Subproject A12

Title

Experimental analysis of thermomechanical properties of thermal sprayed coatings

Project management/-processing

Project management: Prof. Dr.-Ing. K. Bobzin
Project processing management: M.Sc. A. Schacht
Institute for Surface Technology (IOT) RWTH Aachen University

Task definition

- Development of a thermally sprayed coating system for mould temperature control in injection moulding and gravity die casting with the operating principle of an electrical resistance heating
- Insulation of the electrically conductive layer from the tool and the component to be produced
- Investigation of thermal, electrical, mechanical and chemical resistance of the coating system

Procedure

The complete layer system consists of Al2O3 as an insulating layer on both sides of a heating layer. The material TiOx/Cr2O3 was initially used for the heating layer. At the beginning, parameters were developed to apply the coating system to tool steel by means of atmo¬spherical plasma spraying. The electrical insulation effect of the Al2O3 layer was considered uncritical. The dielectric strength was determined on selected samples to validate this assumption. Subsequently, heating tests were carried out to investigate the heating behaviour and the long-term thermal resistance. For a better characterization of the heating layer, the top insulation layer was not used. A modular thermocycle test rig was set up for automatic execution of the long-term tests. As shown schematically in Figure 1, this consists of a LabVIEW control with interfaces to an IR sensor, a voltage source and an oscilloscope as well as a heat exchanger for cooling the sample. The temperature control is voltage-regulated. A power-regulated control is currently not possible.

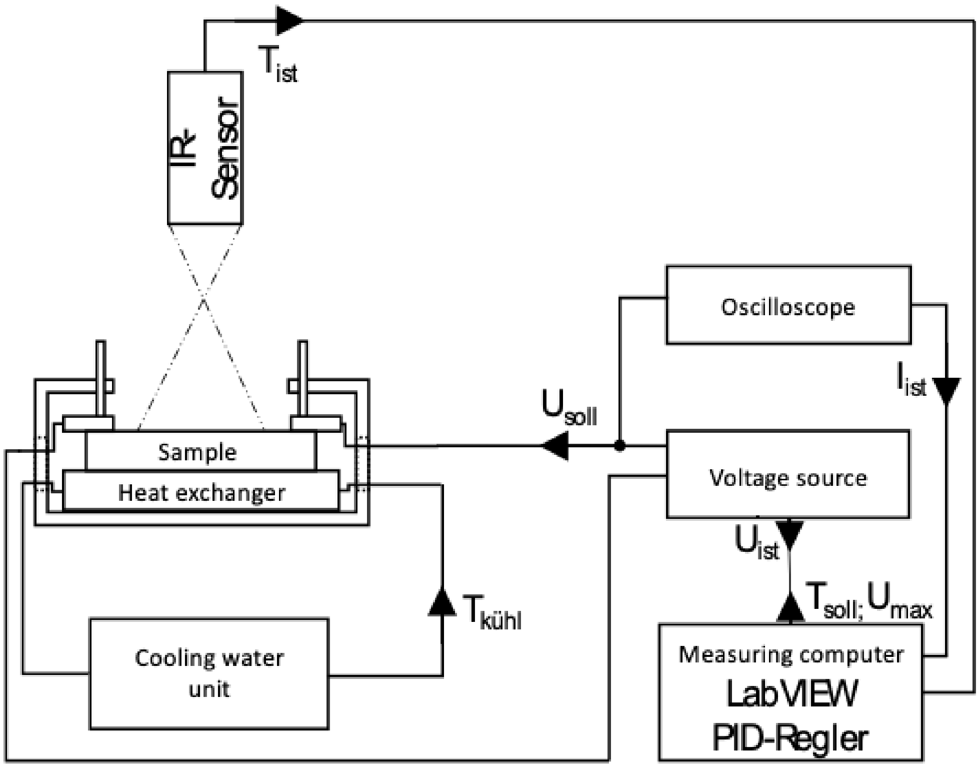

Figure 1: Schematic diagram of the thermal cycle test bench

Results

A layer system of insulation layers and heating layer was successfully applied. The dielectric strength of approx. 1,000 V at 50 Hz alternating voltage and an insulation layer thickness of 100 µm, determined by way of example, is sufficient. By reducing the TiO_2 to TiO_x during the coating process, an electrical semiconductor is produced which is used as an electrical resistance heating element. In initial heating tests, thermography was used to demonstrate a homogeneous, flat heating of the heating layer. The thermocycle test showed that the heating layer used survives 10,000 thermal cycles with a temperature-time curve as shown in Figure 2 without layer failure. The functionality of the heating layer is still given after 10,000 cycles. The target heating rate of $\dot{T}$ > 25 K/s has already been achieved. However, the heating rate drops to 20 K/s within the first 2,000 cycles and then remains constant. This change is accompanied by an increase in the electrical resistance of the heating layer, which is presumably caused by the reoxidation of the TiO_x. With a power-controlled regulation, the voltage applied in the heating phase can be adjusted according to the increase in resistance, so that the heating rate can be kept constant.

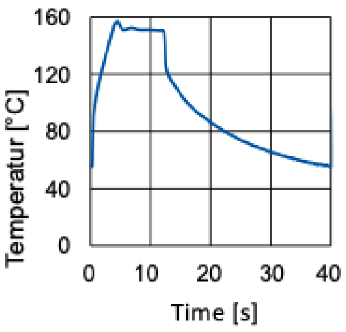

Figure 2: Exemplary temperature-time curve of a thermal cycle with a holding temperature of 150 °C

In order to check whether the observed change is a measurement artifact, thermal cycle tests are carried out with the complete coating system. By combining the Al_2O_3 top layer with a sealer, the contact between TiO_x and oxygen from the environment is made more difficult, which is intended to control the back oxidation of TiO_x. The average heating power in the range of 60 to 150 °C achieved in the thermal cycles is $P_{heating}$ = 21.5 W/cm² and the cooling power at the operating point of T = 150 °C is $P_{cooling}$ = 19 W/cm².

Summary and Conclusion

A functional heating layer system was successfully applied to tool steel. With this layer system a homogeneous heating is possible. Furthermore, it was proven that the planned heating rate of $\dot{T}$ > 25 K/s can be implemented and that the heating layer can withstand 10,000 heating cycles.

Further investigations of the layer system loaded with 10,000 cycles are planned to determine the influence of the load collective on the microstructure and chemical composition. Comparable tests with the complete coating system are also planned.

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Publication

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