EXPERIMENTAL DETERMINATION OF TEST PIECE TEMPERATURE INTENDED FOR STRENGTH TESTING AT INCREASED TEMPERATURES

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This article describes the methodology and presents the results of temperature measurement in different points of a test piece, intended for strength testing at increased temperatures. The aim is to check the temperature field homogeneity and the work temperature deviation from the given values in specialized device for strength testing at increased temperatures. It is concluded that the device answers the requirements for making such tests.

Key words: *temperature measurement, high temperature strength test*

1.Introduction

In order to estimate the material working capacity, a test piece of the material is subjected to strength testing in normal and extreme conditions. The purpose is to determine the different strength material properties, which are of utmost importance to the exploitation –yielding limit, ultimate strength, creep limit etc. These limits represent critical stress values for the material, causing plastic strain or rupture. As these phenomena are inadmissible in practice, the details are designed with allowable stress, which is part of the critical stress.

Various material strain properties are normally defined in the course of the strength testing. More often these are the Young's modulus E of the material, representing the relation between the normal stress and the engendered by it longitudinal strain in the same direction, and the coefficient of the transversal strain μ, (known as the Poisson's coefficient), representing the relation between the transversal and longitudinal strains [1].

The main stress-strain properties of the materials are standardized. So are also the requirements towards the methods and the means for their definition [2]. In the matter of strength testing at increased temperature, the standard specifies the allowable deviations from a specified test temperature θ. For the different temperature ranges they are as follows:

$\pm 3^\circ C$ for $\theta \le 600^\circ C$

$\pm 4^\circ C$ for $600^\circ C < \theta \le 800^\circ C$

$\pm 5^\circ C$ for $800^\circ C < \theta \le 1000^\circ C$.

Three thermocouples, situated at equal distance along its working length (the length of the test piece part with minimal cross-section area), are enough to control the test piece temperature. The thermocouples shall make good thermal contact with the surface of the test piece and their sensitive point shall be screened from direct radiations from the furnace walls.

The temperature measuring device shall have a resolution of at least 1°C and a precision of ±2°C.

In order to be able to carry out strength testing at increased temperatures, the "Strength of materials" department of the Technical University - Sofia, has designed and developed a special device, consisting of a specialized furnace and clamping elements, made of heat-resistant steel [3]. The device has been designed to work together with a standard testing machine ZD 20, allowing a load of up to 20 tons (fig.1). The purpose of the present research is to verify whether the developed device can maintain the test piece working temperature within the range, set by the standard.

2.Furnace's special features

The specialized furnace represents an enclosed heat-insulated space with electric heater mounted on its walls [4]. The maximum working temperature of the furnace is 1100°C. There are 16 electric heaters in total, grouped along the height of the furnace walls in two sections, each with an active power of 1500 W. In order to maintain the working temperature within the required range, each section has got an independent programmable temperature controller, receiving information about the working space temperature in the corresponding section from a special type “K” thermocouple. The operator can set the testing working temperature, as well as the heaters’ switching on and off temperatures.

Fig.1 Heating module for material strength testing at increased temperatures

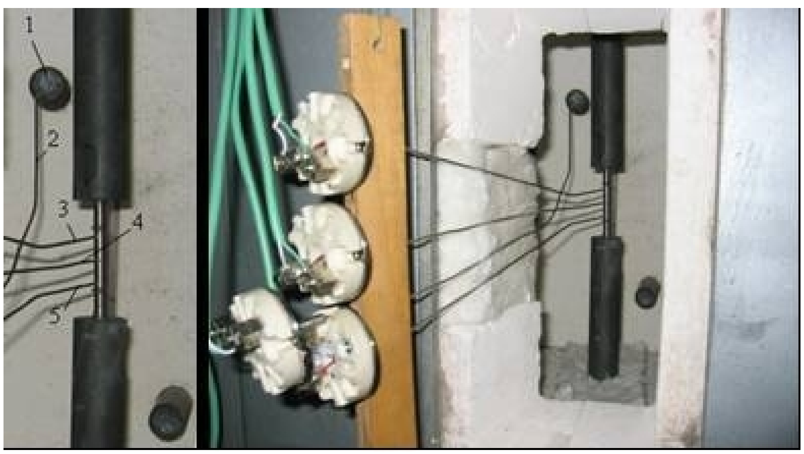

Fig.2 Thermocouples position and numbering

The dimensions of the furnace’s working space are 170x330x230 mm. There are two cylindrical apertures on the back side, letting pass the controlling thermocouples. A cylindrical aperture on the upper and one on the lower part, let pass the clamping elements. A door on the front allows placing or replacing the test piece. Next to this door there is a rectangular opening, through which pass strain measurement system elements. In our case these are the control thermocouples, necessary for the present research. All furnace apertures are made tight with insulating wadding in order to reduce the heat losses.

