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Computer aided process of dimensional distortion determination of bounded plaster sandmix Part II

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Abstract

A computer program allowing calculation of dimensional changes of mould made of cristobalite-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 hydrate α-$CaSO_4 \cdot 0{,}5H_2O$ of various cristobalite ratio. Approximation was carried out in the range of temperatures 100÷700°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 [2]. 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 [2]. The results of phase transformations can be soften by addition of components compensating transformations in plaster (silica, cristobalite) and high temperature treatment leading to anhydrite II creation characterized by linear expansion [2, 4, 5]. 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 [2, 3, 6, 7]. 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 cristobalite-plaster composition just before casting. The analysis of results of calculations realized binary setting plaster sandmix contained gypsum HF1 and silica showed [1], that characteristics DL=f(t) has unfavorable courses in the range 200÷600°C, i.e. in the range of full phase change of anhydrite I to anhydrite II. It should expect, that in this range cristobalite addiction should be likely, because in the range of temperature 250÷400°C cristobalite showed the dimensional change opposite to silica.

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 dihydride plaster α-$CaSO_4 \cdot 2H_2O$ with cristobalite percentage 0.25, 30, 50 and 100% were investigated. Materials and methodology were described in details in [2]. Data for computer program were taken raw with special emphasis given to testing blocks cooling characteristics. Full data are presented in fig. 1

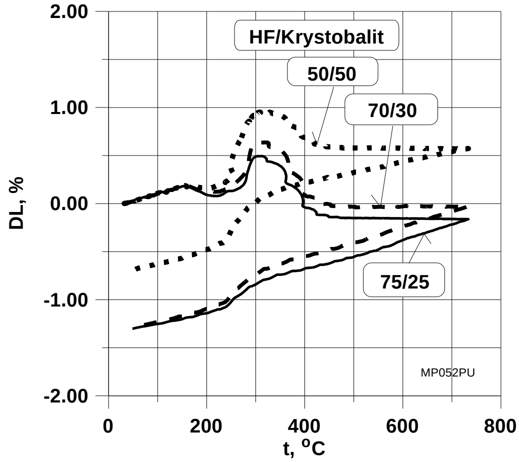

Fig. 1. Relative dimensional change DL vs testing block of gypsum-cristobalite temperature during heating and cooling

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

Lp.	Gypsum/ Crystobalite %	Temperature range ºC	Polynominal factor	Square correlation coefficient R^2
1	100/0	350÷710	Stage 0: 0,00243835 Stage 1: -3,11249	0,990491
2	75/25	350÷710	Stage 0: 0,00153739 Stage 1: -1,30844	0,993755
3	70/30	350÷710	Stage 0: 0,00157221 Stage 1: -1,1898	0,997962
4	50/50	350÷710	Stage 0: 0,00108614 Stage 1: -0,222098	0,998574

3. Elaboration of computer program to calculate dimensional changes of the moulds made of various compositions gypsum-cristobalite, during cooling process

Presented programs give answers for following problems:

KOMCJA3

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

Given: TzalF=***, HFzad=****
Find : DLzadF=?

KOMCJA4

II – For different composition and given quantity of relative dimensional change DL find mould temperature allow obtaining predetermine value of dimensional change of the mould in this moment.
Given: HFzad=***, DLzad=***
Find: TzalF=?

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 "KOMCJA3"
Program relates to composition: HF/Cristobalite
Temperature of the mould TzalF = 0 – 700°C
TzalF= 500 ^{o}C
Composition – HF percentage, %
HFzad=85.00 %
DLzadp= -1.0812 %
- 68.3 % of results contains in the range (-1.1105÷1.0518 %)
- 95.5 % of results contains in the range (-1.1398÷1.0224 %)
- 99.7 % of results contains in the range (-1.1693÷0.9931 %)

CALCULATE FOR NEXT DATA: Y/N

Calculated with use of "KOMCJA3"
Program relates to composition: HF/Cristobalite

Temperature of the mould TzalF = 0 – 700 ^{o}C
TzalF= 400^{o}C
Composition – HF percentage, %
HFzad=65.00 %
DLzad p=-0.3676 %
- 68.3 % of results contains in the range (-0.3752÷0.3600 %)
- 95.5 % of results contains in the range (-0.3827÷0.3525 %)
- 99.7 % of results contains in the range (-0.3903÷0.3449 %)

