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THE THERMAL DEFORMATION OF CORE AND MOULDING SANDS ACCORDING TO THE HOT DISTORTION PARAMETER INVESTIGATIONS

DEFORMACJA CIEPLNA MAS W ŚWIETLE BADAŃ PARAMETRU HOT DISTORTION

Effects which proceed in moulds during casting determinate quality of casts. Dimension accuracy, smoothness of surface and frequency of defetecs appearance are depended on thermal and mechanical deformation rate. The high test instrumentation used to analyze effects like this, affords us to know, how this effects influence on change in core and moulding sands. The results of dilatation and distortion in high temperatures investigation for moulds prepared with cold box and self-hardening moulding sands technology are shown in this article. In second part of this article, the influence of coating type and thickness on sample behavior in high temperature was qualified.

Keywords: hot distortion, thermal degradation, core sands, self-hardening moulding sands, cold box

Zjawiska zachodzące w formie w czasie zalewania ciekłym metalem decydują o jakości odlewów. Od stopnia odkształcenia i deformacji cieplnej i mechanicznej form i rdzeni zależy dokładność wymiarowa i gładkość powierzchni odlewu oraz częstotliwość występowania wad. Stosowanie nowoczesnej aparatury badawczej umożliwiającej analizę tego rodzaju zjawisk pozwoli na dokładne poznanie ich wpływu na charakter zmian zachodzących w masach formierskich i rdzeniowych. W artykule przedstawiono wyniki badań własnych dylatacji i odkształceń w podwyższonych temperaturach mas wykonanych w technologii cold box oraz sypkich mas samoutwardzalnych. W drugiej części przedstawiono badania dotyczące wpływu rodzaju i grubości powłoki ochronnej na zachowanie rdzeni w czasie deformacji cieplnej.

1. Introduction

Investigations of usefulness of core and moulding sands, which are commonly used, are mainly focused on strength properties. This are very important parameters, however they do not describe behaviour of cores and moulding sands in high temperatures, that is in real conditions of casting. Some researches show, that in many cases, high strength properties of cores in environmental temperature do not guarantee good resistance on thermal deformation. The purpose of this article is to set correlation between cores and moulds strength in environmental temperature and its tendency to deformation in high temperature. The thermal deformation of moulds was definite by the hot distortion parameter. This parameter defines behaviour of cores during one-sided radiation heating. As a result of difference in thermal expansibility among heated and cold surface, the sample distorts from the source of heating. This range of deformation is measured and recorded on graph by the sensor which is applied to the free end of sample. As an effect of thermoplastic nature of bounding during heating, a critical point is achieved, where hardened mould can not be longer deformed up and deformation follows in opposite direction. The range of this deformation is also measured and recorded. Finally the sample lost its strength and collapse. The introduced behaviour of moulds and core sands can be divided into two stages: the deformation from source of heating (up distortion) and in direction of source of heating (down distortion). The up deformation from source of heating is definite as the first (I) phase, and the down deformation as the second (II) phase. A point, when the deformation follows in direction of source of heating below initial position of the sample is established as a beginning of II phase of deformation.

For hot distortion parameter investigation the DMA apparatus (Fig. 1) was executed, in co-operation with MULTISERW-Morek Firm, as a part of the research project. Apparatus was designed in the way which makes

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possible to record the deformation as a function of temperature and time.

Particular description concerning construction of the DMA apparatus were described in others authors' publications [1–7].

