Micro-cavities

Characteristic features

Spongy, aerated or micro-porous structure at positions in the casting which are last to solidify.

Incidence of the defect

The defect occurs at those parts of the casting that are last to solidify, and particularly at points where material accumulation has occurred, points of transition between different wall thicknesses and also in the proximity of the gate.

This defect can occur especially when casting alloys with a wide solidification range.

Explanations

Micro-cavities occur as a result of the volumetric reduction of the metal with declining temperature and slurry-type solidification. It is difficult to differentiate these defects from those arising due to gas precipitation and inclusion. The defect is regarded as micro-cavitation where the influence of volumetric contraction predominates, and as micro-porosity when it has been primarily caused through shrinkage and gas precipitation.

Possible causes

Metallurgical
- Solidification interval too large
- Gas content in melt too high

Clay-bonded sand
- Gas formation too high
- Low heat removal rate

Resin-bonded sand
- Gas formation too high

Moulding plant
- Mould stability too low
- Radii on patterns too small

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Fig. 18: Micrograph of porosity in a grey iron casting. Distinctly rounded cavities strongly influenced by gas liberation.
Scale: 10 mm = 0.06 mm
Background information

All alloys with a wide solidification range tend towards micro-shrinkage. Non-directional solidification takes place at overheated points. The volumetric contraction at these points through cooling and solidification cannot be offset by feeding metal from other regions of the casting. Gases from the melt or overheated parts of the mould diffuse into the micro-cavities and enlarge the micro-pores.

The formation of micro-porosity in copper alloys such as copper-tin and copper-zinc during casting in green-sand moulds can be avoided by directional solidification. This requires pouring at higher temperatures.

With iron-carbon alloys, investigations have been carried out regarding the influence of graphite expansion, precipitation of gases out of the melt and gas evolution from mould and core materials.

In order to avoid micro-porosity, it is recommended to work with carbon equivalents of around 0.95. Solidification in critical regions should occur quickly, for which purpose facing sand can be applied at these positions. Use of chromite or olivine sands has proved to be effective. Still better heat removal can be achieved by the application of chills in critical regions. Gas evolution from the mould and core regions must be minimized. With bentonite-bonded sands, the clay and water contents should be as low as possible. The same applies to the amount of binder in cores.

Because “hot spots” promote the occurrence of micro-porosity, it is necessary to avoid sharp edges on the patterns.

As indicated above, as a melt solidifies, small voids develop due to micro-shrinkage, creating defects known as micro-cavities or (micro-)porosity. The porous castings, known as “leakers” are either scrapped or require a costly sealing rework.

Remedies

Metallurgy
- Reduce solidification interval; if necessary, grain refinement.
- Reduce gas content in the melt; if necessary, remove gases by nitrogen or argon flushing.

Clay-bonded sand
- Reduce release of gas from the moulding sand. Reduce contents of bentonite, carbon carrier and inert dust.
- Reduce water content in the moulding sand.
- Apply facing sand at critical points. Improve heat removal.

Resin-bonded sand
- Reduce release of gas from cores. Improve venting of gases.
- Add granular iron or facing sand with higher thermal conductivity at critical points.

Moulding plant
- Make moulds more stable by increasing compacting pressure. Compact mould more evenly.
- Round off the edges of patterns. Reduce “hot spots” by increasing the edge radii.

Description of defects: Micro-cavities

Fig. 19: Micrograph of a grey iron casting. Micro-cavities in the surface zone, partially oxidized surface.
Scale: 10 mm = 0.06 mm
Venugopalan identified an interrelationship between gas precipitation and the degree of porosity in non-ferrous metal castings, determining the degree of porosity both through density differential testing and ultrasonic damping measurement. Smith recommends the application of inert gas flushing with argon; and a further paper reports on the benefits of continuous melt degassing.

In terms of mould structure, particular attention should be paid to the core binders and their gas evolution as a means of combating such defects. While Croning cores release up to 140 ml of gas per g of core sand, the figures for cold box cores and furan binders lie in the region of 80–90 ml/g core sand. Epoxy-SO$_2$ binders and the new furan hot-box binders offer particularly low values of around 60 ml/g core sand.

Rapidly cooling moulding materials such as zircon, chromite, and olivine sand are primarily used for steel casting, with their high refractory qualities also being utilized to good advantage. Significantly more effective is the careful placement of chills of appropriately varied shape and mass at the points of final solidification.

As also described in relation to angular blowholes, points and sharp edges in the mould or core that extend into areas very close to the thermal centre are dangerous as these can cause gas release from the moulding sand due to the suction effect arising from the evacuated condition of the thermal centre.

The defect does not always take the form of a neat pore or blowhole; this is particularly apparent in the case of non-ferrous cast iron. Consequently, the pattern should be constructed so that such points and sharp edges are extensively avoided.

An overview of relevant literature can be found in VDG-Fachbibliothek No. 288 “Porositäten von Gußeisen mit Lamellen- und Kugelgraphit” (German Foundrymen’s Association, Technical Library No. 288, “Porosity in flake and spheroidal graphite cast iron”).

This process of volumetric contraction (volume deficit) causes micro-cavities to form at the points at which final solidification takes place. In terms of the casting technology applied, therefore, it should be ensured that such micro-pores are immediately resealed by positioning feeders at the appropriate locations, or by locating chills in the vicinity of the final solidification point in order to induce directional solidification. The point of final solidification is then transferred to the feeder.

In cases of solidification with dendritic growth at the solidification front (solid/liquid interface), intergranular (also known as intercrystalline) voids can occur which cannot be sealed by replenishment from the feeder. Gases precipitating from the metal melt may also collect in these micro-cavities. Consequently, it is difficult to distinguish between micro-porosity due to volume deficit and that resulting from gas precipitation. As this defect is primarily attributable to metallurgical causes, the first course of action should be to consult the prioritized list provided under the remedial flow chart in order to determine which of the causes indicated are the most likely culprits.

Hasse recommends CE values < 0.95 as a means of preventing micro-porosity in cylinder blocks. The iron oxide content in the slag of the cupola should also be kept as low as possible.

In all cases, the solidification rate of the casting should be maximized. Nieswaag-Prabhakov-Zuithoff investigated solidification rates ranging from 0.5 to 40·10$^{-4}$ cm/s, analysing the structure and also the casting properties produced by directional solidification. Their findings indicate that high speeds of solidification and low sulphur and phosphorus contents are beneficial.

Thury reports on the growth and micro-cavitation of spheroidal graphite (SG) cast iron, highlighting the positive influence of a solid, inflexible mould. He too states that the casting should be made to solidify as quickly as possible. Lapin and co-workers found that the tendency towards micro-cavitation decreases by approx. 50% in solid moulds.

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Description of defects: Micro-cavities

Fig. 21: Micrograph of porosity in a grey iron casting. Interdendritic microstructure. Minor influence of liberated gases.
Scale: 10 mm = 0.06 mm

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