TEST OF CONSTRUCTION FOR HIGH TEMPERATURE INTENSE NEUTRON TARGET PROTOTYPE*

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Abstract

Within the framework of the creation of the high temperature intense neutron target prototype, the thermal tests of the preliminary design were done in BINP. Tests were aimed at experimental definition of temperature and heat flux distribution over the construction, heat transfer via the contact areas between materials selected, specifying the properties of these materials. This paper presents the experimental test results as well as the comparison of experimental data with the results of numerical simulation of the working regimes of the construction.

INTRODUCTION

The proposed target design is described in [1]. It comprises the high-temperature neutron converter assembled on the rotating metal disk. The target is cooled by its own thermal radiation. Nowadays the material of the converter is successfully tested and work on creation of target prototype is in progress. The prototype will be 30 cm in diameter and will be tested at 50 kW of heating power at operating regime. The present paper describes the preliminary test of prototype model before prototype production. The test includes the distributed heating of prototype model by the electron beam up to conditions similar to the operating ones for the prototype. The electron beam formed by the ELV-6 accelerator [2] heats the model up to temperature close to operating regime of prototype and neutron target. It means:

- Beam energy of 1.4 MeV;
- Beam size of 8-10 mm at 10 % level – working beam size;
- Beam linear scanning across the model – simulation of the beam motion around the rotating target;
- Total heating power of 1600 W. It corresponds to 50 kW for the prototype and 150 kW for neutron target.

The main goals of this work are:

- Test of converter-to-metal disk fastening assembly;
- Research of prototype temperature distribution and heat transfer via the mechanical contacts;
- Test of preliminary variant of prototype systems.

EXPERIMENTAL DEVICE

The design of the model is presented in fig.1. It comprises a sector of prototype with angular size of 12^0 (1/30 part of prototype) mounted on the flange inside the vacuum chamber. The heated graphite plate is fastened to the metal part with graphite clamps. Up to 13 thermocouples are positioned on the metal part in order to measure the temperature distribution over the model. Temperature of the converter is detected by IMPAC IS10 pyrometer. The Faraday cup is placed behind the small hole in the converter and is intended for beam current distribution measurement during the experiment. Total heating power is measured by the current over the model since the target has the full-stop thickness for the beam used.

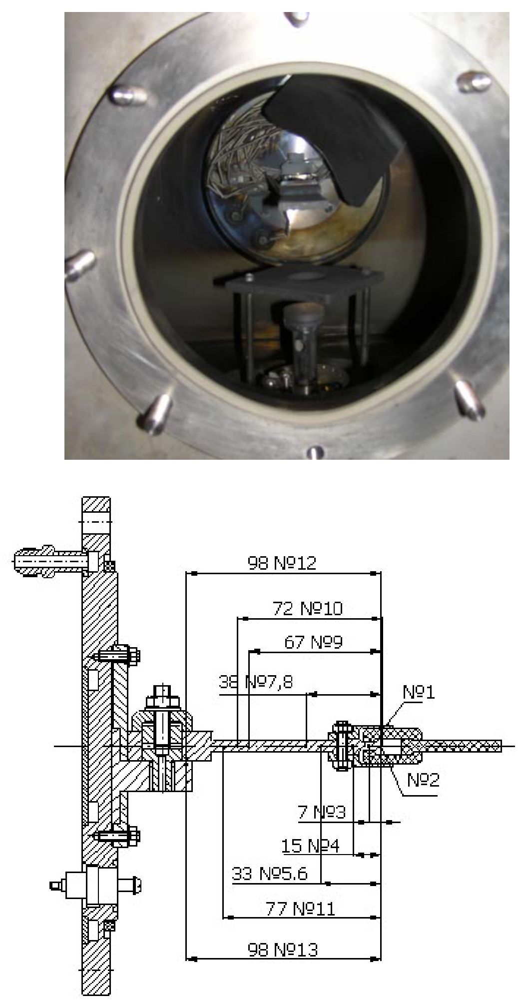

Figure 1: Scheme of prototype model (above) and view of model assembly inside the vacuum chamber. The thermocouples positions are shown.