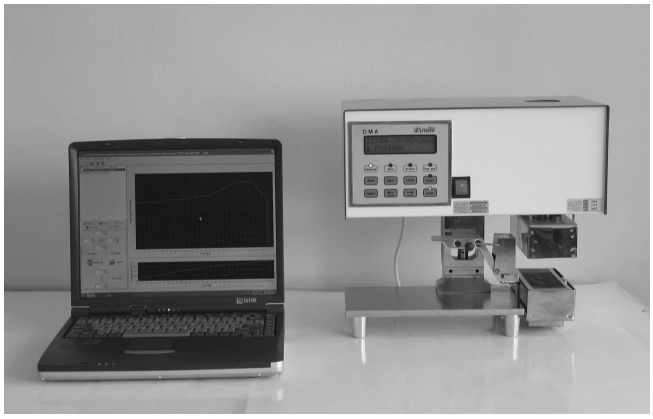

Fig. 1. Prototype apparatus DMA for measuring the distortion in high temperature [8]

The introduced changes in moulding structure have place in real cores and forms during casting. They manifest itself as a distortion of cores, cracking, erosion and veins. Under this regard the conditions of test simulate the conditions in casting practice well.

The profiles of phenomenon of the hot distortion parameter for moulds and cores with different binders differ significantly. According to this, the main destination of this research method is to get to know the binders susceptibility to thermal deformation.

2. Experimental results

2.1. Cold box technology

The first part of the research was to define thermal deformation using DMA apparatus and reference their results to dilatometric and thermogravimetric analysis.

The investigation was made on samples prepared with cold box technology. The following composition of moulding sands were used: quartz sand – 100 part by weight, resin – 0,8 part by weight, hardener – 0,8 part by weight, catalyst – 1,0 cm^3/250 g of moulds.

Thermal deformation begins at near 40°C temperature (Fig. 2). In the I phase of deformation a small distortion from initial position follows. It tells about good resistance of core sand on heating. Such state keeps to temperature about 220°C when the second phase of distorton beginning. As a result of continuous heating of the sample bottom surface, resin distorts thermoplasticly. It causes distorting in direction of heating source, until the moment when the binder undergoes the thermal destruction and sample collapse. It takes place at temperature near 280°C.

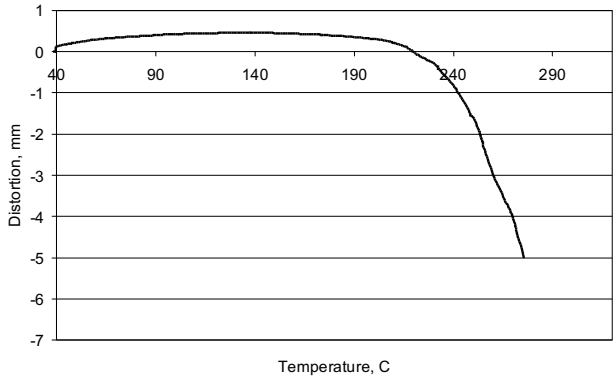

Fig. 2. The hot distortion parameter as a function of temperature for moulds prepared with cold box technology

Thermogravimetric analysis research, using BAHR STA503 apparatus, were also executed. The heating of samples followed in atmosphere of air to temperature 1130°C with speed 5°C/min.

The analysis of thermogram received for moulds prepared with cold box technology (Fig. 3) shows, that when the second phase of thermal deformation starts, near temperature 220°C, decrease of mass of sample carries out about 0.15%. This leads to conclusion that deformation sets not as a result of thermal destruction of resin, but as a result of resin thermoplasticity. Near the temperature of 280°C the decrease of mass carries out less than 0.20%. During hot distortion investigation sample has collapsed near this temperature. It means that binder did not undergo total destruction, but lost its strength enough to collapse the sample.

