Penetration

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Characteristic features

Degree of roughness which is greater than the size of sand grains, at hot spots or under-compacted sections.

Incidence of the defect

Penetration particularly occurs at positions where parts of the mould have been heated to a greater degree (edges, thick-walled castings, near to the gate), and at sections where the sand has been poorly compacted.

Explanations

Physical penetration is said to occur where the depth of ingress is larger than the size of the sand grains and there is no chemical reaction between the moulding material and the infiltrating metal. However, if there is a reaction, this is said to be penetration due to chemical reaction (q.v.). In addition to penetration through exceeding the critical mettallastic pressure, this defect can arise through explosions (see Explosive penetration) and, with iron-carbon alloys, through graphite expansion (this latter is not dealt with here).

Possible causes

Clay-bonded sand
- Sand too coarse
- Insufficient carbon carriers
- Insufficient fines
- Excessive compactability

Resin-bonded sand
- Sand too coarse
- Insufficient compaction of cores

Moulding plant
- Insufficient and non-uniform mould compaction

Gating and pouring practice
- Mould and core sections overheated

Remedies

Clay-bonded sand
- Make the sand finer by using finer inflowing core sand, or by adding finer sand to the circulating sand.
- Increase quantity of carbon carrier. Increasing the lustrous carbon producing capacity reduces the wetting of the surface of the sand.
- Increase coke content; this helps to further reduce the pore size.
- Increase quantities of fines. The silica contents of the dust removed from the coke residues make suitable fines.
- Reduce the compactability of the sand. This increases its flowability. Better compaction is also possible.
- Flowability can be improved by using carbon carriers containing graphite, or combinations of bentonite/graphite.
Penetration depth

<table>
<thead>
<tr>
<th>Pressure in cm Fe-column</th>
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<tr>
<td>0</td>
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<table>
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<tr>
<th>Average grain size</th>
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<td>0.63 mm</td>
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Background information

The critical pressure above which molten metal penetrates a porous sand surface depends on the surface tension, the pore diameter and the wetting angle of contact between the molten metal and the sand grains. If metallastatic pressure is greater than $P_{crit}$, penetration will take place.

$$P_{crit} = \frac{2\sigma r}{r} \cos \Theta$$

Resin-bonded sand

- Use finer core sands or add fines such as iron oxide.
- Compact cores more uniformly and effectively; if necessary use a less viscous binder.
- Dress cores at risk or, if necessary, increase the thickness of dressing.

Moulding plant

- Improve mould compaction. Increase the compacting pressure. Achieve more uniform mould compaction through better sand distribution.
- Products containing graphite improve compaction and increase packing density. At the same time, mould compaction becomes more uniform.

Gating and pouring practice

- Improve gating. Avoid excessive quantities of inflowing metal and thus local overheating.
- Increase spacing of patterns. Under certain circumstances this leads to reduction of overheated areas.
- Reduce casting temperature.

Fig. 29 shows how the penetration depth of molten steel depends on metallastatic pressure.
If a high proportion of core sand flows into bentonite-bonded sands, the grain size of the core sand is crucially important to the grain size distribution in the green sand. Inflowing coarse cold-box sands increase the pore diameter. The critical pressure for the onset of penetration becomes lower. If penetration occurs, a finer sand may be necessary. An addition of extracted fines can help to avoid this defect. The lustrous carbon producing capacity has a lower influence on the pore diameter. It may be necessary to increase the amount or to use a lustrous carbon producer with higher coke formation. The mould surface should be uniformly and well compacted. Uniform compaction can be achieved by using products which contain graphite.

Penetration frequently occurs in the proximity of the gate. The inflowing quantities of metal are too great and cause too much heating of the moulding material in this area. The defect disappears when inflowing metal is better distributed.

References

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2. Thorpe, P. J.
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   Penetrations- und Lunkererscheinung infolge Wechselwirkung zwischen erstarrendem Gusstück und Form
   Gießerei 60, 1973, P. 485–495

Fig. 31: How the critical pressure for the onset of penetration of molten steel depends on the pore radius in the moulding sand.

Comparable results are also given for other molten metals and have been discussed in numerous papers.\textsuperscript{1,2,3}

In the case of iron alloys, surface tension is increased by adding magnesium, aluminium and chromium. As a result, the tendency to penetration of SG cast iron is lower than that of grey cast iron.

In the case of resin-bonded mould parts, the likelihood of penetration depends heavily on the selected sand grain. Thus, Croning cores are prepared with fine sands, cold-box moulds with as coarse a sand as possible. Dressing, particularly of cold-box cores, is frequently necessary in order to avoid penetration. Penetration can occur if, during pouring, the dressing layer cracks because of expansion of the cores. Uniform compacting of the cores is necessary in order to keep the pore volume as low as possible.

Fig. 31 shows how the critical pressure for the onset of penetration of molten steel depends on the pore radius in the moulding sand.