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EXPERIMENTAL STUDY ON HEATING DEVICE FOR TESTING MATERIALS, INTENDED FOR A LONG WORK AT INCREASED TEMPERATURES

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Summary: *The requirements towards a heating device for long testing of materials intended for work at increased temperatures are given in the present article. A temperature measurement and registration methodology within the device's working chamber, as well as along the height of the test piece, has been described. Estimation has been made of the heating device's ability to maintain the specified temperature of the test piece in case the electric heater burns out. It has been verified whether a burnt electric heater could be replaced without interruption of the experimental study and without disturbing the testing conditions.*

Keywords: *heating device, increased temperature strength test, temperature measurement*

1. INTRODUCTION

Materials, working for a long time at increased temperature and at great load are widely used nowadays in the energetics, in the chemical industry, in the aviation, in the automotive industry and in many other technical domains. These exploitation conditions put forward a number of requirements towards the details used. Quite often these high and various requirements should be combined with a minimum strength reserve. Otherwise the development of some machines and equipment (for example jet engines) would turn up to be a technically impossible task. That's why when designing construction elements, intended for a long work at increased temperature and at great load, it is extremely important to have a good knowledge of the behaviour of the material used at such exploitation conditions. The presence of experimental data allows the constructor to work with minimum strength reserve and to create a light, cheep and reliable construction.

2. TECHNICAL REQUIREMENTS

Specific testing equipment should be used for gathering experimental data for the behaviour of materials, working for a long time at temperatures above 700°C. The requirements towards the testing installation are defined by standards [1].
The heating device shall ensure heating of the test piece up to a specified temperature T. The permitted deviations between the indicated temperatures T_i и T, as well as the permitted maximum temperature gradient are given in Table 1. For working temperatures greater than 1000°C, the permitted deviations shall be defined by agreement between the parties concerned.

Table1: Permitted deviations between T_i and T and maximum admissible temperature gradient

Specified temperatureT, °C	Permitted deviation between T_i and T, °C	Maximum admissible temperature gradient, °C
$T \leq 600$	± 3	3
$600 < T \leq 800$	± 4	4
$800 < T \leq 1000$	± 5	5

The indicated temperatures T_i are the temperatures measured at the surface of the parallel length of the test piece. Instead of this it is permitted to carry out indirect measurement of the temperature in each heating zone of the heating device, provided that the tolerance, defined in Table 1, is fulfilled.
For a test piece with a parallel length less than or equal to 50 mm, at least two thermocouples should be used, while for a test piece with a parallel length greater than 50 mm, at least three thermocouples should be used. If the thermocouples are two, they should be placed at each end of the parallel length and if a third thermocouple is used it should be placed in the middle of the parallel length.
The thermocouple junctions shall make good thermal contact with the surface of the test piece and shall be screened from direct radiations from the heating source.
The temperature measuring equipment shall have a resolution of at least 0,5°C and a precision of ± 1°C.

3. STAND FOR TESTING MATERIALS AT INCREASED TEMPERATURES

In order to carry out long strength testing at increased temperatures, in the "Strength of materials" department of the Technical University of Sofia, a special stand has been designed and worked out, as shown on fig. 1. The work space of the heating device consists of three zones, placed one above the other – upper, middle and lower. Each zone has an active power of 880 W and two heaters - left and right. Each zone is controlled by an „S" type thermocouple (thermocouples № 1, 2 and 3 on fig. 2), a transformer and a temperature controller. A special system tracks the heaters' break-off. If a heater breaks off, the temperature in the given zone is maintained by the other heater in the couple. The construction of the heating device allows changing a heater during operation, without interrupting the experiment. More details about the heating device are given in [2].
The experimental stand is controlled by an electronic block, connected to a personal computer (fig.1). A special program has been set up for visualising and writing down the parameters from the experiment (force of tension, test piece strain, controlling thermocouples' temperature in the three zones).

