeeze head has been compressed to its maximum, further compaction is impossible. This means that the greater depth of sand around the sides of the pattern cannot be fully compacted and the mould sidewalls are substantially weaker. Mould hardness comparisons between flat horizontal surfaces and vertical sidewalls will show this difference and this emphasises why mould hardness should always be measured on vertically moulded faces. In cases where flat single squeeze heads are used to compress the sand in deep boxes, consideration should always be given to the use of profiled squeeze heads which preferentially squeeze the sand around the sides of the pattern. These produce substantially more rigid moulds and therefore sounder and more dimensionally accurate castings. Foundries using this technique change the squeeze head at the same time as the pattern, using a simple locking device onto the underside of the machine squeeze head surface.

Multiple squeeze heads

A multiple squeeze head is normally fitted to a high pressure squeeze machine and comprises a number of small individual squeeze heads positioned close together and operated hydraulically, as shown in Fig 6. Sometimes they all squeeze together, but more commonly they operate from manifolds such that those around the edges of the box squeeze separately from those at the centre. This provides substantially superior operation and acts in a similar manner to the profiled squeeze head previously described, whereby the edges of the box can be squeezed close to their maximum compactability. Such a system is relatively foolproof, although good maintenance and control is required to ensure that the head pressures do not deteriorate. When
Mould Related Defects

Castings are transferred from jolt/squeeze moulding machines with a flat squeeze head to a high pressure squeeze machine with a multiple squeeze head. It is normal for the castings to be slightly smaller, more dimensionally accurate, lighter and less prone to shrinkage defects. All these factors are associated with the fact that the mould is more rigid.

The importance of an adequate sand fill

On all moulding machines, but particularly on jolt/squeeze machines where the squeeze head overlaps the sides of the box, it is imperative that the sand level is well above the top of the box prior to the final squeeze. Failure to do this results in soft moulds because the squeeze head comes into contact with the moulding box and full compaction of the sand is prevented. This is shown in Fig 7. Some machines automatically ensure that the sand level is above the top of the box prior to squeezing. Where this is not the case a suitable frame should be constructed, which can be fitted on the top of the box during filling (and jolting) but which can be removed prior to squeezing.

Control of Squeeze Pressure

Low squeeze pressures will result in soft moulds. Generally as part of the sand testing routine squeeze pressures should be recorded, as low values may indicate potential problems. On hydraulically operated machines low squeeze pressures are rare, but they are sometimes variable and it is not unknown for the wrong pressure to be used on the wrong pattern. On pneumatically operated machines low air pressure is a common cause of soft moulds, particularly if other equipment is also piped to the same air supply, or if compressors are operating at their maximum capacity and all machines operate simultaneously. Each moulding machine should be fitted with its own air-pressure gauge and it is preferable to install an audible alarm which sounds if the machine operates at inadequate air-pressure.

Control of soundness in greensand moulds

- Compact moulds to a high and uniform density
- Do not overload the machine
- Ensure operation at correct pressures
- Use strong boxes to prevent distortion
- Use boxes with good reinforcement - ensure that sand between reinforcing bars is well compacted
- Regularly measure mould hardness on faces and sections of moulds to ensure consistency
- Control sand composition to obtain maximum compaction
- Weight moulds so that load is uniformly distributed
- Clamp moulds to avoid parting at the jointline during solidification
Mould Related Defects

Cross joint/mismatch

Cross joint/mismatch defects occur when the cope and drag halves of the mould are offset as shown in Fig 8. The important point about this defect is that the offset which occurs is the same on both sides of the casting, i.e. dimensions 'X' and 'Y' on Fig 8 are the same.

The reason for misalignment of this type is fairly obvious and easy to overcome. It is related to:

- Patternmaking problems, whereby the two pattern halves are misaligned on the plates and require fairly simple repositioning. This produces a situation whereby every casting is the same, off the affected pattern.

- Pin and/or bush wear, such that the two mould halves are misaligned. Normally on an automatic moulding line, pins and bushes do not all wear at the same rate and this produces a situation where only some of the castings show misalignment, but the problem may be spread over a number of patterns. It is not unknown for the complete bush to fall out of the box without being noticed, resulting in a problem of varying severity, depending upon the accuracy of closure.

