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ISSN 0543-5846
METABK 53(4) 591-593 (2014)
UDC – UDK 621.744:669.083:621.742.522.45:620.18=111

COMPRESSIVE STRESSES OF MOULD MIXTURE

Received – Primljeno: 2013-12-20
Accepted – Prihvaćeno: 2014-05-15
Preliminary Note – prethodno priopćenje

The source of compressive stresses lies in the structure of quartz sand. By reaching the critical temperature (from 560 to 580 °C), the quartz sand grains increase volume. The increase in volume causes the movement of surrounding grains of sand. In this paper, it is shown by the dilatometric investigations of different granulometric compositions of quartz sands how the granulometric composition affects the size of the mould dilatation caused by heating during pouring of the melt.

Key words: mould, quartz sand, compressive stresses, grain size, dilatometric investigations, scabbing

INTRODUCTION

The types of sand that can be used for making of the expendable moulds are: quartz, zircon, chromite, olivine, etc. The most commonly used sand is quartz sand. The use of quartz sand is usually justified from an economic point of view. It is cheap due to its abundance in nature. However, the most commonly used quartz sand has its disadvantages. One of the disadvantages is the increase in volume that occurs during the heating of quartz grains at the temperatures ranging from 560 to 580 °C (Figure 1) [1]. At this temperature, the structure of quartz grains changes from α to β phase, which is manifested in the rotation of crystal lattice and the change in volume. The volume change causes the compressive stresses in the mould mixture, resulting in the deformation of mould cavity. Upon the occurrence of deformation, some parts of the mould can break off. If this happens, as the result of casting, we get a casting defect with so called ‘scabs’. [1]

Scabbing is a phenomenon that occurs when a 2-6 mm thick layer on the inner surface of the casting mould breaks off. The tendency to scabbing (SO) can be explained as a function of the quotient of compressive stresses (σ_t) and the strength of condensation layer (σ_{rek}).

$$SO = f\left(\frac{\sigma_t}{\sigma_{rek}}\right) \quad (1)$$

However, scabbing (as a casting defect) can occur also in a dry layer of mould, i.e. the layer that is heated to a temperature higher than 100 °C, where the process of allotropic modification of sand (mould mixture) occurs. The process of scabbing is shown in Figure 2.

Tendency to scabbing can be decreased by reducing the amount of compressive stresses (σ_t). This is achieved by the appropriate choice of granulometric composition of sand and the technology of mould making.

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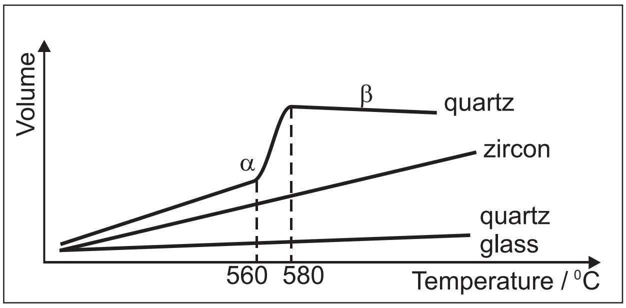
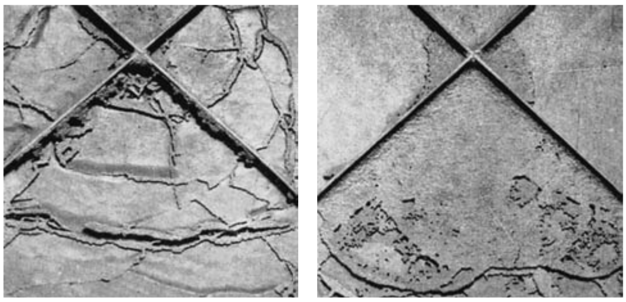


Figure 1 Temperature – volume curves for different mould materials



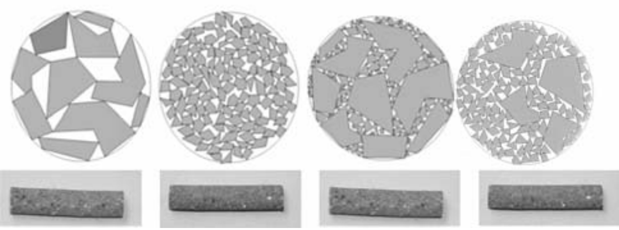
a) b)

Figure 2 Casting defect: a) Scab (wedged) b) Scab (free) [2]

EXPERIMENTAL

Since the sand is subject to the change in volume and is the main cause of the compressive stresses [3 - 7], the paper will examine its influence on the appearance of scabbing with a special emphasis on the investigation of the dilatation of the mould mixture.

Different granulometric composition of the mould sand causes also different packing of sand grains in the mould mixture. Therefore, it is important to examine which granulometric composition causes greater, and



a) b) c) d)

Figure 3 Different structures of mould mixture – test samples a) Sample G1, b) Sample G2, c) Sample G3, d) Sample G4

Figure 4 Electronic dilatometer Netzsch 402 EP

which smaller dilatation forces of the mould mixture at the temperatures of allotropic modification.

Four test samples (G1, G2, G3, G4) were made for determining the dilatation of the mould mixtures.

Sample G1 is composed of granulation diameter of 0,6 mm. Sample G2 is composed of granulation diameter of 0,1 mm. The mould mixture G3 consists of 50 % of G1 and 50 % of G2. The mould mixture G4 consists of 33 % of G1 and 67 % of G2. The cylindrical-shaped test samples of mould mixture (diameter of 12 mm and length of 50 mm) are shown in Figure 3.

The test samples were used for measuring of dilatation forces. Electronic dilatometer Netzsch 402 EP (Figure 4) was used for measuring.