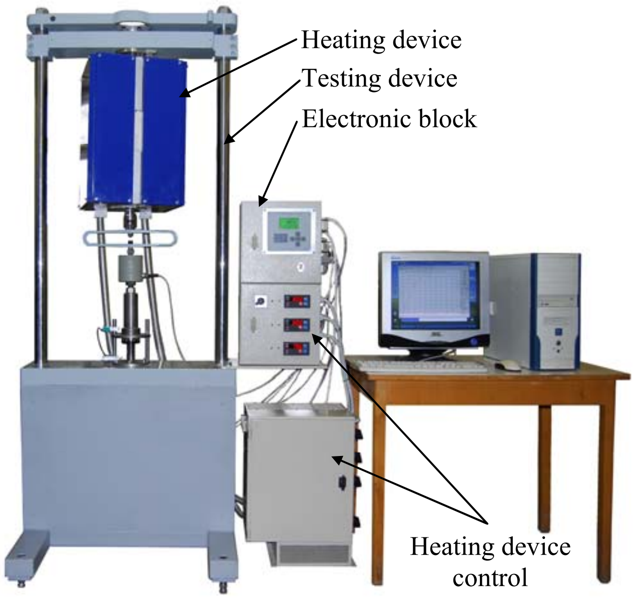

Figure 1: Testing stand for materials, working for a long time at increased temperatures

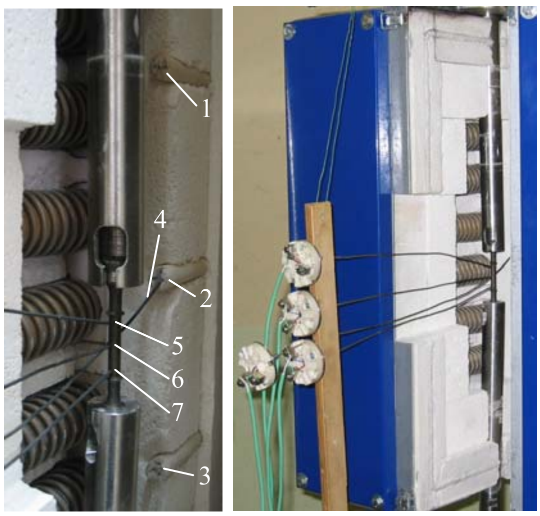

Figure 2: Location and numbering of the thermocouples

4. AIMS OF THE EXPERIMENTAL STUDY

- Check whether the heating device provides and maintains, according to the standard, a working temperature of 900°C of the test piece.
- Check how does the switching off of a heater in different zones influences the test piece temperature.
- Check the influence of a whole zone switch-off on the test piece surface temperature (necessary for heater replacement).

5. TEST PIECE TEMPERATURE MEASURING METHODOLOGY

The following experiment has been planned and carried out on the basis of the experience, accumulated during previous elaborations [3]:

1. Along the parallel length of the test piece (on both ends and in the middle) 2 mm deep apertures have been made.
2. Three thermocouples, of the type TSSB(K)-NiCrNi(M7/M8) – № 5, 6 and 7 on fig.2, with working temperature of up to 1100ºC, have been placed in these apertures.
3. Near the top of the middle controlling thermocouple of the heating device (№4 on fig.2), a thermocouple of the type TSSB-NiCrNi(M7/M8) has been placed. The aim is to find out the difference between the indications of the two thermocouple types.
4. Thermocouples with numbers 4 through 7 are connected to a programmable 8-channel indicator and analogue-to-digital converter TC800, which is connected via interface adapter IA100 to a PC. The gathered information is shown and recorded using the specialised software “PolyMonitor”. A bold outline of the implemented measured temperature recording system is shown on fig. 3.
5. The three temperature controllers RT384 are set for working temperature of 900^{o}C with hysteresis 1°C.
6. The heating device is switched on. After reaching the working temperature it is left working for three hours to allow the process to settles down.
7. The temperature visualization and recoding programs are started. A relatively long recording is made in order to determine the working temperature cycles, resulting from the constant switching on and off of the three zones.
8. One of the heating devices in the upper zone is switched off (a heating device break-off during a long experimental testing is simulated) and its influence on the test piece temperature, until settling down of the process, is observed.
9. The whole upper zone is switched off and its influence on the test piece temperature is observed.
10. Points 8 and 9 are repeated with the middle and lower zone, and before each switching-off the heating device is left working long enough with all heaters on.