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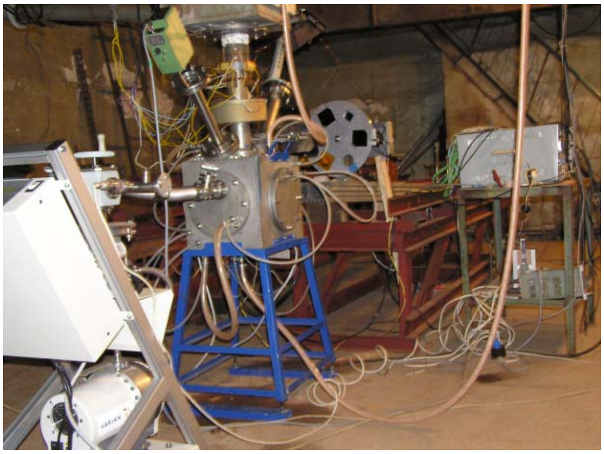

Figure 2: View of the experimental device assembled with the accelerator.

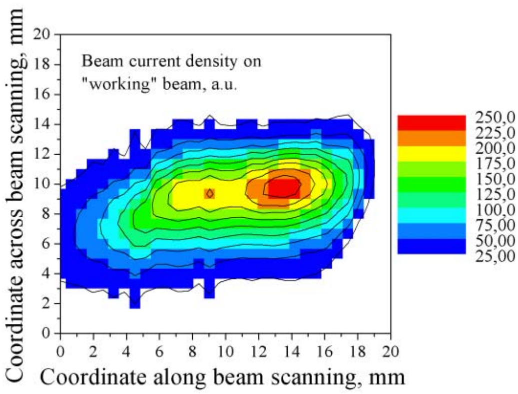

Figure 3: Working beam current distribution.

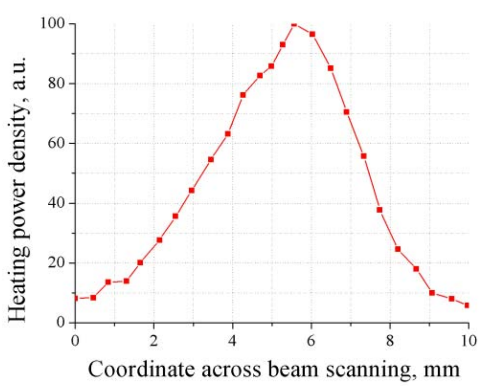

Figure 4: Heating power distribution at working beam size.

View of the experimental device in accelerator hall is presented on fig.2.

The most important experimental parameters and their limits are:

- Maximum temperature of graphite converter. It should not exceed 1900 ^{0}C at operation regime in order to prevent the evaporation of graphite;
- Temperature of the metal part near the metal-to-graphite contact. It should not be more than 800 ^{0}C, which is the operating limit for stainless steel used.
- Temperature of metal sector near the flange. This temperature should be less than 250-300 ^{0}C in order to prevent the overheating of shaft supporting bearings.

BASIC EXPERIMENTAL RESULTS

Fig. 3 presents the measured beam current distribution at operating regime. The heating power distribution over the converter is shown in Fig.4. Fig. 5 shows the temperature distributions over the model at different total heating power. This data were used for numerical simulation of model and prototype.

Fig. 6 presents the maximum temperature of graphite converter and metal part of model tested with working beam at nominal heating power.

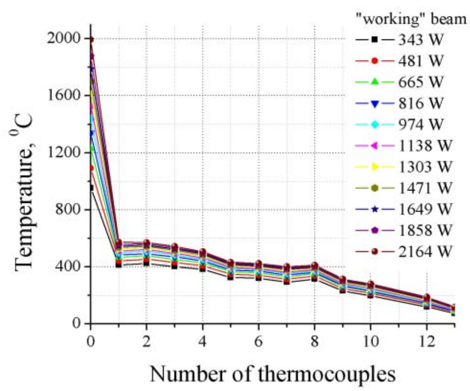

Figure 5: Model temperature distribution for different total heating power.

