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Mechanical and wear properties of aluminium coatings produced by high pressure and low-pressure cold sprayed processes

A. Manap[1,*], S.N.A. Yusof[1], N.F. Afandi[1], S. Mahalingam[1], Z.M. Rosli[2], K. Ogawa[3]

[1)] Institute of Sustainable Energy, Jalan Ikram-Uniten, 43000 Kajang, Selangor, Malaysia.
[2)] Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal. Melaka, Malaysia.
[3)] Fracture and Reliability Research Institute, Tohoku University, 2 Chome-1-1 Katahira, Aoba Ward, Sendai, Miyagi Prefecture 980-8577, Japan.

[*]Corresponding e-mail: abreeza@uniten.edu.my

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ABSTRACT – In this study, aluminum powders were deposited using two different cold spray processes which are high pressure cold spray process (HPCS) and low-pressure cold spray process (LPCS). The main objective is to investigate and compare the microstructure, mechanical and wear properties of aluminum coatings using HPCS and LPCS processes. The microstructure, hardness, wear and elemental composition were evaluated using Scanning Electron Microscope, Vickers Hardness test, pin-on disc wear test machine and Energy-dispersive X-ray spectroscopy, respectively. It was found that the aluminium coatings using LPCS process exhibited slightly better mechanical and wear properties compared to the aluminium coatings using HPCS process.

1. INTRODUCTION

Aluminium (Al) alloys are lightweight with high corrosion resistance, its ductility and strength led to its increased use in transportation systems to reduce fuel consumption. However, Al is highly susceptible to severe crack and wear. In order to overcome these damages, cold spray (CS) is used to repair and minimize any potential phase transformation and keeps the particles in their unmodified solid state. There are two processes of CS known as high pressure cold spray process (HPCS) and low-pressure cold spray process (LPCS) as deposition method of wear resistant coatings and repair of defective structural constituent elements. Furthermore, Wang et al. reported bonding mechanism between particles in the CS Al coating [1]. They found high strain-rate deformation on the surface area due to the mechanical bonding between two particles [1]. This study focuses on the mechanical and wear properties of Al coatings prepared using HPCS and LPCS processes by means of Scanning Electron Microscope (SEM), Vickers Hardness test, pin-on disk wear test machine and Energy-dispersive X-ray spectroscopy (EDX).

2. METHODOLOGY

The CS deposition process for HPCS and LPCS was conducted using PCS-203(Plasma Giken Kogyo Co. Ltd, Japan) and DYMET403J (Obninsk Center for Powder Spraying, Russia), respectively. The feedstock powder of Al (AL G-AT, Fukuda Metal Foil & Powder Corporation) with diameter of 25 µm and aluminium 1100 as substrate were used. Helium and compressed air were used as working gas for HPCS and LPCS, respectively.

The hardness of the different coating processes was measured using Vickers hardness test machine at room temperature. Meanwhile, friction and wear test were performed with micro pin-on disc tribotester (model CM-9109, Ducom, Bangalore). The tests were conducted for different loads 2N, 3N and 5N and sliding velocity constant at 0.1 m/s.

The samples were cut using Buehler Isomet Precision Saw and followed by grinding and polishing processes for highly reflective surface. The cross-sectional microstructures, surface morphologies and wear tracks, and elemental composition were examined using SEM (Hitachi SU1510) and EDX analysis.

3. RESULTS AND DISCUSSION

3.1 Microstructure and mechanical

Figure 1 shows the SEM images of Al coatings using (a) HPCS and (b) LPCS processes. Larger pores were observed in HPCS coatings compared to that of LPCS coatings indicating higher porosity with larger pores and partial deformation due to subsequent high velocity impact among particles. On the other hand, the Al coating deposited via LPCS process was fully deformed with excellent bonding between particles in the coating with small pores.

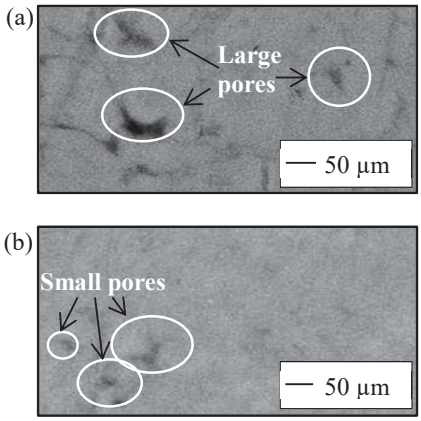

Figure 1 SEM images of Al coatings using (a) HPCS and (b) LPCS processes.

