Test Results of Active Thermography Method for Plasma-Wall Interaction Studies on the KTM Tokamak

ID: 1045

B. Chektybayev, E. Batyrbekov, A. Sadykov, M. Skakov, E. Kashikbayev
Institute of Atomic Energy of National Nuclear Center of Republic of Kazakhstan
chektybaev@nnc.kz

ABSTRACT

- Test results of the measurement method of the temperature distribution on the surface of first-wall materials for KTM tokamak are presented.
- The method is based on the application of a thermographic camera and external IR radiator. This approach is intended to increase the accuracy of thermographic measurement of the surface of test materials in a wide range of temperatures.
- Considering method is tested in the different conditions of tungsten sample heating: electric heater and electron beam.
- Implementation of the measurement method to the conditions of the KTM tokamak is described as well.

BACKGROUND

Thermographic camera is a good tool for temperature distribution measurements on a surface of research material with a high spatial and temporal resolution. According to the physical principle of a thermographic camera it is required to set the correct body emissivity value to achieve precision temperature measurements.

Emissivity depends on condition of material surface. In the tokamak conditions the surface of first wall material might able to vary with time due to the both surface modification under effect of plasma emission and deposition material dust particle on the surface. Metallic first wall compared with graphite wall leads to the much more problem of precise determination of the surface temperature by optical thermometry.

For the correction of thermographic measurements the original method was suggested [1]. The basics of the proposed method, its justification and preliminary experiments on its configuration and optimization were presented in ref. [2].

[1] Concept of a new approach in thermographic measurements for plasma-wall interaction studies on KTM tokamak / B. Chektybayev, E. Batyrbekov, M. Skakov, A. Sadykov // Program and Abstracts of 27-th IAEA Fusion Energy Conference, Ahmedabad, India, 22-27 October, 2018.

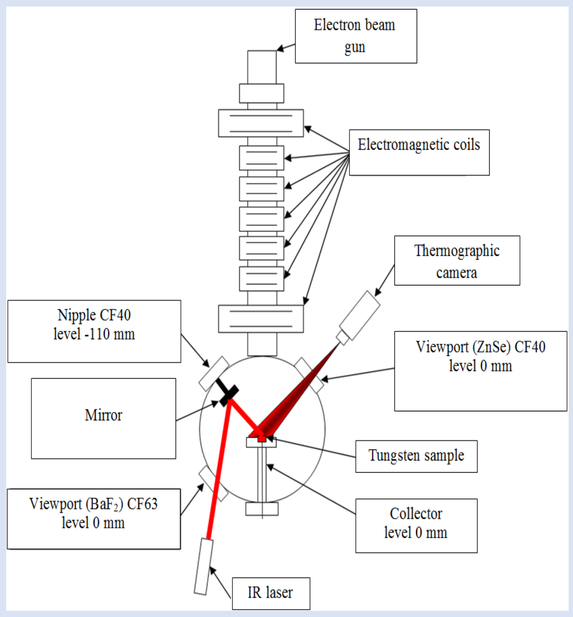
[2] B.Zh. Chektybayev, E.G. Batyrbekov, M.K. Skakov, A.D. Sadykov, E. A. Kashikbayev, On the possibility of improving the accuracy of thermal image measurements of candidate materials of the first wall of thermonuclear reactors on KTM tokamak, IAST: thermonuclear fusion series 42 (4) (2019) 41–48 (42) (In Russian).

VALIDATION OF THE METHOD AT THE TEST BENCHES

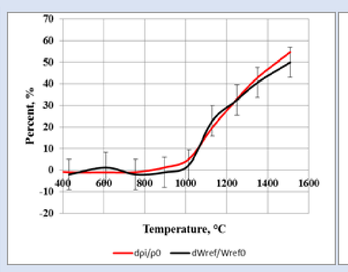
Testing the method with heating a sample by an electron beam

To test the proposed method of measurement under conditions close to plasma exposure, the experiments were conducted with the irradiation of metal samples with electrons on the test bench with a plasma-beam facility (PBF). Detailed information on the methodology and conditions of the experiment on the PBF, as well as a detailed analysis of the obtained measurement results are given in [3].

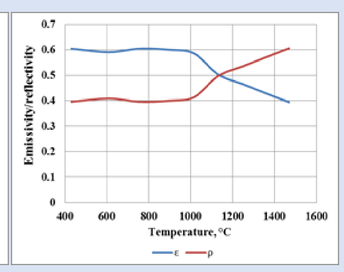
[3] Batyrbekov E., Chektybayev B., Sadykov A., Skakov M., Kashikbayev E., Olkhovik D., Zhunisbek S. Fusion Engineering and Design, 161 (2020) 112014. https://doi.org/10.1016/j.fusengdes.2020.112014



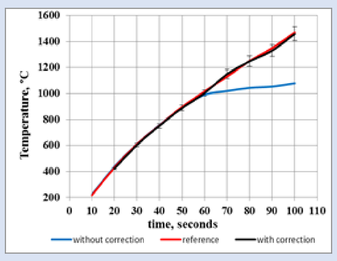
Layout of thermographic measurement on the PBF



