Modification of Cold Sprayed CoCrMo Alloy Coatings via Laser Shock Peening

Wen Sun[1,2](✉), Niroj Maharjan[3], Kaiqiang Wu[4], Adrian Wei-Yee Tan[5],
Renzhong Huang[1], Yingchun Xie[1], Haiming Lan[1], Xin Chu[1], and Erjia Liu[4]

[1] National Engineering Laboratory for Modern Materials Surface Engineering Technology,
Institute of New Materials Guangdong Academy of Sciences, Guangzhou 510650, China
`SUNW0013@e.ntu.edu.sg`
[2] School of Materials Science and Engineering, South China University of Technology,
Guangzhou 510641, China
[3] Advanced Remanufacturing and Technology Centre, CleanTech Loop, Singapore 637143,
Singapore
[4] School of Mechanical and Aerospace Engineering, Nanyang Technological University,
50 Nanyang Avenue, Singapore 639798, Singapore
[5] School of Engineering, University of Southampton Malaysia, 79200 Iskandar Puteri,
Johor, Malaysia

Abstract. In this study, CoCrMo alloy coatings were fabricated by high pressure cold spray deposition. Laser shock peening with and without an ablative layer was applied to the coatings. The microstructure characteristics and mechanical properties of the both as-sprayed and laser shock peened CoCrMo coatings were systematically investigated. Laser shock peening without a protective overlay resulted in both mechanical and thermal loading of the coatings, leading to melting and solidification of the outermost surfaces of the coatings along with deformation. For comparison, laser shock peening with a polyvinyl tape as sacrificial layer was also applied to the as-sprayed CoCrMo coatings. It was found that this sacrificial layer could protect the samples from thermal effects and introduce a deep compressive residual stress in the coatings, which resulted in cracks in the coating. Those cracks in the coatings appeared to be continuous and parallel to the coating/substrate interface due to the strong shock wave imposed during the laser peening process.

Keywords: High pressure cold spray · CoCrMo alloy coating · Laser shock peening · Microstructure · Mechanical properties

1 Introduction

Cold spray is an emerging technology that can be used for coating deposition, metal surface repair and additive manufacturing, which has attracted more and more attention in recent years [1]. The fundamental working principle of cold spray technology is that micro-sized metal particles are accelerated by a high-pressure gas to a supersonic speed via a convergent-divergent nozzle. With high kinetic energies, the metal particles deposit

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on the substrate surface and form a dense coating of a high adhesive strength with a low temperature input. Cold spray deposition is applicable to nearly unlimited materials, such as pure metals, metal alloys, polymers, and hybrid materials [2, 3]. Thus, cold spray technology holds great potential as a next-generation large-scale and low-cost coating/additive manufacturing technology in industry [4].

Micropores and microcracks within the as-sprayed coating are inevitable due to the bonding nature of cold spray particles, which can lead to the degradation of mechanical properties of the coating and its bonding to the substrate [5, 6]. Sun et al. [7] reviewed the effects of various post-process treatments on the microstructures and properties of the cold sprayed coatings. However, each method has its benefits and limitations, and further post-process treatment methods need to be explored.

Laser shock peening (LSP) is an innovative contact-free surface modification technique, which is employed to improve the material performances, such as fatigue life, anti-corrosion, and wear resistance. The LSP process utilizes short and high energy laser pulses to generate a high-pressure plasma that can impart surface compressive residual stress, increase surface hardness and refine grain of metals [8]. This study aims to evaluate the effects of LSP on the microstructures and mechanical properties of the cold sprayed CoCrMo coatings.

2 Materials and Methods

The feedstock power material used in this study was F75 CoCrMo (TLS Technik GmbH & Co, Germany) with average particle size of 25 μm. The CoCrMo particles are spherical. The substrates used in this study were Inconel 718. A high-pressure cold spray system was used for the deposition of the CoCrMo coatings on the IN718 substrates. N_2 was used as the propelling gas.