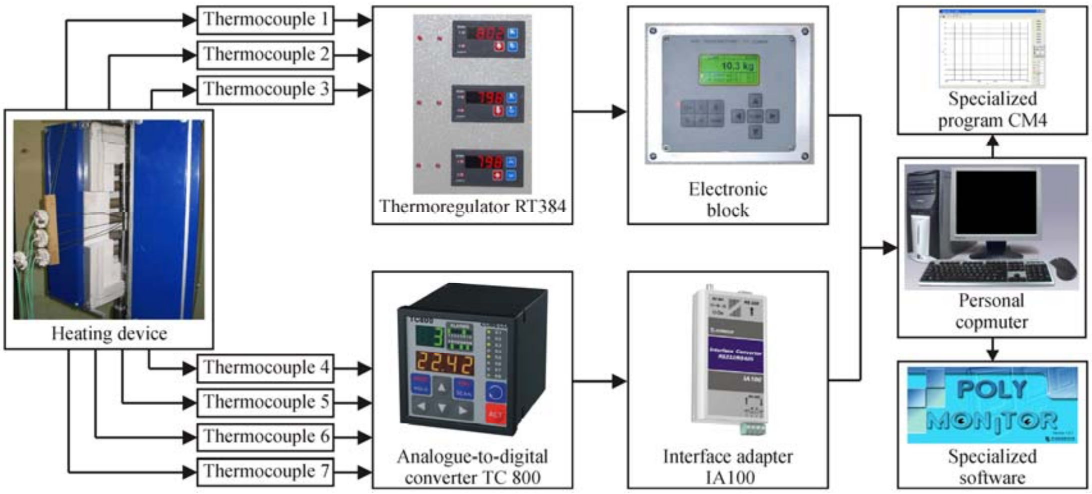

Figure 3: Measured temperature recording system

6. MEASURED TEMPERATURES

The temperature fluctuation in the heating device, after settling down of the process at working temperature of 900°C, is shown on fig. 4.

The results obtained show that there is a small difference between the measured temperatures by the two types of thermocouples. This is due to the construction of the body of the two types of thermocouples. Thermocouples 1, 2 and 3, controlling the three zones of the heating device, are to a great extent protected from direct heat radiation. For that reason the measured temperatures with thermocouple № 2 are within the interval 899-900°C, and with thermocouple № 4 – within the interval 898,7-902,2°C. The highest measured temperature of the test piece is 903,3°C, and the lowest – 899,8°C.

The temperature fluctuations after switching off one of the two heaters in the upper zone are shown on fig. 5.

The results obtained show that the temperature in the upper zone drops to 898°C, which has no considerable effect on the test piece temperature – T_5, T_6 and T_7. The highest measured temperature of the test piece is 902,7°C, and the lowest – 899,5°C.

The temperature fluctuations after switching off the upper zone are given on fig. 6.

After switching off of the upper zone the temperature in it starts dropping quickly. As a result the middle zone starts working almost without interruption and the test piece temperature increases. The results obtained show that the maximum permitted deviation of +5°C is reached in 95 seconds. At that moment the temperature in the upper zone is 892°C.