Fig.3 Temperature measurement device

The clamping elements are details made of high-alloy steel, ensuring the connection between the test piece, placed in the middle of the furnace working space, and the clamps of the testing machine. The material of the clamping elements allows a maximum working temperature of 1250°C at a relatively low thermal conductivity. Nevertheless, as these elements are made of steel and are in contact with the furnace working space, as well as with the atmosphere and the cold details of the testing machine, it is supposed that there will be considerable heat losses through them. The present research will verify whether these losses will lead to inhomogeneous heating of the test piece, or even to lower temperature of the test piece compared to the furnace working space temperature.

3.Test piece temperature measurement

The experiment has been carried out in the following sequence:

3.1. Holes 2 mm deep are driven in the working part of the test piece.

3.2. The clamping elements and the test piece are mounted in the furnace.

3.3. Three thermocouples type TSSB(K) - NiCrNi (M7/M8) with work temperature up to 1100ºC are placed in the driven holes (№ 3, 4 and 5 on fig. 2).

3.4. A thermocouple of the same type (№2 on fig.2) is placed near the sensitive point of the thermocouple, controlling the heaters' upper section (№1 on fig.2), in order to determine whether there is a difference between the indications of both thermocouples.

3.5. The values of both temperature controllers are set to the desired work temperature and the furnace is put in operation.

3.6. After the work temperature in both sections is reached, the furnace is left working for three hours in order to steady the process.

3.7. Using a portable temperature measuring device HS 700 (fig.3) the test piece temperature is observed in the three points of its working part.

The measurement is made at a work temperature of 1000°C. The temperature controllers are programmed so that to switch on the heaters at 996°C and switch them off at 1000°C. After reaching 1000ºC the temperature continues to increase, due to the process inertness, and reaches 1001-1002ºC before decreasing again. The work temperature variations lead to constant changes in the test piece temperature.

A periodicity of the furnace operation was established in the course of the measurement. The temperatures, measured with the five thermocouples for one furnace working cycle are given in Table 1. The curves of the five temperatures changes in time are shown on fig.4.

Table 1. Measured temperatures

time, s	**T_1, °C**	**T_2, °C**	**T_3, °C**	**T_4, °C**	**T_5, °C**
0	1000	993	996	996	997
10	1001	994	997	997	998
20	1002	995	997	998	999
30	1001	997	999	999	1001
40	1000	999	1000	1002	1003
50	1000	1001	1002	1003	1004
60	998	1003	1004	1004	1004
70	995	1004	1004	1003	1002
80	995	1004	1003	1001	1000
90	996	1001	1001	999	999
100	997	997	999	998	998
110	998	994	997	997	997
120	1000	993	996	996	996

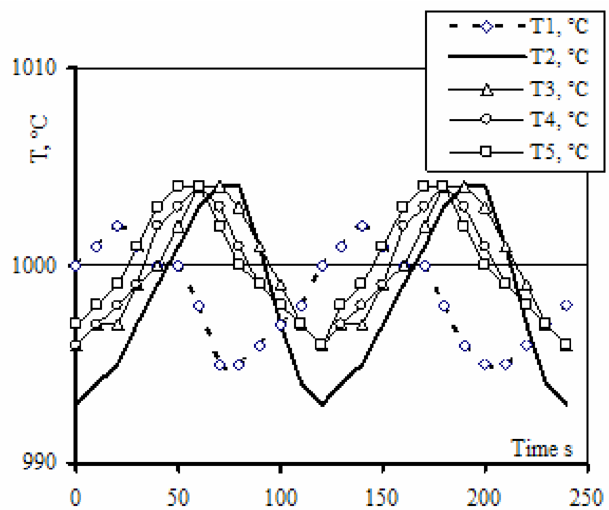

Fig.4 Temperature variations with time

The results obtained show that there is little difference and dephasing in the temperatures, measured by both types of thermocouples. This is due to the different construction of their bodies - that of the controlling thermocouple has greater diameter, which makes it more inert. That's why the measured temperatures with thermocouple №1 are within the range of 995-1002°C, and those measured with thermocouple № 2 – are within the range of 993-1004°C.

The results obtained show that the highest test piece temperature measured is 1004°C, and the lowest – 996°C.

4.Inferences

1. The developed experimental device provides test piece heating up to 1000°C.

2. The measured temperatures of the test piece are within the allowable limits according to the standard EN 10002-5.

3. For one heaters' work cycle the test piece temperature in the three controlled points does not differ with more than 3°C. This difference follows the temperature variation cycle within the working field. This shows that the temperature field in the vicinity of the test piece has got the necessary homogeneity for the needs of the planned strength testing at high temperatures.

5.Conclusion

The developed experimental device answers the necessary requirements for running tests at temperatures within the range of 800-1000°C and it can be used to determine the materials' stress-strain properties at such temperatures.

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