Before LSP, the as-sprayed CoCrMo coatings were cut into 50 mm × 20 mm × 10 mm and subsequently cleaned in deionized water. All the specimens were degreased by ultrasound in ethanol. A Nd:YAG laser system with a 1.064 μm wavelength, 10 J pulse energy, 18 ns laser pulse width and 4 Hz repetition rate was used to peen the samples in presence of water confinement. Two sets of samples were made: with a protective coating and without a protective coating. A black vinyl tape was used as a protective coating.

3 Results and Discussions

Figure 1 shows the optical micrographs of the cross-sectional CoCrMo coatings under different conditions. It can be observed that the as-sprayed CoCrMo coating consists of a very low porosity level, which is around 0.7%, as shown in Fig. 1(a). The irregular shape micro-pores are uniformly distributed within the coating. The interface between the coating and substrate is intimate without signs of delamination, indicating a strong bonding. Besides, there is no obvious cracks within the as-sprayed coating. However, after LSP treatments, some changes for the coating microstructures occur. Figure 1(b) shows the microstructures after LSP with an ablative layer. It can be seen that a continuous crack exists within the coating, which is almost parallel to the coating/substrate interface due to the very high amplitude pressure induced by LSP. Figure 1(c) shows the microstructures after LSP without an ablative layer. It can be seen that no obvious crack exists within the coating because of the combined mechanical and thermal effects of the LSP.

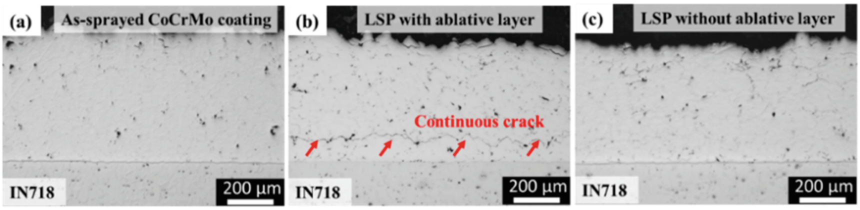

Fig. 1. Optical micrographs showing cross-sectional microstructures of cold sprayed CoCrMo coatings on IN718 substrates: (a) as-sprayed, (b) LSP with an ablative layer and (c) LSP without an ablative layer.

Figure 2 shows the micro-hardness values of CoCrMo coatings and IN718 substrates before and after LSP treatment. It can be seen that laser shock peening (with or without an ablative layer) could improve the micro-hardness of the coating surface because of plastic deformation, high density dislocations and fine grains induced on the material surface by high-pressure shock waves. With the increase of depth, laser shock peening has less effect on the coating micro-hardness because of the reduced strength of shock waves.

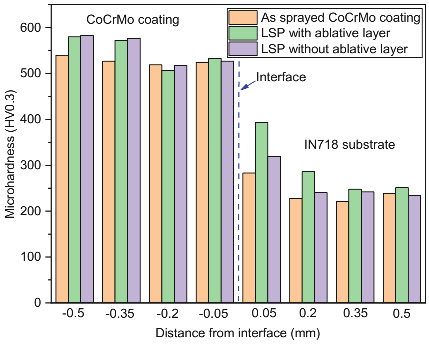

Fig. 2. Microhardnesses of CoCrMo coating and IN718 substrate before and after LSP.

4 Conclusions

In this study, CoCrMo alloy coatings were fabricated by high pressure cold spray deposition. Laser shock peening was applied to the coatings. The microstructure characteristics and mechanical properties of the CoCrMo coatings were systematically investigated. The main conclusions are drawn as below:

(1) For the laser shock peening without an ablative layer, the coating surfaces showed presence of a non-uniform melting layer that increased the hardness and roughness of the surfaces.
(2) For the laser shock peening with a polyvinyl tape as sacrificial layer, it was found that this sacrificial layer could protect the samples from thermal effects, which resulted in cracks in the coating. Those cracks in the coatings appeared to be continuous and parallel to the coating/substrate interface due to the strong shock wave imposed during the laser peening process.
(3) Laser shock processing could improve the coating surface micro-hardness because of plastic deformation, high density dislocations and fine grains induced on the material surface by high-pressure shock waves.

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