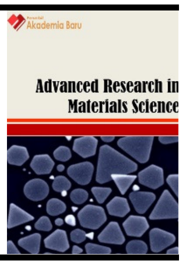
Penerbit Akademia Baru

Journal of Advanced Research in Materials Science

Journal homepage: www.akademiabaru.com/arms.html
ISSN: 2289-7992



Effect of cold sprayed Al coating on corrosion behaviour of sponson spar

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ARTICLE INFO

Article history:
Received 15 November 2016
Received in revised form 9 January 2017
Accepted 12 January 2017
Available online 25 January 2017

Keywords:
Cold spray, Sponson spar, Aging aircraft, Salt spray

ABSTRACT

Aluminium types 7075 alloys are widely used in aircraft components example helicopter because of their inherent weight advantages over other metals but premature failure due to corrosion is one of the main challenges associated with this alloys, which affects the safety and readiness of aircraft. Current practise of corrosion treatment is using DOW-17process or thermal spray coating. Disadvantage of DOW-17 process it involves hazard material and thermal spray coating issue of porosity and fatigue failure. A promising coating technique cold spray, CS powder particle in supersonic jet of compressed gas impact a solid surface to cause plastic deformation without the creation of heat affected zone. Salt spray testing, SST show no rust on surface specimen of coated area and EDX result show higher weight % of Aluminium on coated area as well. Corrosion treatment is the utmost concern in the aircraft industry.

1. Introduction

Sikorsky S61A-4, Nuri Helicopter currently use for multipurpose transport, carrying troops &humanitarian aid. Fitting sponson spar part is often the main structural member of the wing, running span wise at right angles to the fuselage. The spar carries flight loads and the weight of the wings while on the ground. Other structural and forming members such as ribs may be attached to the spar or spars, with stressed skin construction also sharing the loads where it is used [1]. Fitting sponson spar Nuri Helicopter is made from Aluminum 7075-T6 but premature failure due to corrosion is one of the main challenges associated with this alloys and the most common effect of corrosion on

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aluminum alloys is called pitting. It is first noticeable as a white or gray powdery deposit, similar to dust, which blotches the surface [2].

Corrosion control is the utmost concern in the aircraft industry because it potential impact on human safety. In the military, winning the war on corrosion is essential to military preparedness and national security. Military aircraft are very expensive, such as the B-1B strategic bomber, cost over $200 million each. On top of that, military aircraft are flown throughout the world and are therefore exposed to the most severe corrosive environments on earth. Corrosion control of commercial aircraft is also paramount importance for similar reason. Fight safety is essential to the airline industry. Commercial airlines are exposed to highly corrosive environments all over the world. Commercial aircraft represent investments of up to $100 million per unit for some of the wide body aircraft [3]. The potential for corrosion of aircraft structures is a major consideration in the design of aircraft. There are many forms of corrosion on Aluminum 70775-T6. The form of corrosion depends on the material involved, its size and shape, its specific function, atmospheric conditions and the corrosion producing agents present. Common forms found on airframe structure are surface corrosion, dissimilar metal corrosion, intergranular corrosion, stress corrosion, fretting corrosion and local pitting or crevice corrosion. Pitting corrosion produces deterioration of airframe structure by forming cavities and oxidation products in localized areas of the affected components. The severity of pitting corrosion is determined by the susceptibility of the airframe material to pitting attack [3].

Some studies about 7075-T6 aluminum alloy exfoliation corrosion sensitivity were performed. Al 7075 high-strength aluminum is widely used in manufacturing sheet metal structural parts such as stringer and civil fuselage bulkhead because of its light-weight, excellent mechanical properties and processing performance. Statistics show that aluminum alloy sheet metal parts accounts for 50–75% of the total fuselage parts [4].7075 aluminum alloy is solution treated for 35–45 minutes under temperature 460–470°C and quickly quenching. 7075-T6 aluminum is obtained after artificial aging under 121°C for 22–24 hours. It is most widely used for its high strength and excellent overall performance.7075-T6 aluminum manifests corrosion resisting property because there forms a thin compact oxidation film (γ-Al_2O_3) on aluminum alloy surface which separates corrosive medium from substrate [5,6]. However, numerous studies show that the comparatively complex environment of aircraft can lead to lots of water in fuselage. Being soaked in such corrective solutions for long period, the protective layer on components is gradually ineffective. The aluminum alloy parts are inevitably exposed to corrosive solution thus suffering corrosion [3].

There are many techniques that are available for preventing and controlling airframe corrosion. Some of these corrosion controls methods have been used for many years such as the application of grease to bearings in aircraft control mechanisms, wheel and rudder posts. Other approach is application of advanced composite materials to secondary airframe structure. Current method to provide corrosion protection to Aluminum or Magnesium aircraft structure through application of DOW 17 process or Thermal Spray technology. DOW 17 process involved sodium dichromate containing hexavalent chromium that is very dangerous in case of skin contact, ingestion and over exposed by inhalation may cause respiratory irritation. This will contradict with OSHA regulation & requirement and on top of this, even with chromoted surface treatment, Al and Mg components suffer severe degradation in service. On the other hand, issue with Thermal Spray coating application involve with heat to the substrate, hence it will build internal stress in substrate that leads to fatigue failure [7].