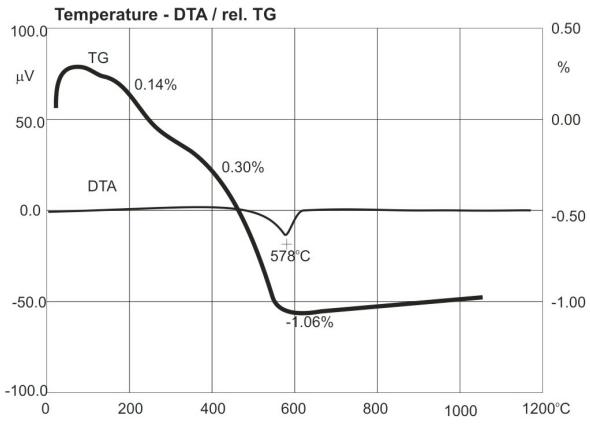

Fig. 3. Thermogram for mould prepared in cold box technology

Dilatometric investigations were made on dilatometer Linseis L75. There is a curve of dilatation shown at figure 4. This results are similar to investigations,

which are described above. After crossing 222°C the coefficient of inclination of curve of dilatation enlarges. This indicates larger thermal expansibility of moulds in this range of temperatures. Because of no polymorphic changes at this range of temperatures, the strength decrease and thermoplasticity of binders are responsible for described phenomenon.

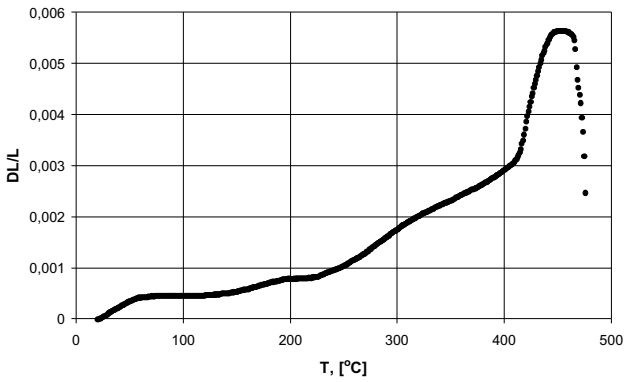

Fig. 4. Dilatation curve made for mould prepared in cold box technology

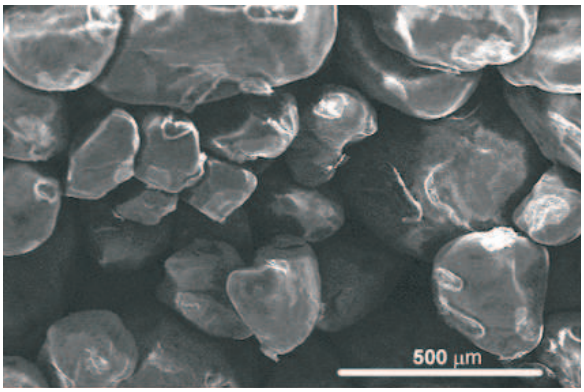

Fig. 5. Photo of fractures of mould heated in temperature 100°C

The observations of fractures of heated samples are some interesting supplement for described investigations. The observation were executed on scanning microscope (Fig. 5–9). It is possible to observe the heterogeneous grains of sand, covered in even way with binder. In shown photos, some linking bridges are seen and they are observed independently from heating temperature. This means, that in spite of high temperature, part of binder does not undergo thermal destruction. However binder lost its strength in degree which causes sample collapse during time of investigation of thermal deformation near the temperature of 280°C.

