10th - 11th April, 2018
Teslova 3, Plzeň, 301 00, Czech Republic

Workshop on thermal spray coatings technologies and characterization

Abstracts

Prof. Lech Pawlowski

The use of solid and liquid feedstock in the thermal barrier coatings thermal spray technologies

Lech Pawłowski[1)], Pablo Carpio Cobo[2)], Pawel Sokołowski[3)]

[1)]IRCER, University of Limoges, France

[2)]Institute of Materials Technology, University of Valencia, Spain

[3)] Faculty of Mechanics, Technical University of Wrocław, Poland

Thermal barrier coatings (TBCs) are applied for gas turbine engines in order to provide the thermal isolation of metallic components against hot gas. The TBCs enable a considerable increase of temperature of engines and improvement of their thermal efficiency. The conventional coating technologies include atmospheric plasma spraying (APS) of powders and deposition using gaseous phase by electron beam physical vapor deposition (EBPVD) and the coatings are generally made of yttria stabilized zirconia. The microstructure and properties of conventional coatings have been intensively studied since the 1970-ties and are well known now. In particular, the advantage of columnar microstructure of EB PVD promoting strain tolerance and resulting thereof increase of TBCs lifetime in service is well understood. The emerging thermal spray technologies include suspension and solution plasma spraying (SPS and SPPS respectively) as well as highly productive plasma spray physical vapor deposition (PS PVD). The use of the liquid feedstock influences considerably the microstructure of obtained deposition by formation of pores much smaller than in the conventional APS coatings. Similarly, the appropriate optimization of operational spray parameters enables obtaining columnar microstructure. The thermophysical properties of coatings are strongly influenced by feedstock used to spray. The microstructure and properties of the coatings spraying using liquid feedstock are carefully discussed and compared with that sprayed using solid powder.

Prof. Nicolaie Markocsan - University West, Sweden

Axial suspension plasma spraying of TBCs: Coating properties and functional performances

Nicolaie Markocsan

University West, Trollhättan, Sweden

Extensive research and development efforts have been devoted over the past decades to develop Thermal Barrier Coatings (TBCs) with new coating microstructures that give better functional performances and lifetime. Axial suspension plasma spraying (ASPS) is one of the emerging coating process that enables the deposition of ultrafine droplets (typically from nano- to sub-micron size) that permits the production of coatings with unique microstructures, one or two orders of magnitude finer than those achieved typically in other thermal spray processes. ASPS has shown to be a very promising technique to produce coatings with lower thermal conductivity as well as higher lifetime than the state-of-art TBCs used today. However, tailoring the microstructure of these TBCs for enhanced durability is challenging due to their inherently wide pore size distribution (ranging from few nanometers up to few tens of micrometers). Moreover, to accurately characterize coatings with such complex microstructure is a challenge. In this work a brief description of the typical microstructures that can be achieved by ASPS is given as well as how microstructure can influence the coatings thermo-mechanical properties and functional performances. A short review and description of the characterization methods that can be suitable for ASPS TBCs is presented as well. The promising results promote ASPS as a serious candidate for more studies and investigation for advanced TBCs so that new coatings candidates can be available for next generation products.

Dr. Georg Mauer

Recent Developments in Plasma Spray Processes for Thermal Barrier Coatings

Georg Mauer, Dapeng Zhou, Robert Vaßen

Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Institute for Energy and Climate Research

IEK-1: Materials Synthesis and Processing

Material development covers material synthesis on the one hand and processing techniques on the other hand. These scopes are closely related to each other and must be both considered correspondingly. With respect to the manufacture of thermal barrier coating systems (TBCs), some present development goals are metallic bond coats with dense microstructures and low oxygen content. Regarding ceramic top coats, strain tolerant microstructures with low thermal conductivity are required. Furthermore, the processing of new materials with particular difficulties like decomposition and inhomogeneous evaporation is challenging. This lecture focuses on recent developments of plasma spray processes in this context. High Velocity Atmospheric Plasma Spraying (HV-APS) is a novel variant of plasma spraying devoted to materials which are prone to oxidation or decomposition. It is shown how this process can be used for metallic bondcoats in TBC systems. Furthermore, Suspension Plasma Spraying (SPS) is a new method to process submicron-sized feedstock powders which are not sufficiently flowable to feed them in dry state. SPS is presently promoted by the development of novel torch concepts with axial feedstock injection. Some examples for ceramic TBCs are given. Finally, Plasma Spray-Physical Vapor Deposition (PS-PVD) is a novel technology operating in controlled atmosphere at low pressure and high plasma power. At such condition, vaporization even of high-melting oxide ceramics is possible enabling the formation of columnar structured coatings from condensates and nano-sized clusters.

