Computer aided process of dimensional distortion determination of bounded plaster sandmix

M. Pawlak*, Z. Niedźwiedzi

*Department of Materials Technology and Production Systems, Technical University of Lodz, Stefanowskiego 1/15, 90-924 Łódz, Poland
*Corresponding author. E-mail address: marek.pawlak@p.lodz.pl

Received 21.04.2009; accepted in revised form 24.04.2009

Abstract

A computer program allowing calculation of dimensional changes of mould made of silica-gypsum composition in process of its heat treatment and preparation for molten metal casting is presented in this paper. The composition of the mixture and casting temperature to obtain cast of predetermined dimensions can be calculated using presented software. The base for program elaboration were the results of dilatometric test of bounded plaster sandmix composed of half hydroxide $\alpha$-$\text{CaSO}_4$·0.5$\text{H}_2\text{O}$ of various silica $\text{SiO}_2$ ratio (0, 30, 40, 50, 60, 70 and 98%). Approximation was carried out in the range of temperatures 100–800°C.

Keywords: Innovative foundry technologies and materials, Precision casting, Plaster mould, Dilatation

1. Introduction

Plaster, as a mould material for preparation casts of medium melting temperature alloys had many advantages. It is a material which perfectly projects complicated casting shapes assuring simultaneously good dimensional accuracy and smooth surface. However it brings lot of technological problems. The reasons for that are mainly phase transformations during heating and bounding. These transformations are connected with crystal lattice rebuilding and thus changes of density. This causes high thermal stresses leading even to mould cracking [1].

Independently on above described problems, advantages of this technology, especially with use of underpressure, make wide application of it in jewellery, art foundry, prosthetics and low series casting of high quality [1].

The results of phase transformations can be soften by addition of components compensating transformations in plaster (silica, anhydrite) and high temperature treatment leading to anhydrite II creation characterized by linear expansion [1, 3, 4].

Thus, the basic problem is to determine appropriate, the most advantageous composition of the plaster sandmix at which it is possible to obtain predetermined dimensional changes of bounded sandmix and as low as possible phase stresses during thermal treatment. The next problem is to find out the temperature of the mould the best from the viewpoint of dimensional accuracy of the mould and therefore made cast [1, 2, 5, 6].

It is very time consuming and difficult to define listed above parameters. The work task of elaborated computer program is therefore to calculate mould dimensions made of silica-plaster composition just before casting.
2. Results of dilatometric measurements of the block made of various plaster compositions during cooling phase and theirs approximation

Testing blocks of dimensions ø 7x35 mm made of dihydrate plaster $\alpha$-CaSO$_4$·2H$_2$O with silica percentage 0, 30, 40, 50, 60, 70 i 98% were investigated. Materials and methodology were described in details in [1]. Data for computer program were taken raw with special emphasis given to testing blocks cooling characteristics. Full data are presented in fig. 1.

Fig. 1. Relative dimensional change DL vs testing block temperature during heating and cooling
The analysis of presented in fig. 1 dependence show that phase transformations of the components hale significant influence on final dimensions of tested sample heated and cooled down. This dependence is partially of additive character because of different temperature ranges for particular components of the sandmix.

Results of approximation of dimensional change of blocks in cooling phase, are presented in table 1. Many functions were used for experimental data approximation. After numerous trials those which allowed the best fitting were chosen. Above data are the base for elaboration of suitable computer programs.

Table 1.
Results of approximation of dimensional change of blocks in cooling phase