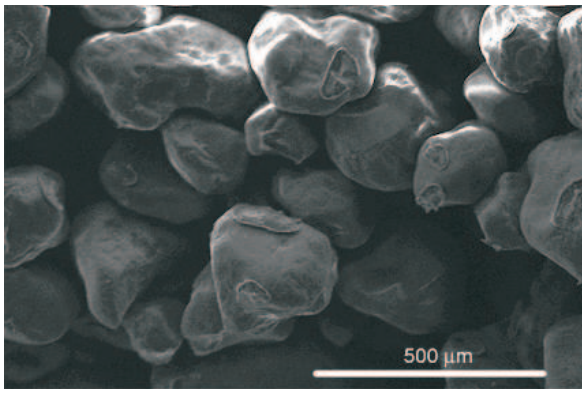

Fig. 6. Photo of fractures of mould heated in temperature 380°C

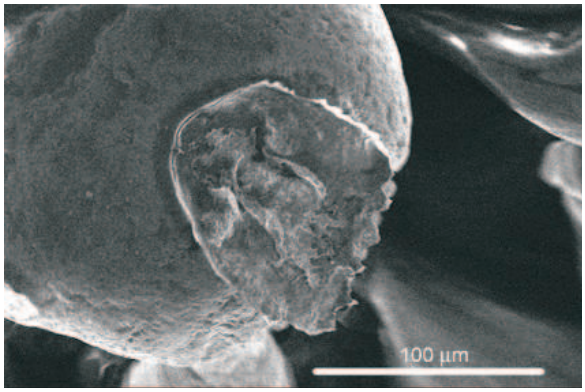

Fig. 7. Photo of fractures of mould heated in temperature 380°C

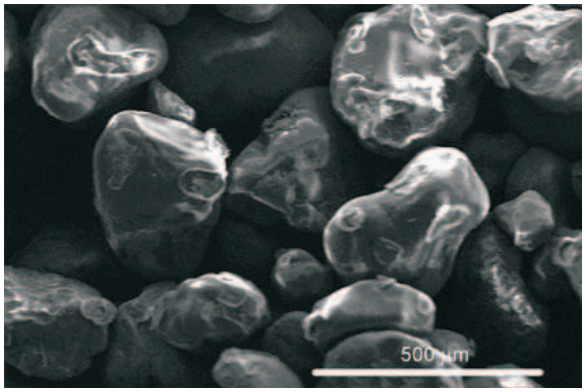

Fig. 8. Photo of fractures of mould heated in temperature 460°C

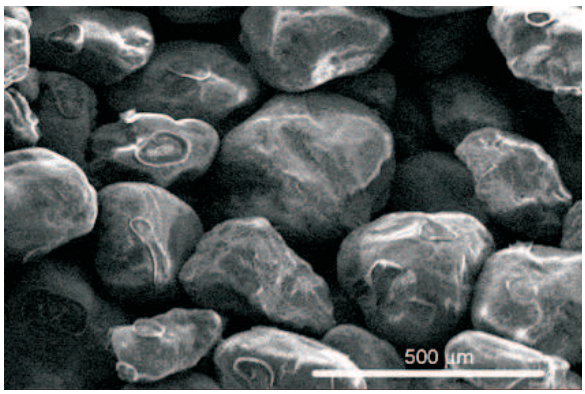

Fig. 9. Photo of fractures of mould heated in temperature 540°C

2.2. The technology of self-hardening moulding sand

The next stage of research concerns investigation of moulds and cores prepared in technology of self-hardening moulding sand. Sand quartz from Jaworzno Szczakowa was used as a warp. The urea-furfuryl, phenolic, polyurethane and alkaline resol were used as a binder. The specification of applied components were contained in different publication [9].

Five from eight investigated moulds were binders with urea-furfuryl resins. Mould prepared with this kind of resins characterize very large increase of bending strength (the large speed of hardening) during first 2 hours of hardening. After this time they achieve about 85–90% their final bending strength (measured after 24h of hardening). However the moulds which were bonded with others resins (not including furfuryl alcohol in their composition), achieve only 40–60% their final strength after two hours. The kinetic of strength growth for particular moulds is shown on figure 10.

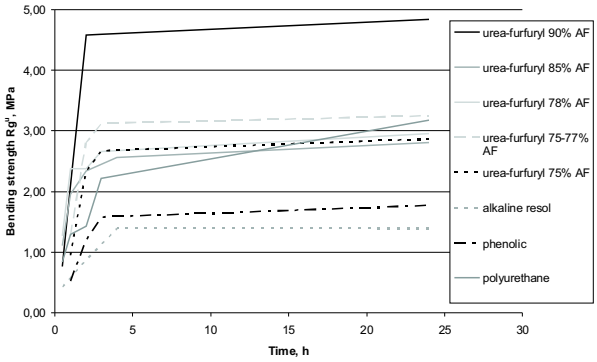

Fig. 10. Composition of curves illustrating the kinetics of strength growing for moulds prepared with self-hardening moulding sand technology with synthetic resins, AF – furfuryl alcohol

Analyzing the data from figure 10 it could be noticed that enlargement the content of furfuryl alcohol in resin causes the growth of kinetics of bonded mould prepared with this resin.

