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The utilization of laser thermal testing with thermographic measurement for TBC lifetime performance evaluation

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Research for your achievements

The utilization of laser thermal testing with thermographic measurement for TBC lifetime performance evaluation

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Are you testing the lifetime performance of your TBCs ?

The main task of thermal barrier coatings is to protect the base material from the effects of high temperatures and thermal shocks.
The TBC structures are developed and optimized to fulfill the range of their applications with specific time temperature loading curves.

Gas turbines in power generation:
- **long-time endurance on the operation temperature**

Gas turbine engines in aerospace:
- **medium-time endurance according the aircraft flight**

Diesel engines in automotive:
- **fast cyclic change of the operation temperature according the diesel engine cycle**

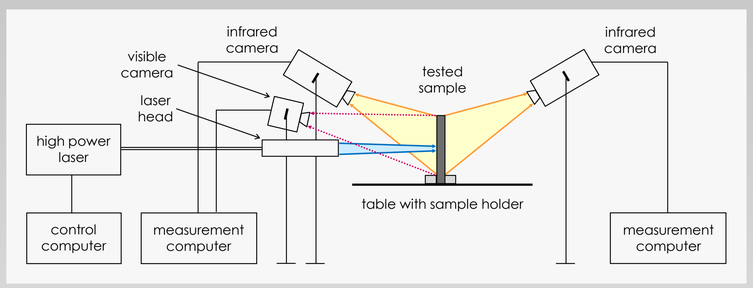
The TBC operation loading conditions are taken into account already in the TBC structure design, deposition method parameters and especially during TBC performance testing. Lifetime performance testing belongs to the fundamental testing procedures. The common methods are gas burner rig test and thermal cycle fatique test.

Our new laser thermal testing methods with thermographic measurement are offered for cooperation in the development and testing of TBC systems.

Laser thermal testing methods with thermographic measurement

Laser thermal testing methods have been developed at New Technologies Research Centre. The methods are suitable for thermal testing of bulk and layered high temperature materials. These methods are commonly used for testing of thermal resistence of developed materials for high temperature thermal insulation in building applications, energy industry applications, and testing of plasma facing components in fusion technology. The other possibility of utilization of laser thermal testing methods is TBC lifetime performance testing.

Principle of laser thermal testing methods:
- **high power fiber laser loading of the front side sample surface**
- **thermographic measurement of the front and back sides of the sample**
  - **evaluation of the time and space distribution of the surface temperature, temperature gradient over the thickness of the sample**
- **visible video recording of the sample surface**
  - **evaluation of the material degradation and cracking**
- **possibility of static and dynamic laser heating**

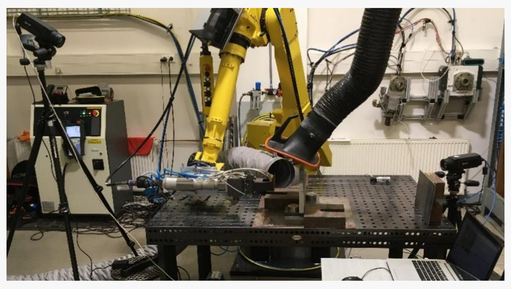


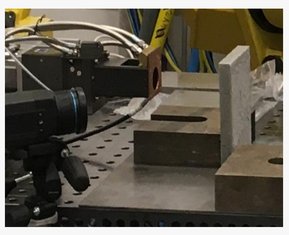
Advantages of laser thermal testing methods for TBC lifetime testing:
- **precisely predefined time and space distribution of heat loading**
- **precise and rapid power control**
- **wide range of loading temperatures**
- **very good repeatibility**
- **thermographic measurements without interference due to flame and soot radiation**
- **possibility of rapid thermal shock or fatigue thermal loading**

METHOD VARIABILITY ACCORDING TO TESTING REQUIREMENTS

STATIC THERMAL TESTING

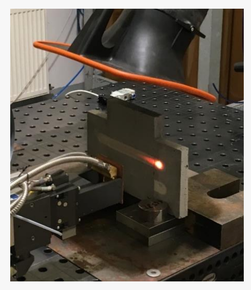
Loaded area:	circular region of laser spot, diameter of 10-20 mm
Position of laser spot:	static position
Power distribution in laser spot:	top hat circular spot
Time distribution of power:	predefined curve
Laser power/wavelength:	up to 4 kW / 1030 nm





