DETERMINATION OF THE THERMAL EXPANSION COEFFICIENT FOR A NEW TYPE ALLOY STEEL

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Abstract. The subject of research in the present paper is the experimental determination of the thermal expansion coefficient for a definite type of steal at high temperatures. The presented methodology is proved by investigation of a new type of steel.

Keywords: thermal expansion, steel, residual stress

1. Introduction

Computer simulations significantly contribute to the improvement of mould technologies. That is why they are widely used in practice. Specialized commercial software is usually utilized. There are not many software products which offer options for calculation of residual stress and strain and their capabilities to adapt to specific problems are not always sufficient. A lot of studies are made by using universal software products in which calculation models are created [1].

Simulation of residual stresses and strains at moulding requires accurate information about the properties of the used materials. Some of these properties can be obtained from specialized literature or from experimental data. Some of the material properties are temperature-dependent and they have different degree of influence over the results from a numerical solution. Significant experience is required to decide which properties should be accurately determined (by experimental investigation) and which can be taken with an approximate value from literature resources when defining a numerical model.

A temperature change Δt of a structural element leads to a change of its length L which can be expressed by $\Delta L^t = \alpha \cdot \Delta t \cdot L$, where α is the material thermal expansion coefficient for the relevant temperature range [2]. In the case of a mould the uneven cooling induces residual stresses [3]. Important parameter in a numerical simulation of such stresses in moulds is the material thermal expansion coefficient. Determination of the elongation which a specimen made of definite material undertakes at 1°C temperature change can lead to obtaining of this coefficient.

2. Aim of the study

The study aims to obtain the thermal expansion coefficient of a new type alloy steel 1.4852 M developed by Centromet PLC – Vratsa. The chemical ingredients of the alloy steel are given in Table 1. The steel is used for mould production.

Table 1. Chemical composition of steel 1.4852 M (in %)

C	0.45÷0.5
Ni	45÷48
Cr	34÷37
Si	≤2.2
Mn	≤1.5
Nb	≤1.8
S	≤0.03
P	≤0.03
Ti	0.1÷0.25
Zr	0.1÷0.2

3. Experimental study and results

The specimens made of the investigated steel are shown in Figure 1. They are made according to the standard EN 10291:2000 [5].

Figure 1. Test pieces

The experiments are conducted with a testing stand which is shown in Figure 2. It consists of heating device, testing machine and equipment for control and recording of experimental data [4]. The heating device allows the test specimens to be heated to 1100 °C.

The extensometer used for the longitudinal deformations measurement is shown in Figure 3. It is produced by Epsilontech (USA). Its range is up to 1100°C and the initial measurement length is 25 mm. The extensometer corresponds to the standard EN 10002-4 [6].

Figure 2. A stand for testing materials at elevated temperatures

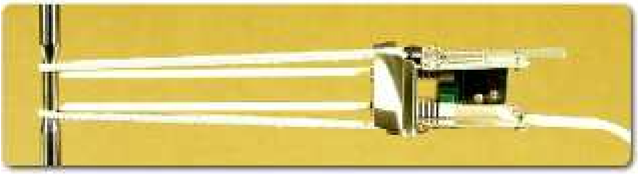

Figure 3. Extensometer made by Epsilontech

The experimental investigation is conducted according to the following procedure:

1) The specimen made of steel 1.4859 M is fixed in the testing machine.
2) The extensometer is mounted and the heating section is closed.
3) Initial working temperature of 100 °C is adjusted.
4) The measuring device is put to zero and the heating section is switched on.
5) After reaching the required temperature the heating section is left to work at least 1 hour [7]. Then the elongation is measured with the extensometer.
6) Steps 3 and 5 are repeated for temperatures of 200, 300, 400, 500, 600, 700, 800, 900 and 1000 °C.

Additionally, three specimens are tested at temperature of 20 °C. Processed test results are shown in Table 2.