<table>
<thead>
<tr>
<th>Lp</th>
<th>Plaster/Silica %</th>
<th>Temperature range °C</th>
<th>Polynominal factor</th>
<th>Square of correlation coefficient $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100/0</td>
<td>99,6÷802,43</td>
<td>Stage 0: -4,01243</td>
<td>Stage 1: -0,000281502</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: 2,48914E-006</td>
<td>0,999317</td>
</tr>
<tr>
<td>2</td>
<td>70/30</td>
<td>99,79÷655,36</td>
<td>Stage 0: -1,80086</td>
<td>Stage 1: 0,000793243</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: -1,21456E-006</td>
<td>0,998957</td>
</tr>
<tr>
<td>3</td>
<td>70/30</td>
<td>655,36÷800,97</td>
<td>Stage 0: -1,09928</td>
<td>Stage 1: -0,000265307</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: 1,37398E-006</td>
<td>0,999426</td>
</tr>
<tr>
<td>4</td>
<td>60/40</td>
<td>101,00÷611,56</td>
<td>Stage 0: -1,5432</td>
<td>Stage 1: 0,000487235</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: -7,17829E-007</td>
<td>0,998193</td>
</tr>
<tr>
<td>5</td>
<td>60/40</td>
<td>611,56÷801,63</td>
<td>Stage 0: -19,7992</td>
<td>Stage 1: 0,0774738</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: -0,000104629</td>
<td>0,998774</td>
</tr>
<tr>
<td>6</td>
<td>50/50</td>
<td>100,09÷661,43</td>
<td>Stage 0: -1,18682</td>
<td>Stage 1: 0,00106838</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: -2,42824E-006</td>
<td>0,998453</td>
</tr>
<tr>
<td>7</td>
<td>50/50</td>
<td>661,43÷800,75</td>
<td>Stage 0: -0,337467</td>
<td>Stage 1: -0,000201761</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: 1,03788E-006</td>
<td>0,999489</td>
</tr>
<tr>
<td>8</td>
<td>40/60</td>
<td>99,84÷646,79</td>
<td>Stage 0: -1,09678</td>
<td>Stage 1: 0,00179944</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: -4,72855E-006</td>
<td>0,997053</td>
</tr>
<tr>
<td>9</td>
<td>40/60</td>
<td>646,79÷800,55</td>
<td>Stage 0: 0,100811</td>
<td>Stage 1: -0,000631196</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: 1,1069E-006</td>
<td>0,999153</td>
</tr>
<tr>
<td>10</td>
<td>30/70</td>
<td>100,74÷622,00</td>
<td>Stage 0: -0,771956</td>
<td>Stage 1: 0,00155437</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: -3,63483E-006</td>
<td>0,997708</td>
</tr>
<tr>
<td>11</td>
<td>30/70</td>
<td>622,00÷800,16</td>
<td>Stage 0: -25,0834</td>
<td>Stage 1: 0,103572</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: -0,000140312</td>
<td>0,996157</td>
</tr>
<tr>
<td>12</td>
<td>0/100(98)</td>
<td>100,64÷622,47</td>
<td>Stage 0: 0,0389928</td>
<td>Stage 1: -0,00624164</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: 4,10124E-005</td>
<td>0,997738</td>
</tr>
<tr>
<td>13</td>
<td>0/100(98)</td>
<td>622,47÷800,00</td>
<td>Stage 0: 1,44197</td>
<td>Stage 1: -9,55938E-005</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stage 2: 7,80694E-011</td>
<td>0,812482</td>
</tr>
</tbody>
</table>
3. Elaboration of computer program to calculate dimensional changes of the moulds made of various compositions, during cooling process

Presented programs give answers for following problems:

**KOMCJA51**

I - Calculate dimensional change of the mould made of particular plaster composition in specific casting temperature:

Given: \( T_{zalF} = \text{***} \), \( \text{SiO}_2\text{zad} = \text{****} \)
Find: \( D_{Lzad} \)

**KOMCJA6**

II – For given quantity of relative dimensional change of the mould \( DL \) find mould temperature \( T_{zalF} \) and composition of different mixtures (\( \text{SiO}_2 \) to plaster ratio - HF) allow obtaining predetermined value

Given: \( DL\text{zad} = \text{***} \)
Find: \( T_{zalF} = ?, \text{HFzad} = ? \)

Examples of calculation results at given temperature and composition of the mould ready for casting, to find its dimensional changes under such conditions.

**Calculated with use of "KOMCJA51" 04-12-2008***
Program relates to composition: HF/\( \text{SiO}_2 \)*
Temperature of the mould \( T_{zalF} = 100 – 800 \degree C \)
For composition \( \text{SiO}_2 = 0-98 \% \)
\( T_{zalF} = 328.2 \degree C \)
Composition – \( \text{SiO}_2 \) percentage, %
\( \text{SiO}_2\text{zad} = 27.56 \% \)
\( DL\text{zadp} = -1.717 \% \)

**Calculate for next data: Y/N**

Second example relates to situation in which dimensional change is given and the chemical composition and mould temperature are to be found.