Ram-off defects

Ram-off defects are often misdiagnosed as cross joint/mis-match and this causes confusion when patterns, pins and bushes are found to be satisfactory. An example of ram-off is shown in Fig 9 and the visual similarity to cross-joint is obvious. With respect to Fig 8, the important point about ram-off defects is that dimensions 'X' and 'Y' are often not the same, in fact in some instances there can be misalignment on one side of the casting only. The problem causing ram-off is usually traced to either the pattern, the moulding boxes or the moulding machine.

- Pattern - With repeated impact and vibration, patterns may become loose on the plate. This is quickly checked and the remedy is obvious.
- Moulding Boxes - The use of lightweight moulding boxes is known to produce ram-off defects. At the top of the stroke the box may leave the pattern plate for a brief instant, and then impact the pattern at a later time in the jolt cycle. This out-of-phase motion causes some spread of the sand face and if this is biased in one direction owing to the pattern contours, then a ram-off effect occurs. Sometimes this box movement is clearly visible and clamping of the box is an obvious cure; in some cases the movement can only be detected by feel. Excessive pin clearance usually produces a true cross-joint and pin clearance has not been found to be a factor in the production of ram-off defects.
- Moulding Machine - The defect normally occurs when using machines of the Jolt Squeeze variety. It is far less common with straight squeeze high pressure machines. A ready check on machine performance may be carried out by placing a loose weight or handful of dry sand on the table and noting if there is any prefer-
Mould Related Defects

ential movement in one direction during jolting. Any such movement shows a
fault in the machine set-up, which may be due to any of the following causes:

*Machine out of level* - This can readily be checked, but correction may be
difficult. If the machine is level, then the pattern plate may be incorrectly fitted or
there may be taper in the plate.

*Unsatisfactory machine foundation* - Loose nuts on the bolts holding the
machine to the foundation are easy to find and tighten. More serious and often only
found by a process of elimination are cracks around the bolts such that they are
loose in the foundation, a foundation which is too small for the machine, a founda-
tion which is loose in the surrounding ground or a cracked foundation. These fea-
tures are normally only found by removing the moulding machine and carrying out
trial excavations.

*Squeeze head movement during simultaneous jolt-squeeze action* - The squeeze
head movement is often due to excessive play in the head bearings. To cure this, the
screw clamps may be adjusted or bearings replaced. Many machines are operated in
an overloaded condition which can produce squeeze head movement. It is therefore
important to install and use machines of suitable capacity for the work to be handled.

*Jolt piston wear* - This is usually due to the joltpiston having insufficient
bearing surface or too much clearance. Both conditions may be present in the ma-
chine and they only become a factor when certain plates are used. The condition may
also be brought about by wear and neglect of maintenance.

*Machine jolting unevenly due to wear* - In this case the anvil does not take the
impact squarely and the load receives a side kick. This is a severe condition and can
only be rectified by machine overhaul.

Crush and Flash

Crush results in sand inclusions in the castings and the cause is normally moulding
and pattern related rather than being associated with sand quality. The defect is rare
in moulds which contain no cores, the major problem being the result of closing over
core prints which are larger than the equivalent print on the pattern. This is usually
either a patternmaking fault, wear in the corebox which increases the diameter of the
core print or vibration/misalignment during the closing operation.
Flash around the jointline is not a common problem and can easily be ground off.
The flash is occasionally caused by a distorted pattern plate but is more often the
result of ferrostatic pressure parting unclamped or loosely clamped boxes during
filling. Mould explosions can have the same effect. If the flash freezes off quickly
the gap that occurs between the cope and drag can be maintained during solidifica-
tion, resulting in oversizing across the joint. This can cause machining difficulties on
computer controlled machines operating to tight tolerances at high speeds and feeds.
Because the flash has been ground off and the castings are often painted, the prob-
lem and its cause are often not related.
Mould Related Defects

Fig. 1  Effect of mould rigidity on casting dimensions and soundness.

Fig. 2  Movement and shrinkage in moulds of low rigidity.

Fig. 3  Sound castings from rigid moulds.

Fig. 4  Variation in weight of brakedrums.
Mould Related Defects

Fig. 5 Swollen brake drum from low rigidity mould

Fig. 6 Mouldmaster squeeze head.

Fig. 7 Effect of sand level on mould rigidity.

Fig. 8 Patterns in the two mould halves - the cope and the drag - must be aligned to prevent cross joint/mismatch.

Fig. 9 Ram-off.