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Laser-glazing of Plasma-sprayed Thermal Barrier Coatings - Experimental and Computational Studies

Tese de Mestrado em
Processamento e Caracterização de Materiais

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Tratamento de Revestimentos de Barreira Térmica por Laser e sua Modelação

Resumo

O recurso a lasers para o desenvolvimento das propriedades dos revestimentos de barreira térmica (Thermal Barrier Coatings - TBCs) tem vindo nos últimos anos a demonstrar um elevado potencial. A redução da rugosidade e eliminação da porosidade superficial, as quais resultam numa melhoria da resistência à erosão e à corrosão a altas temperaturas, associadas à criação de uma rede de fissuras que promove a resistência ao choque térmico, são algumas das principais potencialidades.

É neste campo que se enquadra o trabalho desenvolvido no âmbito desta dissertação, que consiste em duas partes: uma primeira experimental e a segunda de carácter teórico. Na primeira procedeu-se ao estudo do efeito da irradiação por laser na superfície dos revestimentos, nomeadamente alteração da morfologia superficial e microestrutura, estabilidade estrutural (Capítulo 3) e avaliação da resistência à corrosão a altas temperaturas (Capítulo 4). Para isso, utilizaram-se dois tipos de lasers com diferentes características: CO_2 e Nd:YAG e procedeu-se aos tratamentos variando os principais parâmetros. No entanto, a quase totalidade dos trabalhos apresentados referem-se ao laser de CO_2. A segunda parte consistiu na elaboração de um modelo computacional que proporcionasse um conhecimento mais profundo acerca da influência dos parâmetros de processamento e características do material, ajudando a prever resultados experimentais como distribuição de temperaturas, largura e profundidade das pistas geradas pelo feixe de laser e distribuição de tensões térmicas (Capítulo 5). O modelo foi pensado para simular os fenómenos ocorridos apenas no revestimento cerâmico externo e tem em conta a sua rugosidade, microestrutura, propriedades físicas, térmicas e mecânicas, tendo sido consideradas algumas delas dependentes da temperatura.

A tese começa por apresentar detalhadamente o "estado da arte" de modo situar o actual panorama de investigação no campo dos revestimentos de barreira térmica (Capítulo 1), dando enquadramento aos trabalhos desenvolvidos. Segue-se, no Capítulo 2, uma descrição dos princípios básicos, modo de operação, características e aplicações de lasers em processamento de materiais.

Laser-glazing of Plasma-sprayed Thermal Barrier Coatings – Experimental and Computational Studies

Abstract

The use of lasers has been demonstrating a great potential for the development of the properties of TBCs deposited by plasma-spraying. These include the reduction of the roughness and elimination of the porosity at the surface which result in the improvement of the high temperature corrosion and erosion response, and the generation of a crack network which lead to an increase of the thermal shock resistance.

This is the research field in which the work developed and presented in this thesis is based on. It consisted on two components: an experimental and a theoretical one. The first component refers to the study of the morphological, structural and microstructural modifications imposed by the laser irradiation on the surface of the coatings (Chapter 3). Two types of lasers have been used, CO_2 and YAG, and the main operating parameters were varied. However, almost all presented results refer only to the CO_2 laser. Furthermore, it has also been evaluated the hot corrosion response of both as-sprayed and laser-glazed coatings, and the corrosion mechanisms were revealed (Chapter 4). The second component consisted on the development of a computational model which could provide a deeper insight about the influence of the material properties and laser characteristics on the laser-glazing process, by predicting experimental results such as temperature and stress distribution within the material, and width and depth of the melted tracks (Chapter 5). The model was developed taking into account the phenomena occurring solely on the external ceramic layer and considers the material's physical, thermal and mechanical properties. Moreover, typical features such as surface roughness and porosity were also included.

The thesis begins with a detailed overview of the state-of-the-art in what concerns to thermal barrier coating research directions (Chapter 1) being a background support for the work carried out. Subsequently, in Chapter 2, is made a description of the basic fundamentals, operation, characteristics and applications of lasers in material processing.

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List of acronyms / abbreviations

APS	–	Atmospheric plasma-spraying/sp rayed
BE	–	Backscattered electron
BS	–	Backscattered
CW	–	Continuous wave
DXF	–	Autocad data exchange format
EB-PVD	–	Electron beam physical vapor deposition/deposited
EDS	–	Energy dispersive X-ray spectroscopy
FDM	–	Finite difference method
FEM	–	Finite element method
IR	–	Infrared
PS	–	Plasma-spraying/sprayed
SE	–	Secondary electron
SEM	–	Scanning electron microscopy/microscope
TBC	–	Thermal barrier coating
TDP	–	Temperature-dependent properties
TIP	–	Temperature-dependent properties
UV	–	Ultraviolet
VRML	–	Virtual reality modeling language
YAG	–	Yttrium aluminum garnet