Surface & Coatings Technology 278 (2015) 171–182

Contents lists available at ScienceDirect

Surface & Coatings Technology

journal homepage: www.elsevier.com/locate/surfcoat

Laser surface patterning to enhance adhesion of plasma sprayed coatings

R. Kromer [a,*], S. Costil [a], J. Cormier [b], D. Courapied [c], L. Berthe [c], P. Peyre [c], M. Boustie [b]

[a] Univ. Bourgogne Franche-Comté, UTBM, IRTES EA7274, F-90100 Belfort, France
[b] Institut Pprime, Physics and Mechanics of Materials Department, UPR CNRS 3346, ISAE-ENSMA, BP 40109, 86961, Futuroscope Chasseneuil, France
[c] PIMM, UMR 8006 CNRS, Arts et métiers ParisTech, 151 Bd de l'Hôpital, 75013 Paris, France

ARTICLE INFO

Article history:
Received 7 May 2015
Revised 1 July 2015
Accepted in revised form 13 July 2015
Available online 1 August 2015

Keywords:
Laser surface texturing
Thermal spraying
Surface topography
Adhesion tests
Adherence

ABSTRACT

In thermal spraying, adhesive bond strength is a feature of surface properties. An adapted surface is studied with prior-surface treatments to enhance interface energy. This study deals with Ni–Al coatings on 2017 aluminum alloy substrate produced by atmospheric plasma spraying. The adherence was evaluated with several controlled surface topographies obtained by grit-blasting and laser surface texturing technique. Adherence has been tested with two different techniques: pull-off test and LASer Adhesion Test. They induce different stresses at the interface. The results showed that the adhesive strength is mostly controlled by a contact adhesion area. A large contact area increases the energy release rate at the interface during coating failures. The bond strength tendency for the two adherence tests is similar: apparent adherence is tripled thanks to laser surface patterning. Fracture propagation is stopped nearby laser-induced holes due to the complex shape and has to deviate inside the coating to maintain crack propagation (inter-splat cracks). The energy at the interfaces being stored locally due to pattern: pattern morphology, pattern localization and powder feed rate are important factors that control the adhesion strength of the thermally sprayed coatings.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

The adhesion strength of thermal sprayed coating depends strongly on the substrate surface: temperature, topography and nature [1]. For instance the preheating of the substrate, generally achieved with the plasma spray jet, is thus a key issue to obtain good splatting [2]. Oxide layer is formed especially for metallic substrate [3]. Substrate surface nature changes the contact quality (desorption of the pollutants adsorbed on the surfaces and the droplets wetting) [4]. Substrate and coating temperatures during spraying also control residual stresses distribution [5].

Surface contaminations such as oxides, carbon or oils have to be removed from a metallic surface before its final use as they change the physico-chemical behaviors and/or surface topography [6]. Among the conventional techniques, degreasing and grit-blasting are used in most cases before thermal spraying. The degreasing agent leads to chemical modifications of the surface while grit-blasting modifies the surface morphology by creating a random roughness thus promoting a mechanical anchorage of the incoming particles to the substrate [7]. This technique is very effective for most materials except for ductile materials that may be damaged with a risk of micro-crack nucleation on the surface [8]. In addition, grit inclusions can occur decreasing the adherence of the subsequent coating. New technologies such as laser tools are developed to adjust the coating/substrate adhesion. Shortly, laser tools have been shown to improve surface behaviors of materials as surface treatment techniques (for cleaning purposes, topography modification, heating treatment, etc.) [9–13]. Lasers present advantages such as easy automation, localized treated area, three dimensional treatments and great flexibility. Using a controlled ablation technique, topology modifications may occur for all types of materials such as glasses, ceramics, polymers and metals [14]. A specific laser tool adapted to the material to be treated (in terms of wavelength, pulse duration, spot size and pulse energy) added to a scanner for 3D shape modification can promote mechanical adherence for thick coating elaborated by thermal spraying. Those parameters influence logically the topography but also the material microstructure due to the heat flux which can be absorbed during the treatment according to the pulse duration [15–17]. Laser–matter interaction is commonly described considering three main factors: laser light, material and environment. Conversion of absorbed energy via collision processes into heat is the most important effect that occurred during the laser interaction up to the vaporization of micro-metric layers through ablation phenomenon corresponding to the fast transition from the overheated liquid to a mixture of vapor and drops (laser surface texturing) [18,19]. Short pulse duration (10^{-10}–10^{-15} s) is needed to localize the laser interaction on the extreme surface [20].

Coating substrate systems need to be quantitatively tested to evaluate in-service life span. Adhesion is related to the nature and strength of the bonding forces between two materials in contact such as ionic, covalent, metallic, hydrogen and Van der Waals forces [21]. But it is also essential to evaluate mechanical anchoring (or

---

[*] Corresponding author.
E-mail address: robin.kromer@utbm.fr (R. Kromer).

http://dx.doi.org/10.1016/j.surfcoat.2015.07.022
0257-8972/© 2015 Elsevier B.V. All rights reserved.

interlocking) which is usually recognized as the main bond strength contributor in thermal sprayed coating [7]. This is why in this paper, a comparison between conventional method (grit-blasting) and laser surface texturing has been carried out with Ni–Al coating on 2017 aluminum substrate systems [22]. Different surface topographies will be presented in this paper and characterized with the use of 2 adhesion tests. Furthermore, considering some specific field such as thermal barrier coatings (TBC), laser surface patterning could be a solution to remove bond coat by an application oriented surface topography (hence decreasing the processing costs and minimizing the number of parameters controlling the durability of a TBC coating system).