Table 2. Processed experimental results

T_i [°C]	$\Delta L_1^{T_i}$ [μm]	$\Delta L_2^{T_i}$ [μm]	$\Delta L_3^{T_i}$ [μm]	$\Delta L_{cp}^{T_i}$ [μm]	α^{T_i} [m/m.°C]
$T_1 = 100$	46	59	51	52	26.00×10^{-6}
$T_2 = 100$	105	117	111	111	24.67×10^{-6}
$T_3 = 300$	160	175	166	167	23.86×10^{-6}
$T_4 = 400$	212	225	223	220	23.16×10^{-6}
$T_5 = 500$	267	276	273	272	22.67×10^{-6}
$T_6 = 600$	319	328	322	323	22.28×10^{-6}
$T_7 = 700$	369	377	373	373	21.94×10^{-6}
$T_8 = 800$	421	426	425	424	21.74×10^{-6}
$T_9 = 900$	472	475	475	474	21.54×10^{-6}
$T_{10} = 1000$	525	525	528	526	21.47×10^{-6}

Figure 4 shows the graphic representation of the relationship between expansion coefficient and the temperature. The elongation measured with the extensometer of specimens 1, 2 and 3 is denoted with $\Delta L_1^{T_i}$, $\Delta L_2^{T_i}$, $\Delta L_3^{T_i}$ respectively and the average elongation of the three specimens is denoted by $\Delta L_{cp}^{T_i}$.

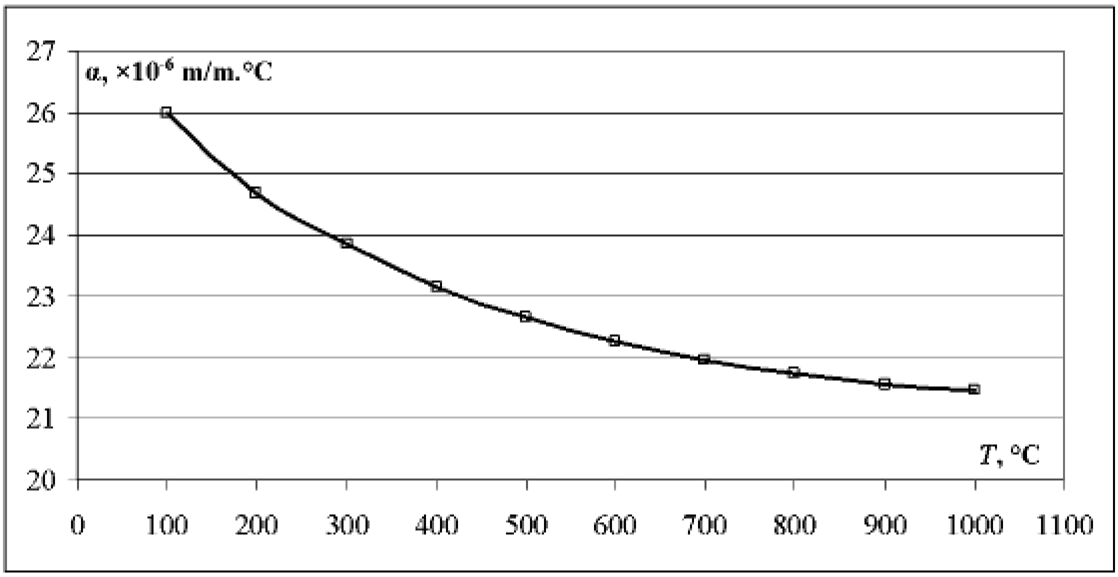

Figure 4. Graphic representation of the relationship between expansion coefficient and the temperature

The thermal expansion coefficient α is calculated according to the following formula:

$$\alpha^{T_i} = \frac{\Delta L_{cp}^{T_i}}{0.025 \cdot (T_i - 20)} .$$

The obtained results show that the thermal expansion coefficient of steel type 1.4852 M decreases with the increase of the temperature. After 800 °C its value trends asymptotically to 21.4×10^{-6} m/m°C. This leads to the conclusion that $\alpha = \text{const} = 21.4 \times 10^{-6}$ m/m°C at temperatures higher than 1000 °C.

4. Conclusion

The thermal expansion coefficient of a new steel type (1.4852 M) is obtained. It is observed that this coefficient decreases with the increase of the temperature. The acquired results can be used for the numerical simulation of the residual stresses and strains in moulds made of 1.4852 M steal.

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