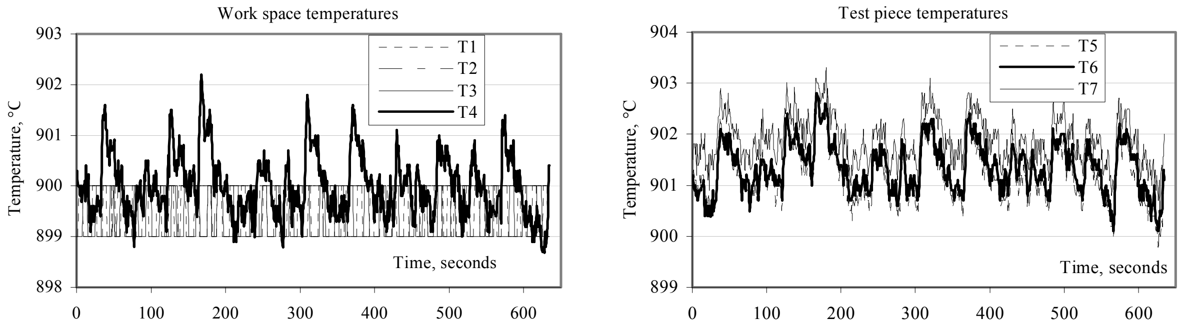

Figure 4: Measured temperatures during normal work of the heating device

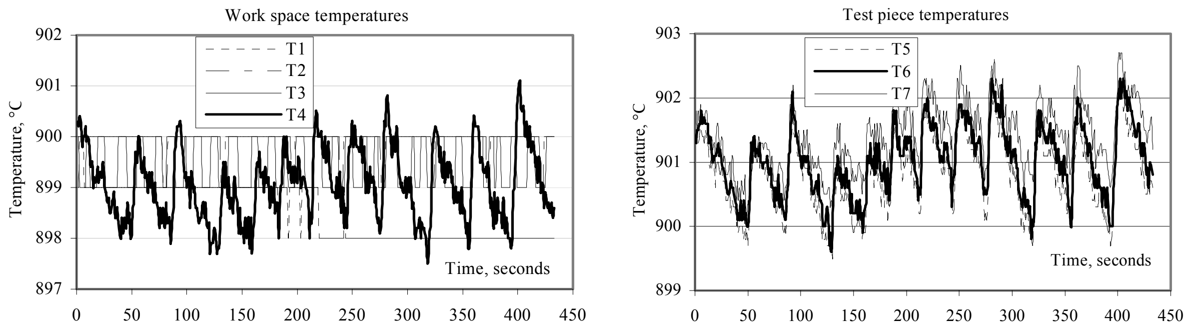

Figure 5: Measured temperatures while a heater in the upper zone is not working

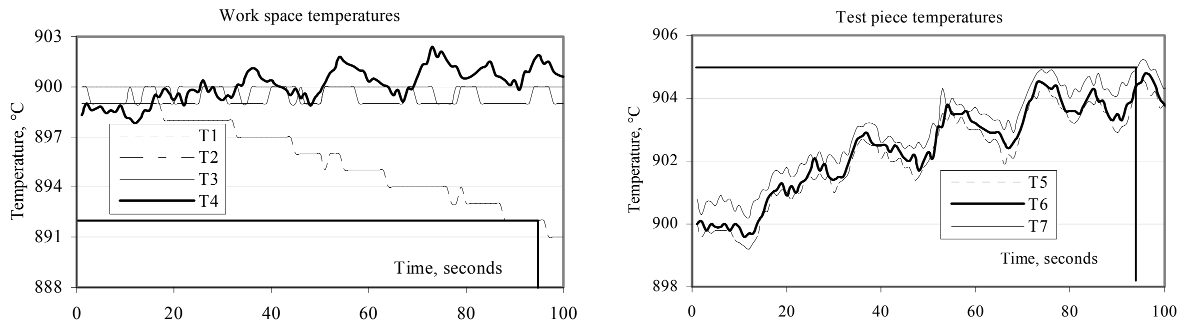

Figure 6: Measured temperatures while the upper zone is switched-off

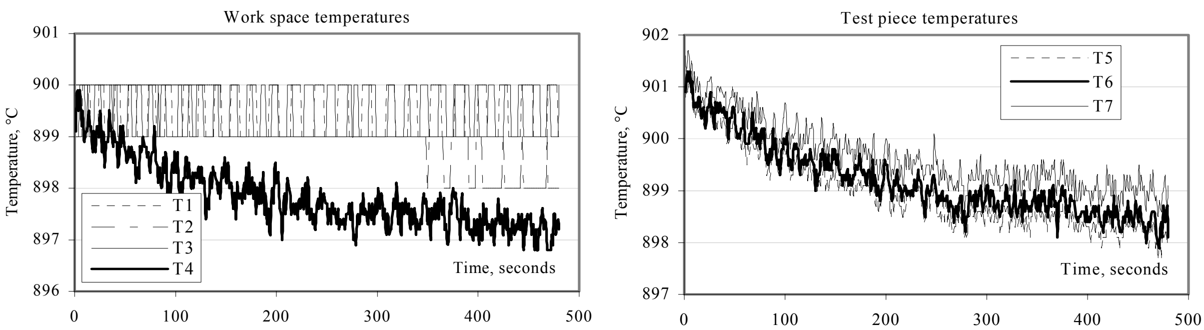

Figure 7: Measured temperatures while the middle zone is switched-off

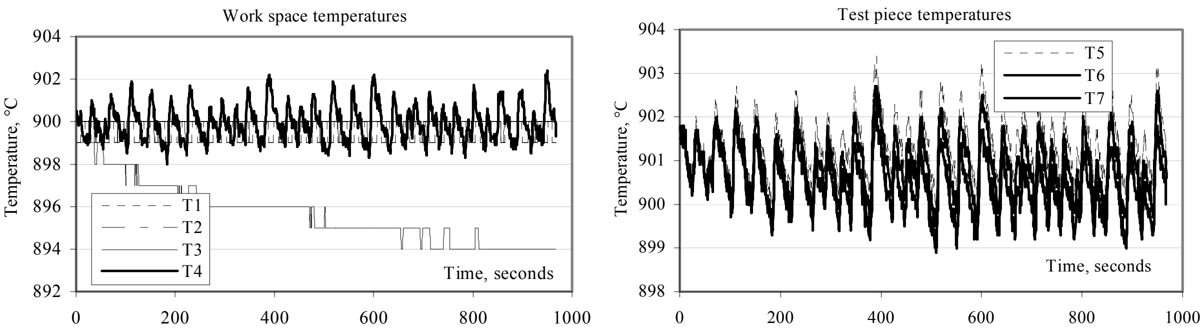

Figure 8: Measured temperatures while a heater in the lower zone is not working

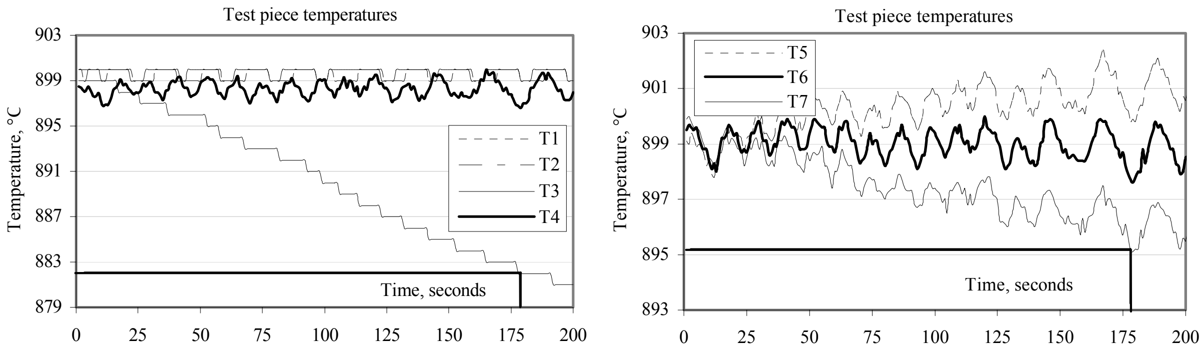

Figure 9: Measured temperatures while the lower zone is switched-off

The temperature fluctuations after switching off the middle zone are given on fig. 7.
The heat losses through the middle zone of the heating device are minor and at stable process it works least. It could be seen from the figure, that its switching off has no great effect on the temperature field in the heating device. The temperature in the middle zone is maintained by the other two sections. The fluctuations in the test piece measured temperatures are within the permitted limits. The results obtained at switching off of the whole middle zone make pointless the experimental study of a situation with one working electric heater in that zone.
The temperature fluctuations after switching off an electric heater in the lower zone are given on fig. 8.
The results obtained show that the temperature in the lower zone drops to 894°C, which has no great effect on the test piece temperatures T_5, T_6 and T_7. The highest measured temperature of the test piece is 903,4°C, and the lowest – 898,9°C.
The temperature fluctuations after switching off the lower zone are given on fig. 9.
