International Journal of Engineering Science 144 (2019) 103142

Contents lists available at ScienceDirect

International Journal of Engineering Science

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

Modeling the topographic evolution of a rough metallic surface resulting from impact of water droplets

Jing Xie[a,*], Daniel Rittel[b], Pengwan Chen[a]

[a] State Key Laboratory of Explosion Science and Technology, Beijing Institute of Technology, 100081 Beijing, PR China
[b] Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, 32000 Haifa, Israel

ARTICLE INFO

Article history:
Received 23 May 2019
Revised 15 August 2019
Accepted 15 August 2019

Keywords:
Waterjet
Rough surface
Randomness
Coverage
Area roughness

ABSTRACT

Waterjet peening (WP) is usually used to roughen metallic surfaces in order to improve cell adhesion on biomedical implants. Hence, surface roughness control using WP is of prime importance for such applications. A random finite element model of WP was developed, aimed at characterizing the surface coverage (the ratio of jet-affected area over total contact area) and surface roughness (in particular, the heights distribution). One perfectly flat and three rough metallic surfaces with different initial *Sa* (area arithmetic mean height) were generated, impacted and compared with each other. Numerical results show that a rougher initial surface necessitates more impingements than a smooth one to attain full surface coverage. The mechanisms influencing surface topography evolution, namely plastic deformation-induced roughening, peak clipping, valley deepening and valley filling are discussed. By modeling the roughness evolution resulting from WP, it appears that the process can be applied not only to roughen but also to polish rough initial surfaces in the investigated range. The present approach allows for systematic tuning of the system parameters in order to control the surface roughness.

1. Introduction

Waterjet peening (WP) process was initially proposed by VanKuiken, Byrnes and Kramer (1995) to enhance the bonding of thermally sprayed coating. Further applications followed Hashish's new technique consisting of adding abrasive particles to the waterjet (Hashish, 1984), often referred to as abrasive WP. In the following, we will only consider particle-less (pure) WP.

WP involves a continuous impact of high velocity - high pressure waterjet that impinges a metallic surface, which it can strip, texture or peen. Such waterjet is usually generated by forcing water through a narrow orifice with a diameter of 0.08 to 0.8 mm at a high pressure ranging from 140 to 420 MPa.

Biomedical implants, for instance, possess different surfaces, depending on specific biological requirements (Rupp, Liang, Geis-Gerstorfer, Scheideler & Hüttig, 2018). Some of them enhance cell adhesion while others are aimed at repelling cells or fluids. According to different clinical needs, various surface modification methods have been developed that can be classified into three categories: mechanical, chemical and physical methods (Liu, Chu & Ding, 2004). Specifically, WP has been reported as an attractive option for roughening the titanium alloy's surface with applications e.g. to implant dentistry, because of its

* Corresponding author.
E-mail address: jxie@bit.edu.cn (J. Xie).

https://doi.org/10.1016/j.ijengsci.2019.103142