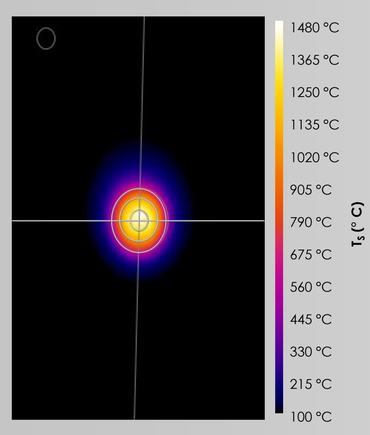
DYNAMIC THERMAL TESTING

Loaded area:	band or circular region, width of 10-20 mm
Position of laser spot:	predefined position
Power distribution in laser spot:	top hat circular spot
Time distribution of power:	predefined curve
Laser power/wavelength:	up to 4 kW / 1030 nm

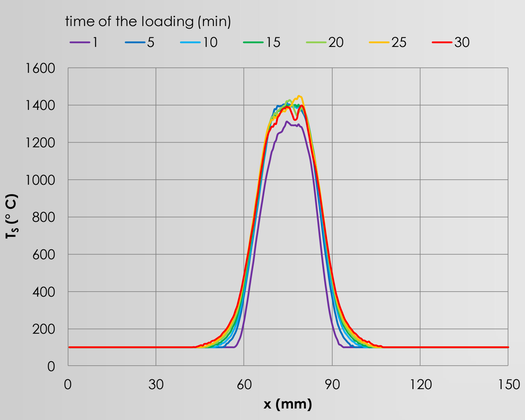


Method example results

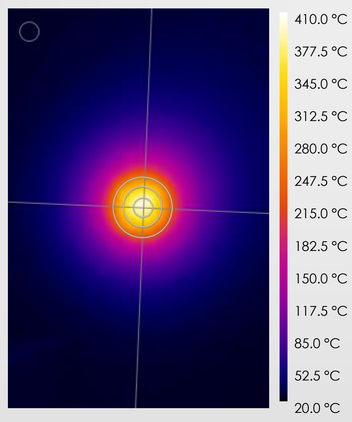
STATIC THERMAL TESTING



Front side surface temperature

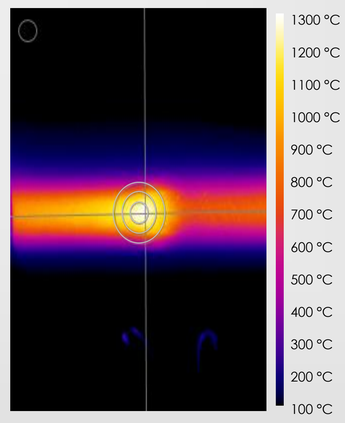


Temperature horizontal profile on the front side surface

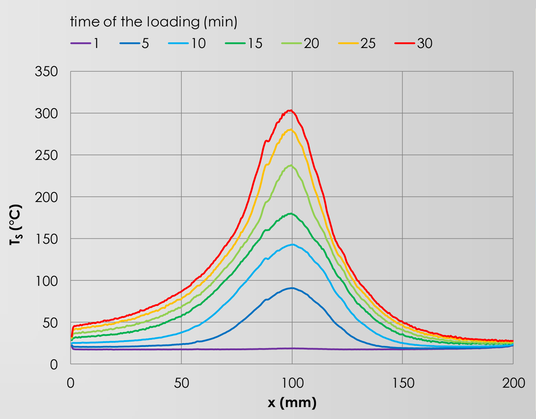


Back side surface temperature

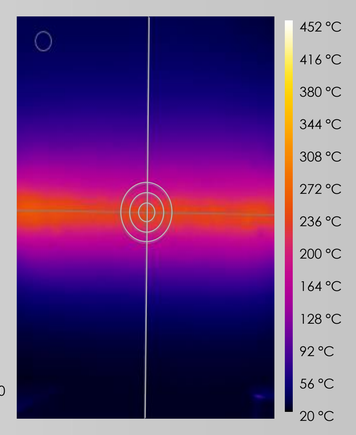
DYNAMIC THERMAL TESTING



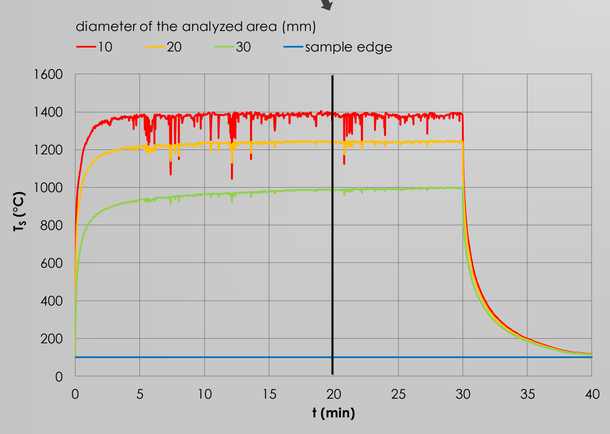
Front side surface temperature



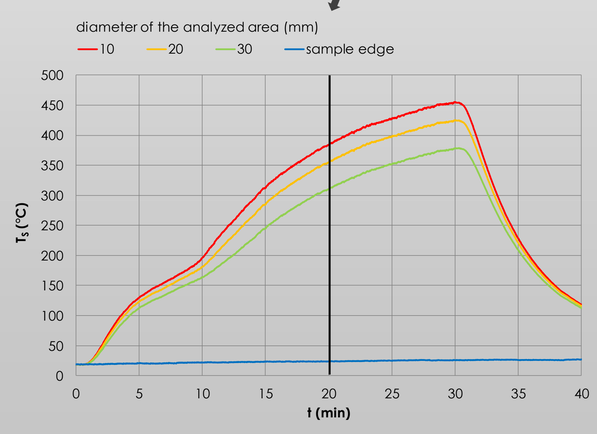
Temperature vertical profile on the back side surface



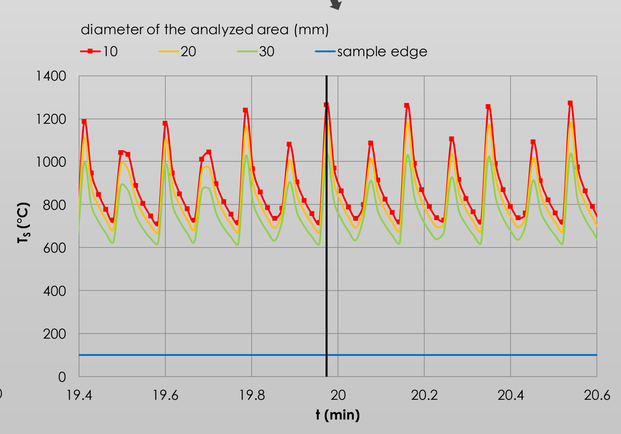
Back side surface temperature



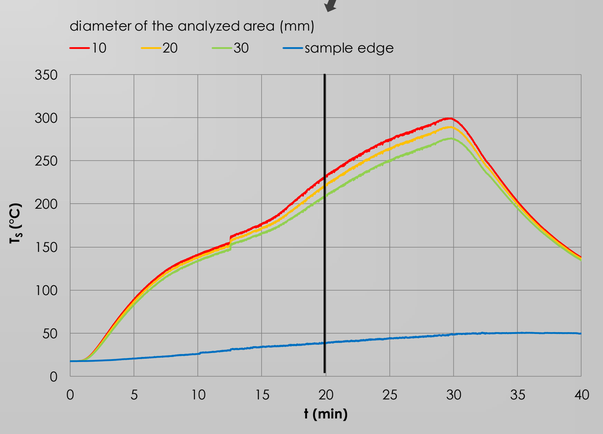
Time course of temperature on the sample front side in the laser spot



Time course of temperature on the sample back side against laser spot



Time course of temperature in the center of the sample front side



Time course of temperature in the center of the sample back side

Photo-thermal properties measurement methods as technical support

Photo-thermal properties measurement methods have been developed at New Technologies Research Centre. The methods are suitable for the measurement of emissivity of coatings and bulk materials at high temperature – spectral normal emisivity (SNEHT) and effective directional emisivity (EDEHT). The results are usually in the form of spectral, temperature and directional dependent quantities.