On figure 11 the values of bending strength were compared (after 24h of hardening) according to content of furfuryl alcohol. It could be affirmed, that the content of furfuryl alcohol in resin has no influence on final strength of moulds prepared with this resins. However resins which were applied come from different producers. Narrow range of resin content and furfuryl alcohol in moulds show that the technology of production has clear influence on strength properties of moulds.

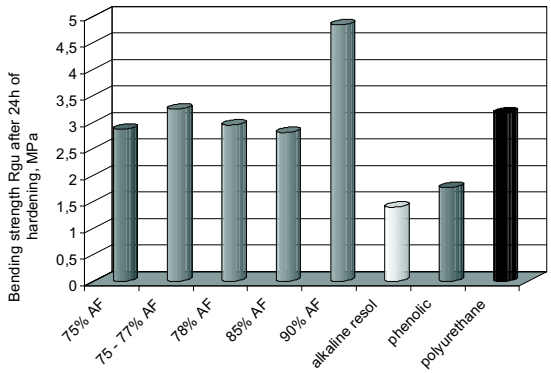

Fig. 11. Composition of value of bending strength Rgu after 24 hours of hardening for moulds prepared with self-hardening moulding sand technology with organic binders

On composition of hot distortion curves for moulds with urea-furfuryl resins (Fig. 12) it is possible to distinguish samples, in which considerable changes in deformation appear in the first phase of deformation, and also these, which kept the satisfactory dimension stability in that phase. The largest deformation undergoes sample (carrying out about 3 mm) prepared with moulds with urea-furfuryl resin contain 85% of furfuryl alcohol. Samples prepared with moulds with urea-furfuryl resins: contain about 75–77% of furfuryl alcohol and contain about 90% of furfuryl alcohol show the very similar size of deformation, about 2.5 mm.

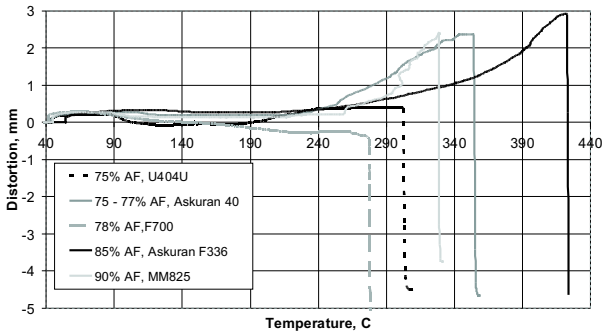

Fig. 12. Thermal deformation of core sands with urea-furfuryl resins

On figure 12 the difference in temperature, when particular resins disintegrate, can be seen. The thermal disintegration of urea-furfuryl resin including 85% of furfuryl alcohol take place near temperature 420°C. By temperature about 280°C happened the thermal collapse of urea-furfuryl resin including 78% of furfuryl alcohol. These temperatures of destruction are extreme examples and the rest of resins undergo among this range of temperatures. Shown results do not let us to find correlation between the contain of furfuryl alcohol and a speed of thermal deformation of this resin. Comparing this results with research got for cold box technology, it can be noticed, that the character of their behaviour is differ-

ent. Moulds prepared with self-hardening moulding sand technology do not show susceptibility to plastic deformation. Some of them show higher thermal stability (the moulds with resin containing 85% of furfuryl alcohol – the sample collapse near 420°C temperature).