**Calculated with use of "KOMCJA51" 04-12-2008***
Program relates to composition: HF/\( \text{SiO}_2 \)*
Mould temperature \( T_{zalF} = 100 – 800 \degree C \) for composition
\( \text{SiO}_2 = 0-98 \% \)
\( DLzadF = -0.4 \% \)

1. FOR \( \text{SiO}_2 = 0.00 \% \) CORRESPONDING CONTRACTION EQUALS:
\( \text{MIN CONTRACTION } DL_{0.00100p} = -0.40157 \% \) (dimensional change for \( T_{zalF} = 100 \) st.C)
\( \text{MAX CONTRACTION } DL_{0.00800p} = -2.6446 \% \) (dimensional change for \( T_{zalF} = 800 \) st.C)

2. DLA KOMPOZYCJI \( \text{SiO}_2 = 30.00 \% \) CORRESPONDING CONTRACTION EQUALS:
\( \text{MIN CONTRACTION } DL_{30100p} = -1.7297 \% \)
\( \text{MAX CONTRACTION } DL_{30800p} = -0.4322 \% \)

3. DLA KOMPOZYCJI \( \text{SiO}_2 = 40.00 \% \) CORRESPONDING CONTRACTION EQUALS:
\( \text{MIN CONTRACTION } DL_{40100p} = -1.4977 \% \)
\( \text{MAX CONTRACTION } DL_{40800p} = -0.2267 \% \)
For given contraction "DLzadF" temp. of mould: \( T_{zalF} = 690.40 \) st.C

4. DLA KOMPOZYCJI \( \text{SiO}_2 = 50.00 \% \) CORRESPONDING CONTRACTION EQUALS:
\( \text{MIN CONTRACTION } DL_{50100p} = -1.0989 \% \)
\( \text{MAX CONTRACTION } DL_{50800p} = 0.1654 \% \)
For given contraction "DLzadF" temp. of mould: \( T_{zalF} = 560.80 \) st.C

5. DLA KOMPOZYCJI \( \text{SiO}_2 = 60.00 \% \) CORRESPONDING CONTRACTION EQUALS:
\( \text{MIN CONTRACTION } DL_{60100p} = -0.9564 \% \)
\( \text{MAX CONTRACTION } DL_{60800p} = 0.3043 \% \)
For given contraction "DLzadF" temp. of mould: \( T_{zalF} = 504.00 \) st.C

6. DLA KOMPOZYCJI \( \text{SiO}_2 = 70.00 \% \) CORRESPONDING CONTRACTION EQUALS:
\( \text{MIN CONTRACTION } DL_{70100p} = -0.6464 \% \)
\( \text{MAX CONTRACTION } DL_{70800p} = 0.3043 \% \)
For given contraction "DLzadF" temp. of mould: \( T_{zalF} = 348.00 \) st.C

Calculate for next data: Y/N

For given dimensional change \( DL\text{zadF} = -0.4\% \) program calculates and presents chemical composition of the mixture that does not fulfill requirements (point. 1 and 2).
Next, program calculates and presents chemical composition of the mixtures fulfilling condition \( DL\text{zadF} = -0.4\% \) giving required for them temperature for mould ready for casting (point. 3, 4, 5 and 6).

**4. 3D graphical representation of dimensional changes of the mould made of various compositions**

The 3D plot was created on the base of carried out calculations. The plot represents relative dimensional changes of the mould DL in the dependence on mineralogical composition of the mould as well as its temperature at the moment of casting.
Fig. 2. Relative dimensional change DL in function of temperature and various content of SiO₂ in the range 100-700°C

The analysis of the dependence DL(T,zal,F, SiO₂) allows easy evaluation of the influence of particular quantities on dimensional changes of the mould, as well as intensity of the change and its character. Previously presented computer software allow to calculate dimensional changes and selection of chemical composition more accurately.

5. Final remark

Elaborated computer programs allow calculations of forecasted dimensional changes of the mould prepared of known composition or determination required temperature and chemical composition of the mould at which mould assures obtaining cast of precise dimensions.

Acknowledgements

The research formed a part of the study No. N N508 3886 33 supported by Polish State Committee of Scientific Research.

References:


properties of gypsum), Polska Metalurgia w latach 2002-2006, PAN, Akapit, Kraków 2006, s. 287-293.