Relative change in the reflectivity and power of reflected laser radiation

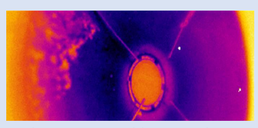


The emissivity and the reflectivity change with temperature

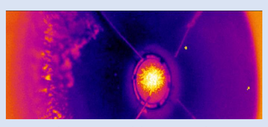


The sample heating temperature measured by thermographic camera with and without correction versus reference temperature

The initial value of the emissivity of the sample after the experiment decreased from ε0=0.596 to ε=0.335



without external laser radiation

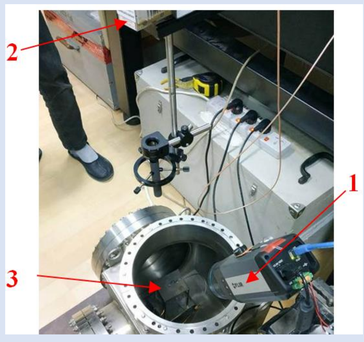


with external laser radiation

Thermal image from the thermographic camera of the irradiated sample inside the PBF

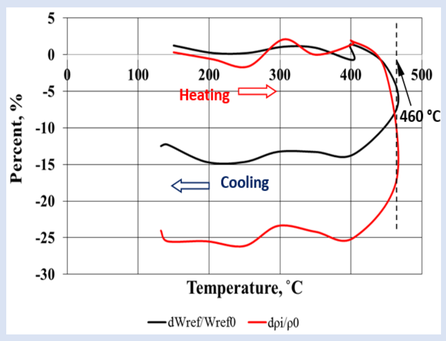
Test results at the bench with an electric heater

Heating of the sample was conducted in the air.

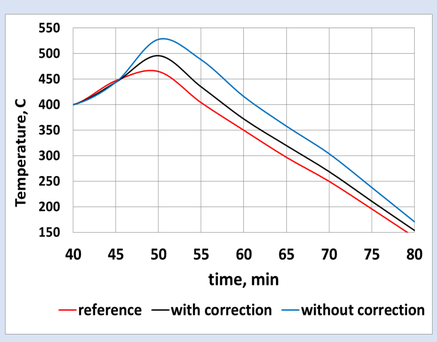


1 – IR camera; 2 – CO2 laser; 3 – heater

Layout of the equipment on the bench with electric heater



Relative change in reflectivity and power of reflected laser radiation



The sample heating temperature measured by thermographic camera with and without correction versus reference temperature

before heating

after heating

Tungsten sample during heating with electric heater

The initial value of the emissivity of the sample after the experiment increased from ε_0=0.38 to ε=0.54

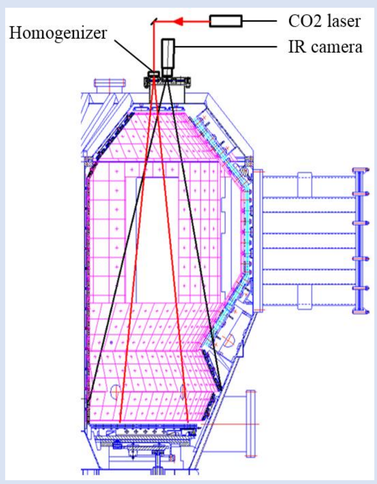
The change in the emissivity of the sample had been occurred due to its oxidation upon heating in the air.

OUTCOME

The results of a tungsten sample heating by the influence of electron beam at the PBF revealed close coincidence of the measurement for the proposed method and reference value. The difference between measured value according to the method and reference value lies within the range of inaccuracy of the measurement method 5% connected with laser radiation power deviation.

In the experiment of the tungsten sample heating in the air, it was revealed that there is a 10% difference in the value of the change in the reflectivity determined by the method and according to the thermocouple evidence. The difference is most likely associated with the difference in the reflectivity of the sample at the laser wavelength and the integral value of the reflectivity in the working range of the IR camera.

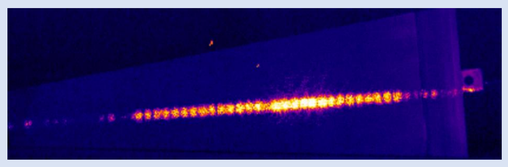
ADAPTATION OF THE METHOD TO THE CONDITIONS OF KTM TOKAMAK



Schematic view of thermographic measurements at KTM according to the proposed method

1-IR laser;2-IR camera with magnetic shield; 3-rotary mirror; 4-homogenizer; 5-viewing window

Equipment layout of thermographic measurements at the KTM tokamak



Thermal image captured by the thermographic camera at the moment of laser irradiation of the divertor plate of KTM

CONCLUSION

- In general, the test results have demonstrated the usability of the proposed method.
- Theoretically, in order to increase the reliability and accuracy of measurements of the considered method, it is necessary either to narrow the operating range of the camera close to IR emitter or to use a source of external IR radiation with a continuous spectrum of radiation in the entire operating range of the IR camera.
- The method was adopted and implemented to the conditions of KTM.

ACKNOWLEDGEMENTS / REFERENCES

This work was supported by Ministry of education and science of the Republic of Kazakhstan under the grant № AP05133148.