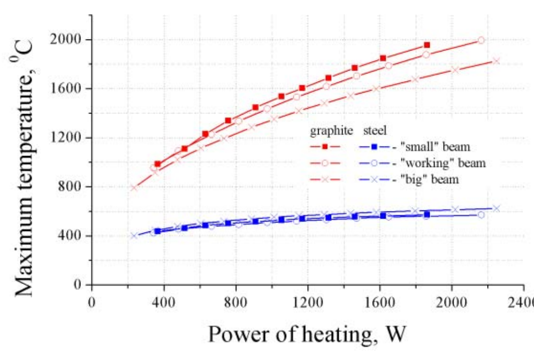

Figure 6: Maximum temperatures of model vs. total heating power for different beam size. “Small” beam size is 4 mm, “working” – 9 mm, “big” – 17 mm.

The most important experimental results are:

- The model stood the test without visible degradation.
- Maximum temperature at the most critical regions never exceeded limits (see above) at working beam size even when the heating power exceeded 30% the operating one. For operating regime the maximum graphite temperature occurred to be less than 1900 ^{0}C, the maximum temperature of metal

part near the graphite-to-metal contact was less than 600 ^{0}C, the maximum temperature of metal near the flange didn't exceed 200 ^{0}C.

- Tested assembly can operate at the beam size of 4-5 mm less than working one at nominal heating power.

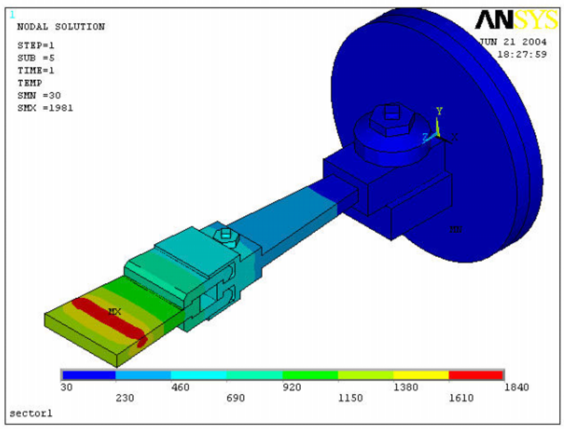

Figure 7: Temperature field along the model.

THERMAL SIMULATION OF OPERATING MODES

Simulation of thermal modes of prototype model operation were done in order to predict the prototype behavior under the nominal power, to determine the critical regions of model in terms of temperature, and to specify the properties of used materials and heat transfer via the mechanical contacts. It was performed using the finite elements method on the basis of ANSYS program complex [3]. Temperature values obtained from thermocouples during the test were taken into account. Heating power distribution over the converter corresponded to that one presented in fig. 4, geometry used in calculations was created on the basis of real geometry of model. Values of heat conductance for contacts were adjusted in order to provide the best agreement between the experimental and calculated temperature values. Fig. 7 shows the temperature field along the model at operating regime (total heating power of 1649 W), while Fig. 8 presents the comparison between the data obtained from thermocouples and the results of simulation.

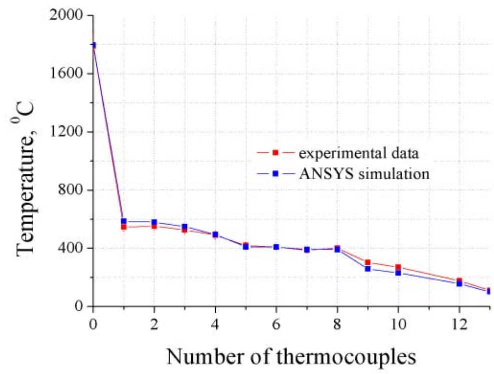

Figure 8: Model temperature distribution under operating regime. Comparison experimental and calculated data.

CONCLUSION

The construction of converter-to-metal disk fastening assembly, which is the most important part of a neutron target, is successfully tested. The production of this assembly for the prototype is started.

The numerical thermo-mechanical simulation of prototype operating modes is in progress. Experimental data obtained allowed to perform the realistic simulation of heat transfer via the target mechanical contacts.

Prototype control and data acquisition systems passed the test without serious faults.

REFERENCES

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[3] ANSYS Release 8.0 Users Manual. ASYS Inc., 2003.