2. Experimental procedure

2.1. Materials

2017 aluminum alloy substrates (Mg = 0.6%, Cu = 4%, Mn = 0.7%, Fe = 0.7% and Si = 0.5% weight), widely used in aerospace structural applications, have been used in this study (solution heat treated, and naturally aged to a substantially stable T4 condition). The substrates were 25 mm in diameter and 10 mm thick buttons and $50 \times 30 \times 1$ mm^3 plates (roughness corresponding to Ra ≈ 0.4 μm). As a ductile material, 2017 Al alloy presents weakening issues (cracks due to abrasive granules) during conventional surface pre-treatment [23].

The powder, deposited on the substrates, was Ni–Al powder (95–5% weight, AMDRY 956, Sulzer-Metco) and the particle size varied from 45 μm to 90 μm ($d_{0.1}$–$d_{0.9}$) with a 67 μm average grain size.

2.2. Substrate surface pre-treatment

To ensure substrate surface pre-treatments, several processes have been carried out. Grit-blasting (GB) was performed by "Econoline" machine (Econoline Abrasive Products, USA) (self-contained, recycling, sealed glove box design). Samples were treated with 3 bars pressure at 5 cm stand-off distance and 70° angles to obtain roughness of Ra ≈ 3 μm and Rz ≈ 16 μm.

Laser experiments were conducted with a pulsed fiber laser (Laseo, Ylia M20, Quantel France), operating with a 1.064 μm wavelength, a 100 ns pulse duration, a maximum mean power of 20 W and repetition rate varying from 20 to 100 kHz. The circular laser beam exhibits a 60 μm diameter and a Gaussian energy distribution. The surface patterning technique consisted of series of equidistant lines of holes covering the whole surface. Various parameters can be selected like the number of shots per drilled hole, the laser energy density, the laps time between two shots as well as the hole area density to achieve the surface texture [24] (see Fig. 1).

Suitable type of laser and adequate setting of processing parameters are necessary in order to tailor textures. The adhesion of thermal-sprayed coatings on textured substrates would be highly influenced by the pattern geometry and "additional" surface roughness (spatters and recast material), as they modify the surface contact area of the substrate. Particularly, the optimal cavity dimensions must be adapted depending on the sprayed powder average size and viscosity that control the wettability of holes. As shown in Fig. 2, the molten splats during coating do not easily fill deep holes [25]. Moreover, the shape and depth of holes need to be optimized to minimize stress-concentration effects which usually degrade the mechanical properties of the substrate (like fatigue behavior).

As many adhesion areas can be obtained on textured surfaces, depending of the shape, height and density of holes, one of our assumptions was to select hole volumes equal to the sprayed powder average volume ($d_{0.5}$) to enable full filling. Considering the mean size of spherical Ni–Al particles equal to 67 μm in diameter, we found a particle volume equal to $V_{particle} = 4/3\pi R^3 \approx 150{,}000\ \mu m^3$. A similar volume was obtained with drilled holes having diameter equal to 60 μm and a depth of 80 μm, which have been considered for texturing, using 40 local pulses at 20 W mean power and 30 kHz, at the focal point position.

The laser holes were oriented at 0° and 30° from the surface to address orientation effect (Fig. 3), and the hole distribution was varied into four matrixes detailed as follows: F[L] − <D> with [L] the distance between two holes in X and Y directions and <D> the angle versus the surface normal. 100, 150, 200 and 300 μm have been studied for [L] and 0, 30° and −30/+30° in staggered rows for <D>. An example of P200–30 condition is shown in Fig. 4 for top and cross-

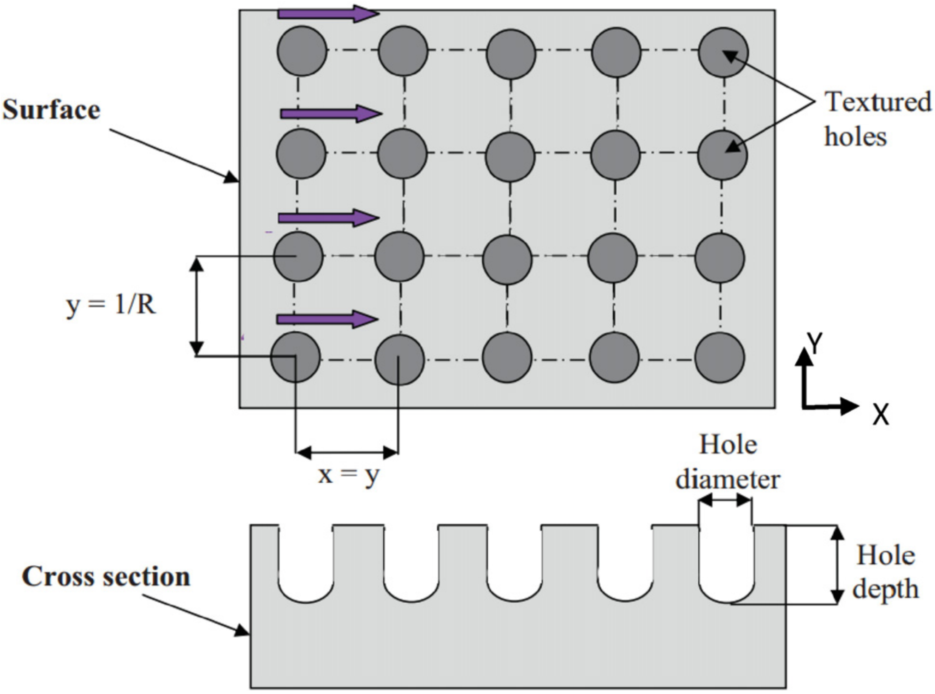

Fig. 1. Shallow spot-shape cavities.

Download English Version:

https://daneshyari.com/en/article/1656943

Download Persian Version:

https://daneshyari.com/article/1656943

Daneshyari.com