CALCULATE FOR NEXT DATA: Y/N

Calculated with use of "KOMCJA3"
Program relates to composition: HF/Cristobalite

Temperature of the mould TzalF = 0 – 700 ^{o}C
TzalF= 300^{o}C
Composition – HF percentage, %
HFzad=90.00 %
DLzad p=-1.7675 %
- 68.3 % of results contains in the range (-1.7968÷1.7831 %)
- 95.5 % of results contains in the range (-1.8626÷1.7090 %)
- 99.7 % of results contains in the range (-1.8556÷1.6794 %)

CALCULATE FOR NEXT DATA: Y/N

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

Calculated with use of "KOMCJA4"
Program relates to composition: HF/Cristobalite
Composition – HF percentage, %

Percentage HF should be in limits:
50>=HFzad<=100%

Contraction in the temperature of pouring moulds equals:
DLzadF=+0.10÷-2.38 % in temp. = 300^{o}C
also
DLzadF=+0.54÷ -1.41 % in temp. =700^{o}C

[1] REMEMBER THIS DATA --> HFzad[%]=60.00 %

[2] REMEMBER THIS DATA --> DLzadF[%]=0.5000%

Temperature of the pouring mould is out of range 300÷700^{o}C
For assumed dates: DLzad=0.5000 % and HF=60.00 %:
TEMPERATURE OF POURING MOULD SHOULD BE AMOUNT --> TzalF=938.53^{o}C

[3] IT SHOULD BE REDUCE --> HFzad
50>=HFzad<=100%

It means that should be reduce percentage of gypsum HF1 in the composition, so as temperature of pouring mould contains in the assumed range of temperature 300÷700^{o}C.
It is allowed to be done as follows:

Calculated with use of "KOMCJA4"
Program relates to composition: HF/Cristobalite
Composition – HF percentage, %

Percentage HF should be in limits:
50>=HFzad<=100%

Contraction in the temperature of pouring moulds equals:
DLzadF=+0.10÷-2.38 % in temp. = 300^{o}C
also
DLzadF=+0.54÷ -1.41 % in temp. =700^{o}C

[1] REMEMBER THIS DATA --> HFzad[%]=52.00 %

[2] REMEMBER THIS DATA --> DLzadF[%]=0.5000%

For assumed dates: DLzad=0.5000 % and HF=52.00 %:
TEMPERATURE OF POURING MOULD SHOULD BE AMOUNT --> TzalF=725.08^{o}C

It means that should be reduce percentage of gypsum HF1 in the composition, so as temperature of poring mould contains in the assumed range of temperature 300÷700^{o}C.
It is allowed to be done as follows:

Calculated with use of "KOMCJA4"
Program relates to composition: HF/Cristobalite
Composition – HF percentage, %

Percentage HF should be in limits:
50>=HFzad<=100%

Contraction in the temperature of pouring moulds equals:
DLzadF=+0.10÷-2.38 % in temp. = 300°C
also
DLzadF=+0.54÷ -1.41 % in temp. =700°C

[1] REMEMBER THIS DATA --> HFzad[%]=50.00 %

[2] REMEMBER THIS DATA --> DLzadF[%]=0.5000%

For assumed dates: DLzad=0.5000 % and HF=50.00 %:
TEMPERATURE OF POURING MOULD SHOULD BE AMOUNT --> TzalF=659.77°C

It means that temperature of pouring mould TzalF contains in the assumed range of dates DL and HF.

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.

The analysis of the dependence **DL(TzalF, Cristobalite)** 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 composition more accurately.

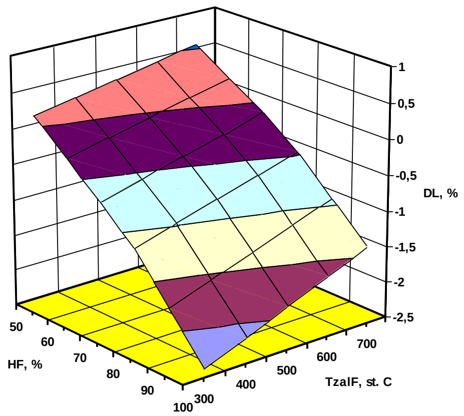

Fig. 2. Relative dimensional change DL in function of temperature and various content of gypsum HF in the range 100-700°C

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.

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