Dr. Radek Mušálek – Institute of Plasma Physic, Czech Academy of Science, Czech Republic

Deposition of Thermal Barrier Coatings by Hybrid Water-Stabilized Plasma Torch

Radek Musalek

Institute of Plasma Physics, Czech Academy of Science, Czech Republic

Protection of components with plasma sprayed thermal barrier coatings (TBCs) is often limited to high-tech applications in aerospace or power generation industry, where the benefits of the TBC layer justify considerable manufacturing costs. One of the possibilities to make thermal spraying cost-effective for deposition of thick&large thermal barriers in new applications is using high-enthalpy WSP-H (hybrid water-stabilized plasma) torch technology enabling deposition with high throughputs and low operating costs. In this study, examples of TBCs deposited by WSP-H torch from conventional coarse dry powders as well as fine suspensions and solutions will be presented and their application-relevant properties will be discussed.

Dr. Nicolas Curry – Treibacher Industrie AG, Austria

Suspension Plasma Spray - An industrial technique for Thermal Barrier Coatings

Nicolas Curry

Treibacher Industrie AG, Austria

Suspension plasma spray (SPS) offers the ability to produce high performance thermal barrier coatings with columnar structures that can bring together the best parts of traditional APS coatings and those produced by vapour deposition. In the last two years, suspension plasma spray coating has gone from being a process under development, to a qualified and industrially accepted production method for thermal barrier coatings. The aerospace certification of suspensions demonstrates the great advances that have been made since the technique was first developed several decades ago. This presentation will focus on the process improvements that have been made in producing SPS coating with industrial spray equipment in recent years. Expected coating properties for such coatings will be described. Comparisons will be made with the traditional APS TBC coatings and possible future improvements will be discussed.

Dr. Benno Gries - H.C. Starck Surface Technology and Ceramic Powders, Germany

Development and Characterization of Plasma Sprayed TBC's: Typical Problems and their Solutions in Practical Work

Benno Gries

H.C. Starck Surface Technology and Ceramic Powders GmbH, Goslar, Germany

Design of structure and material of TBC's has become a broad technology field. In order to achieve the desired coating properties, the right choice of TBC materials (e.g. beyond 8YSZ) and of plasma spray powder type needs to be taken to obtain the desired results. The broad choice among competing plasma spray systems with different technology is an aspect which is gaining more importance and has an impact on how easy or difficult it is to achieve desired coating properties. The usually lengthy development of plasma parameters requires fundamental understanding of the plasma and of the coating formation process. In the evaluation circle of development, profound coating characterization techniques are necessary which are neither standardized nor technically trivial. Typical examples of TBC developments are presented and the typical problems and their solutions presented.

Dr. Gregory Szyndelman - Oerlikon Metco, Switzerland

Applications and Performance of Ceramic Abradable Coatings

Gregory Szyndelman

Competence Team Leader Abradables

Oerlikon Metco AG, Wohlen

Sacrificial ceramic abradable coatings are used in aero engines and stationary gas turbines to minimize the clearance between the rotating blades of the rotor and the stator allowing increased engine efficiency. Abradable coatings developed by Oerlikon Metco have been used in engines for the past 40 years over different temperature ranges observed from the low pressure compressor section (temperatures from -70°C to 400°C) to the high pressure turbine section (temperatures up to 1600°C). In the turbine section, ceramic based abradable coatings are thermally sprayed on the stator to avoid damage to the blade tip arising from the blades thermal expansion associated with stator deformation. When designing new ceramic abradables compatible against tipped or untipped superalloy blades, the engineer must consider different technical criteria such as solid particle erosion resistance, sintering resistance, thermal cycle resistance which are dependent on the engine service conditions. For ceramic abradable coatings (e.g. Yttria or Dysprosia Stabilised Zirconia), the identification of coatings wear mechanisms and blade wear for different operating conditions is essential for the validation of the abradable coating system being developed. An overview of the means of interest to design abradable materials as well as the attributes of commercially available zirconia based powder will be presented.

Dr. Thomas Grund – Technical University Chemnitz, Germany

Influence of PVD-Al interlayers on the characteristics of high temperature coating systems

T. Grund, G. Paczkowski, T. Lampke

Institute of Materials Science and Engineering, Technische Universitaet Chemnitz, Chemnitz, Germany

Thermal barrier coatings (TBC) generally consist of a ceramic top coat (TC) on a metallic bond coat (BC). CoNiCrAlY has been widely used as BC material in TBC systems. The exposure of TBC systems to oxygen containing atmospheres during their application at elevated temperatures leads to the formation of thermally grown oxide layers (TGO) at the BC/TC interface. The formation of Ni-based and mixed oxides in the TGO generates micro-cracks, leading to spalling and hence defining the durability of the whole coating system. It is proven that BC/TC interfaces with a high amount of α-Al_2O_3 prolong the steady-state growth stage of the TGO and by this improve the work life of the TBC system. In the present study, thin Al films were deposited on the raw surface of atmospheric plasma sprayed CoNiCrAlY BC by DC magnetron sputtering, before depositing YSZ top coatings by atmospheric plasma spraying. For comparison purposes, reference TBC systems without Al interlayers were added to the investigations. Samples were treated by cyclic thermal load with dwelling at 1,150 °C. Microstructure, crack formation, TGO thickness and chemical composition of the BC/TC interface area were investigated using SEM/EDXS, XRD and Raman spectroscopy. All investigations were carried out on samples without dwell time as well as on samples with 100, 300 and 600 h of isothermal dwelling at 1,150 °C. The presented results plot the interface change and crack formation as a function of the dwell time. Also, the effect of the applied Al interlayers on constitution and thickness of the TGO areas and the corresponding failure mode are discussed.