The knowledge of photo-thermal properties is the support for:
- **evaluation of thermography measurements during laser thermal testing (EDEHT method)**
- **characterization of radiation heat transfer to the laser tested material (SNEHT method)**

Publications and detailed information

1) Uczak de Goes W., Gupta M., Markocsan N., Thibblin A., Veselý Z., Honnerová P. Porous thermal barrier coatings for enhancing the efficiency of internal combustion engines. International Journal of Engine Research (2022), 14 p.
2) Uczak de Goes W., Ossiansson M., Markocsan N., Gupta M., Honnerová P., Veselý Z. Influence of spray angle on microstructure and lifetime of suspension plasma sprayed thermal barrier coatings. Journal of Thermal Spray Technology, submitted.
3) Veselý Z., Honner M., Hruška M. High heat flux testing method of plasma facing component materials [poster]. In: 32nd Symposium on Fusion Technology, 18th-23rd September 2022, Dubrovnik, Croatia.
4) Veselý Z., Honner M., Honnerová P. The possibilities of using optical properties measurement methods for TBC research [poster]. In: Thermal Barrier Coatings V, 24th-29th June 2018, Irsee, Germany.
5) Veselý Z., Honnerová P., Martan J., Honner M. Sensitivity analysis of high temperature spectral emissivity measurement method. Infrared Physics and Technology 71 (2015), 217–222.
6) Honnerová P., Martan J., Kučera M., Honner M., Hameury J. New experimental device for high-temperature normal spectral emissivity measurements of coatings. Measurement Science and Technology 25 (2014), 095501-095509.

More info can be found at
https://irt.zcu.cz/en

Acknowledgement

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