The advantage of dilatometric tests is the fact that the structural phenomena are determined at the exact moment when they occur (time and temperature), which, for example, cannot be achieved by the micrographic examination.

Electronic dilatometer Netzsch 402 EP allows the continuous measurement by monitoring the changes in length, depending on the temperature of test sample. The length of test samples is from 25 to 50 mm and the diameter is from 3 to 12 mm.

The basic characteristics of dilatometer are:

- test temperature is possible in the range from 20 to max. 1 100 °C,
- heating rate is adjustable in steps of 1 K/min,
- cooling rate is adjustable in steps of 1 K/min.

Using the obtained dilatogram, the coefficient of dilatation of material can be calculated. Different definitions for the coefficient of dilatation are often used. In practice, the most interesting is the mean coefficient of dilatation for a given temperature range.

The initial length of the test sample at room temperature is taken as the reference length. It should be considered that the coefficient of dilatation is the property of the material, which depends on the temperature and is not a constant.

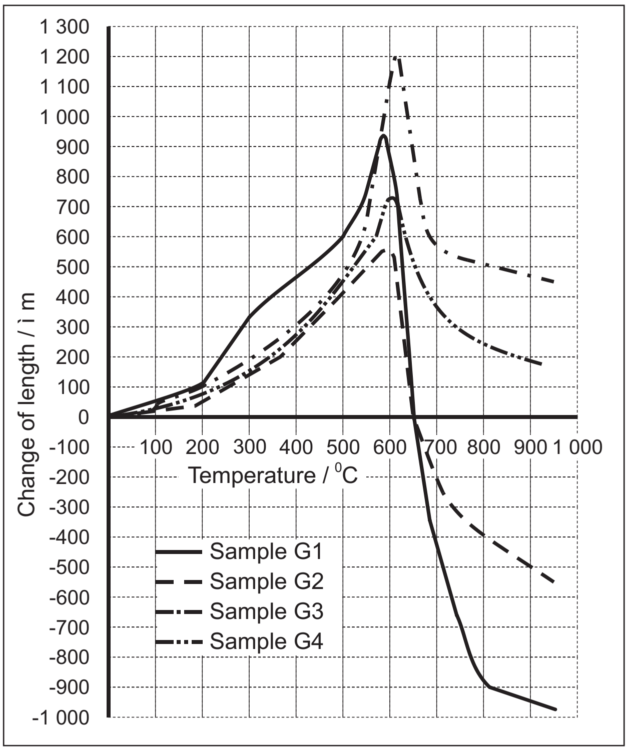


Figure 5 Results of dilatometric testing of mould mixture

The mould mixture, namely the parent material (sand), is packed in a particular structure during moulding. The packing of sand depends on several parameters, such as the size and the shape of grain. The term ‘grain size’ refers to the granulometric proportion of individual fractions of sand. The distribution of grains is shown in Figure 3, which indicates that the granulometric composition and the shape of grain of the parent material make the structure of mould mixture. The results of testing are shown in Figure 5.

The results show that the mixture G2, composed of a larger fraction, causes greater stresses when heated to the temperature of transformation, than the fine sand. Maximum dilatation at the temperature of transformation for sample G2 is about 940 µm, whereas for sample G1, it is 550 µm. Sample G3, containing equal proportions of coarse and fine sand, dilates due to heating to 1 210 µm. Sample G4 that has 1/3 of coarse sand and 2/3 of fine sand dilates to 720 µm.

The reason for different dilatation forces at the combination of fraction proportion lies in the contact surfaces between the sand grains of mould mixture. Due to the combination of grain packing during the mixing of mould mixture, the grain structure, which transmits the dilatation forces to the edges of sample through its contact surfaces, is formed. The dilatation forces are not always transmitted in their maximum value.

The reduced maximum value of the dilatation forces is caused by the mutual displacements of the individual fractions of sand. With their rotation, the factions mutually elude each other and form a new structure. This effect, which happens during the process of occurrence of internal stresses, could be called 'the effect of adjustment'.

As the result of monitoring of the dilatation forces of mould mixtures, it can be concluded that each mould mixture, with respect to its granulometric composition, has a greater or smaller capacity of the internal adjustment of grain.

CONCLUSION

Scabbing, as the main problem, is related to the mould mixtures with the physically hardenable bonding agents. From the previous investigations, it can be concluded that the layer, which is responsible for the occurrence of scabbing, is solely the part of the mould, which was heated to the temperature higher than the temperature of allotropic modification of quartz sand (heated to 570 °C). These layers are very unstable and they are the primary cause of internal stress. With the movement of the structure and the occurrence of great internal stresses, the mould mixture is deformed. This causes the fracturing of small parts of mould mixture that fall into the melt and cause scabbing.

By using quartz sand for the expendable sand moulds, we are faced with its property of allotropic modification during cooling of the casting in the mould. Using the sands, which do not change their structure with temperature, the occurrence of scabbing can be avoided.

Dilatometric testing of different granulometric compositions has shown how the granulometric composition affects the size of dilatation of mould caused by heating during pouring. After heating to 570 °C, larger grains have a much greater volume change. Greater volume change is caused by the higher content of quartz crystals, whose rotation is the main cause of the dilatation of grain. In the case of mixtures with different proportions of individual fractions, even greater dilatation forces, than in the case of uniform granulation, can occur. The reason for this is the filling of the space between the large grains with the smaller factions that prevent the adjustment of large grains, thus transferring the dilatation into the interior of the mould, while causing the occurrence of compressive stresses.

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Note: The responsible translator for English language is Z. Rosandic, Faculty of Mechanical Engineering in Slavonski Brod, Croatia