The next composition of curves (Fig. 13) is related to the rest moulds prepared in self-hardening moulding sand technology. There is no similarities between this curves. Different resins were used for this moulds: polyurethane, phenolic and high condensation alkaline rezol. Moulds with polyurethane resin near 220°C temperature achieves point when II phase of deformation get started.

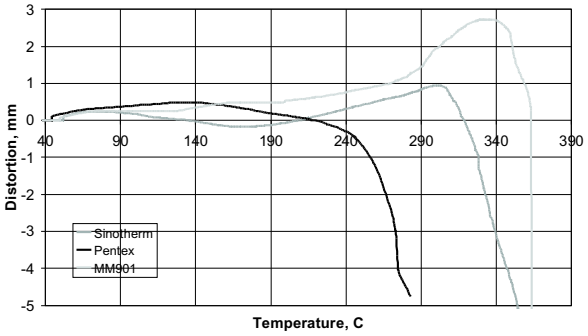

Fig. 13. Thermal deformation of core sands with others organic resin

The moulds bonded with high condensation alkaline resol start the second phase of deformation about 315°C, and after that there is a large thermoplasticity deformation at II phase. However for moulds with phenolic resin deformation grows up achieving maximum near 340°C. At this temperature sample undergoes violent thermoplasticity which leads to quick collapse in II phase of deformation. This mould, comparing to the two previous moulds, has bigger maximum of deformation.

According to the range of applied moulds and resins, the correlation between bending strength in environmental temperature (Fig. 11) and thermal deformation in high temperature, was not affirmed. The lack of dependence between these parameters displays the small usefulness of results of strength investigations in environmental temperature, to expectation cores behaviour during casting. Because apparatus DMA simulating the conditions during flooding the form, parameter hot distortion should stand basic parameter, describing behaviour of cores in high temperature.

2.3. Protective coats

In next stage of research, moulds prepared with self-hardening moulding sand technology with furfuryl resin covered by protective coats were investigated. The thermal deformation was shown as a function of heating time.

The following coatings were laid on prepared samples: graphite coating, silicate aluminum coating, corundum coating, zirconium coating.

Coatings were laid by brush painting. The investigation of the samples covered with single and double layer of coatings were made. The comparison of sample behaviors without coat, single and double layer of coating was shown on the graphs.

The results of investigations of hot distortion parameter for silicate aluminum coating are shown on figure 14. The curve of sample deformation without coating is characteristic for this kind of materials [10]. In initial stage of heating, there are no visible changes in sample behavior. During the time the sample is distorting up. After small deformation, the sample violently breaks down. This is caused by total destruction of binder. The use of silicate aluminum coating does not fundamentally change the profile of deformation curve. The curves have approximate course. In relation to sample without coating both the size and the time deformation increase can be observed.

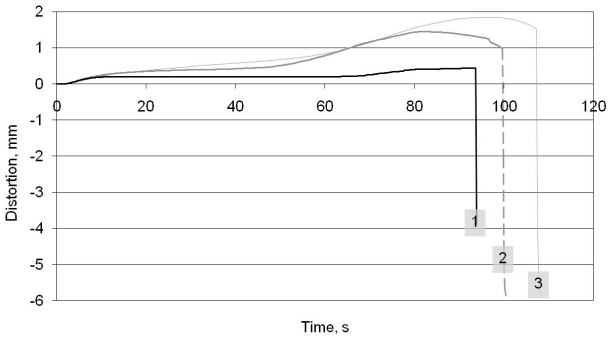

Fig. 14. Thermal deformation of core sands with silicate aluminum coating; 1 – sample without coating, 2 – single layer of Al-Si coating, 3 – double layer of Al-Si coating

It is not possible to qualify how thickness of coating influences on thermal deformation, because comparing results received for single and double layer shows, that rate of distortion are similar for both.