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Furthermore, the coating with LPCS process holds higher hardness of 196.6 HV than that of HPCS hardness of 174.3 HV due to lower porosity as observed in Figure 1. Table 1 tabulates the Vickers hardness and porosity of HPCS and LPCS coatings. LPCS exhibits greater hardness because of the peening effect [2]. Thus, the higher hardness obtained by LPCS process may attributed from high level of plastic deformation and strain hardening caused by the lower porosity.

Table 1 Vickers hardness and porosity.

Process	Vickers hardness (HV)	Porosity (%)
HPCS	174.3	7.72
LPCS	196.6	3.48

3.2 Friction and wear

The specific wear rate is determined as in the following Equation (1).

$$\dot{W} = \frac{v}{F_n d} \quad (1)$$

Where, v, F_n and d is the wear volume, normal load and sliding distance, respectively. Figure 2 shows the specific wear rate and wear resistance of HPCS and LPCS processes.

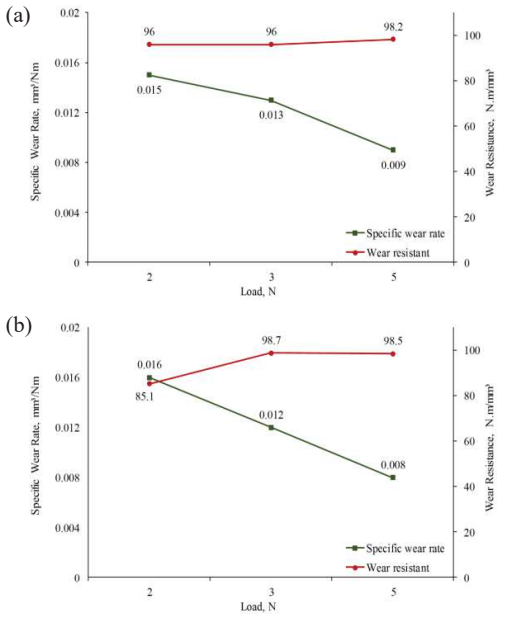

Figure 2 Specific wear rate and wear resistance of (a) HPCS and (b) LPCS processes.

Figure 2 denotes that the high specific wear rate of LPCS at higher applied load leads to greater value of wear resistance in LPCS (98.5 Nm/ mm³) compared with HPCS (98.2 Nm/ mm³), indicating that the oxide transfer layer inhibits contact between the surfaces and slowing down the rate of specific wear.

Besides that, the friction coefficient of LPCS deceased gradually from 1.343 to 1.297 and then to 0.798 with small gaps in the values as the load was increased as seen in Figure 3. Whereas, HPCS process decreased from 1.609 to 1.067 and then to 0.807 with larger gaps. As stated in [2], dense coatings with low porosity generates low friction coefficient that improves wear resistance.

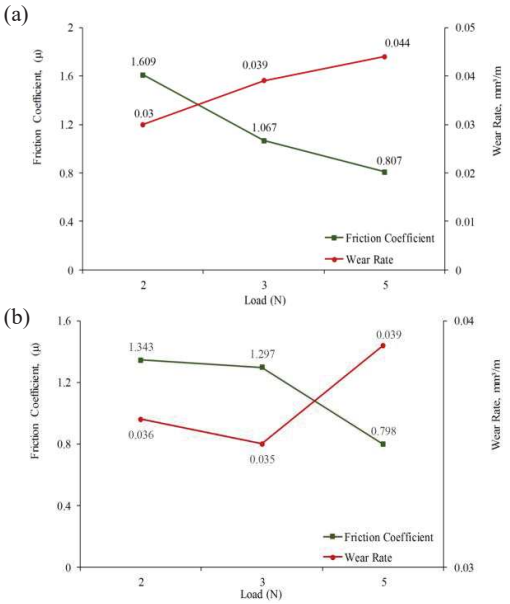

Figure 3 Friction coefficient and wear rate of (a) HPCS and (b) LPCS processes.

4. SUMMARY

In conclusion, the Al coating using LPCS process exhibited smaller pores indicating good bonding between the particles in the coating. Moreover, the LPCS process with lower porosity holds greater hardness than HPCS process. The gradual decrease in friction coefficient obtained by LPCS process denotes good tribological properties of Al coating. Finally, the wear analysis revealed that LPCS process has lower specific wear rate at high applied load. Therefore, the LPCS Al coating exhibited slightly better mechanical and wear properties compared to the HPCS Al coating.

ACKNOWLEDGEMENT

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