Dr. Kateřina Dočekalová – Honeywell International, Czech Republic

Resistance of APS TBC to be investigated and evaluated

Kateřina Dočekalová

Honeywell International, Czech Republic

Thermal barrier coatings (TBC) are necessary for protection of thermally and mechanically loaded parts of aircraft engines. The demands on their operating temperatures are nowadays constantly increasing as well as demands on their phase stability, mechanical and chemical resistance. Since the operating time is very long, there is need of accelerated testing (with its advantages/disadvantages and risks connected with these types of testing) for successful development of better performing TBC systems. The following microstructural analysis of the tested samples have to be fast and reliable. Samples are metalographically prepared and amount of porosity, cracks and oxides is investigated. This evaluation is time consuming and subjective therefore image analysis is suitable tool to be used instead of manual investigation. However, the structural and phase features are similar and widely used commercial software seems to be not sufficient for this purpose. Evaluation methodology and unique software for image analysis of TBC systems was developed by Honeywell International s. r. o. The software processes the images on manually set presets and evaluates pores, cracks, oxides and splats. The results of the analysis are tracked and this helps to follow trends and progress of development route.

Dr. Paolo Bison - Italian National Research Council, Italy

Measuring TBCs' thermophysical properties by photothermal techniques

Paolo Bison[1*], Federico Cernuschi[2] and Stefano Boldrini[3]

[1] CNR-ITC, C.so Stati Uniti 4, 35127 Padova, Italy

[2] RSE, via Rubattino 54, 20134 Milano, Italy

[3] CNR-ICMATE, C.so Stati Uniti 4, 35127 Padova, Italy

In this presentation it is shown how to determine the thermophysical properties of Thermal Barrier Coatings by photothermal techniques.Laser Flash experiments in a controlled atmosphere allow to evaluate the thermal diffusivity of TBCs and its dependence on the microporosity of the material under test. For porous materials, the kind of gas filling the pores can play a key role on the thermal diffusivity evaluation. In particular, the contribution of the atmosphere is strictly dependent on the specific microstructural features of the porous sample under investigation such as pores content, orientation and aspect ratio. By suitable modelling, some pieces of information are obtained on the characteristics of the microstructure of such materials and eventually on their variation due to the sintering effects under cyclic oxidation and exposition to high temperature. Depending on the deposition techniques and parameters, the TBC exhibits different kinds of microstructures that affect its thermal conductivity. As a response to a temperature gradient, the flow of heat in the TBC depends, both in magnitude and orientation, on the percentage of porosity, the shape of the pores and their orientation. IR thermography, thanks to its imaging capabilities, can determine the conductivity anisotropy of Thermal Barrier Coatings. A technique is described that is able to determine the thermal diffusivity in a non-contact and non-destructive way, using IR thermography. A pulsed spot of heat with spatial Gaussian shape is delivered on the surface of the sample by a lamp. Thermography follows the diffusion of the spot as a function of time allowing the determination of the in-plane diffusivity and the in-depth as well.The semitransparency of materials is considered and the measurements process is modeled to improve the accuracy. ZrO_2 is semitransparent to near IR radiation that is typically delivered by the laser in the laser flash equipment. Moreover, the characterization of TBCs at high temperatures is particularly interesting as the typical working temperature of gas-turbine is >1000 °C. At these temperatures heat transfer is no more limited to conduction and the radiative heat transfer becomes paramount. The evaluation of effective heat conduction is carried out in this work by laser flash equipment and IR thermography as well, describing at the same time common practices and countermeasures to minimize the discrepancies from the commonly used models to analyze data. The effects of blackening surfaces by a thin layer of graphite is considered. The role of heat conduction and radiation is also taken into account trying to separate each contribution. Experiments are carried out at ambient temperature by means of a thermographic camera and at higher temperature in vacuum until 1200 °C. Data are treated according to classical scheme taking into account the exchange with the environment. Successively the data are considered by using the possibility of radiative exchange between the two blackened sides of the sample. The possibility of simultaneous heating of the two sides of the sample,

due to the semitransparency of the material to the laser shot is considered, giving rise to a new model that explains in some conditions anomalous immediate heating of the side facing the detector.

Dr. Milan Honner – University of West Bohemia, Czech Republic

Infrared optical properties of thermal barrier coatings

Milan Honner, Zdeněk Veselý, Petra Honnerová

New Technologies Research Center, University of West Bohemia in Pilsen

Optical properties characterising thermal barrier coating behaviour in radiant heat transfer. Typical values of emissivity/absorptivity, reflectivity and transmissivity of TBC materials. Methods for the measurement of spectral distribution, band or total values of optical properties at room and high temperature. Introduction of various methods (SNEHT, EDEHT, SNHRRT and SNHTRT) developed at NTC and possibilities of their application in the research of thermal barrier coatings.