After switching off the lower zone the temperature in it starts dropping quickly. This influences considerably the temperature in the lower part of the test piece. The results obtained show that the maximum permitted deviation of -5°C is reached after 180 seconds. At that moment the temperature in the lower zone is 882°C.
For all tests made the test piece temperature gradient remains within the permitted limits.

7. INFERENCES

The heating device ensures test piece heating up to 900°C.
The deviations between the test piece indicated temperatures and the specified temperature are within the permitted limits, according to the EN 10291:2000 standard.
The heating device maintains the test piece temperature within the permitted limits in case of breaking off of a heater in any zone.
In case the upper zone is switched off, in order to replace a burnt electric heater, the temperature there should not drop under 892 °C. The replacement of the heater should be done for a less than 95 seconds.
The middle zone switching off does not influence considerably the temperature field in the heating module. The test piece temperature remains within the permitted limits.
In case the lower zone is switched off, the temperature there should not drop under 882 °C. The replacement of the electric heater should be done for less than 180 seconds.

8. CONCLUSION

The heating device meets the requirements for carrying out long experimental tests at a temperature of 900°C. The device allows the replacement of a burnt heater without disturbing the test conditions. By way of precaution, as a result from this experimental study, the electronic block is programmed so as to interrupt the experiment if the temperature drops under 892 °C and 882 °C, respectively in the upper and in the lower zone. The EN 10291:2000 standard allows interrupted test implementation.

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