In case of zirconium coating (Fig. 15) a bigger influence of layer quantity on the sample behavior can be observed. The use of coating improves the sample's thermal resistance. The size of deformation grows up when the sample with single layer is investigated. Double coating has better influence than the single one. The binder destruction which causes sample breaking down proceeds after longer time, however the change of deformation size is bigger than for the sample without coating.

The use of graphite coating (Fig. 16) causes the small improvement of thermal resistance (the time of destruction grows up about 14sec), but the size of deformation is bigger. This phenomenon is unfavorable,

because there is a possibility of appearing the dimension accuracy or the additional tensions in cast. The influence of coating thickness on behavior of core sand during heating is not observed.

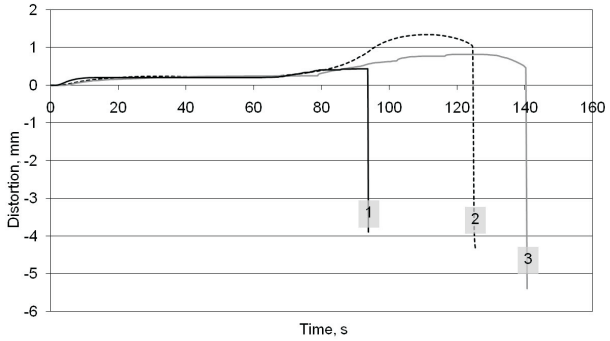

Fig. 15. Thermal deformation of core sands with zirconium coating; 1 – sample without coating, 2 – single layer of zirconium coating, 3 – double layer of zirconium coating

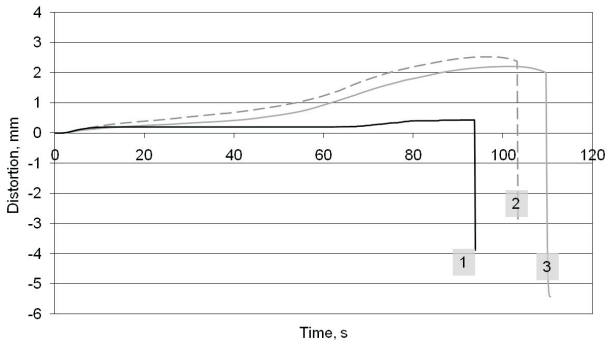

Fig. 16. Thermal deformation of core sands with graphite coating; 1 – sample without coating, 2 – single layer of graphite coating, 3 – double layer of graphite coating

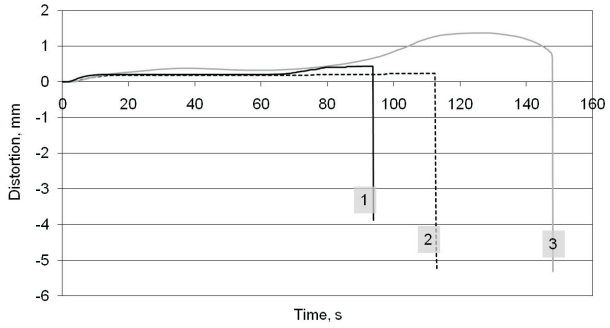

Fig. 17. Thermal deformation of core sands with corundum coating; 1 – sample without coating, 2 – single layer of corundum coating, 3 – double layer of corundum coating

Analyzing curves on figure 17, it is possible to say, that applying corundum coating improves thermal resistance. Divergent results received for the samples with single layer make impossible to say how the thickness of layer influence on size of deformation.

Made investigations show, that in dependence of applied coating, thermal deformation can run in different way. It does not only concern the character of deformation, but also the time which is necessary to binder's destruction or the size of deformation. The best influence on behavior of core sands has the zirconium coating.

3. Conclusion

The investigation shows, that thermal deformation can run in different ways, in dependence of applied binder. Good strength of moulding sand in environment temperature does not mean, that this moulding sand has good properties during thermal deformation. Final selection of binder should be proceeded by exact and detailed investigation in environment and high temperature.

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