In our recent study, a promising coating technique cold spraying (CS) was Cold spray, (CS) or Supersonic particle deposition, (SPD) is a coating technology was initially developed in the mid-16980s at the Institute for Theoretical and Applied Mechanics of the Siberian Division of the Russian Academy of Science in Novosibirsk. CS is a technology in which metal, composite or polymer powder particle in a supersonic jet of compressed gas impact a solid surface with sufficient energy to cause plastic deformation and bonding with the under laying material without the creation of heat affected zones which are typical of other deposition processes and which are undesirable in many structural applications[8].Bonding between substrate and deposit material is a result of high strain rate deformation and adiabatic shear instabilities at the bind interface. Advantages of CS process are low temperature process, which it operates below melting point of metals and this will contribute to porosity control below 1% [9].

To date, there has been no detailed investigation of application high pressure cold spray process as corrosion protection for Malaysian aging aircraft [10,11]. The objective of this paper to investigate corrosion properties of sponson spar coated using high pressure cold sprayed process on Malaysian aging aircraft. The finding of this study will help to propose new corrosion treatment process for maintenance, repair and servis, MRO services in aviation industry in Malaysia. The Asian region is forecast as fastest growing aviation market for the next 20 years. By 2025 Asian airports are expected to handle more than three times the volume of movement handled in 2005 with growing average 6% per year. Aircraft maintenance and repair play a major role in increasing useful life of aircraft part and on top of that, it increases confident level of user. Malaysia forecast to become regional maintenance, repairing and overhaul (MRO) hub to be worth US$65 billion by 2020 [12].

2. Materials and methods

2.1. Materials

Scrap fitting sponson spar is made of 7071-T6 Aluminum and 6061 Aluminum powder of nominal particle size is 45µm

2.2. Cold sprayed process

The CS coatings were produced using 8000 series a high pressure CS system. The CS system consists of high pressure gas supply used for the main flow and the feedstock powder and carrier flow. The feedstock powder used was composed of 6061 aluminum with spherical morphology and sieved to particle size averaging 45µm. 7071-T6 aluminum were used as substrates. The substrate plate was prepared by grit blasting method that utilized 120grit aluminum oxide. The experimental parameters are listed in table 1. The sample surface was characterized using Field Electron Scanning Electron microscope, FESEM to study the morphology of coated and not coated area. Salt Spray Testing, SST in salt spray chamber for 48 hours was conducted in accordance with ASTM B117 to measured corrosion resistant.

Table 1
Cold spray process parameters

Powder /Substrate	6061 Aluminum/ 7071-T6 substrate
Pressure (MPa)	2.0
Particle Velocity (ms^{-1})	780
Temperature (ºC)	
Standoff distance (mm)	300
Thickness of coating (mm)	15
	4

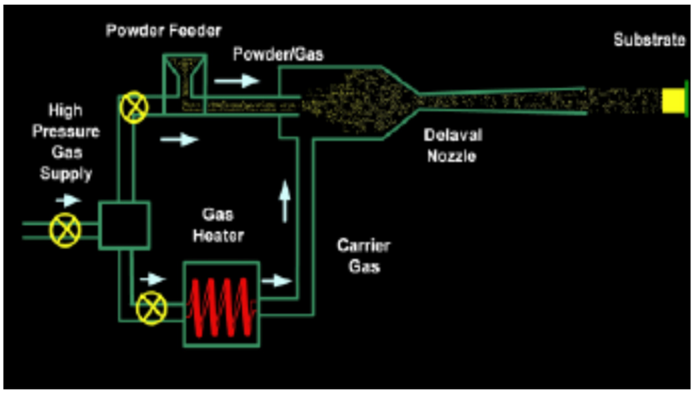


Fig. 1. The schematic diagram of high pressure cold spray system [8]

3. Results and discussion

3.1. Salt spray testing, SST

To investigate the corrosion resistant of cold sprayed substrate, the surface condition after salt sprayed testing for 48 hours are observed. Fig 2 and fig 4 shows surface conditions without any rust before SST conducted. Meanwhile, fig 3 and fig 5 show surface condition after SST conducted. Reference sample after SST covered with pitting corrosion, on other hand, cold sprayed sample after SST still remains clean without any rust. This condition maybe due to the deformation of other material by using cold spray can be the element to increase denseness of particle and reduce the corrosion defect. However, without the coating deformation, the tenseness to corrosion are highly deform at the surface of Al 7075 substrate. Al 6061 powder particles plays an important role in providing a corrosion protection against alternated salt spray environment [13].

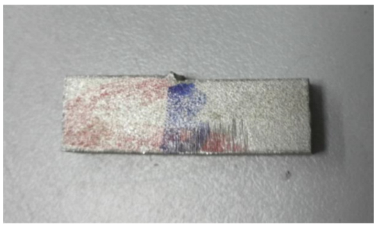


Fig. 2. Reference sample before SST

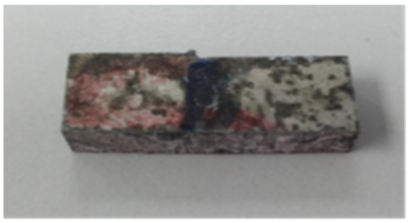


Fig. 3. Reference sample after SST

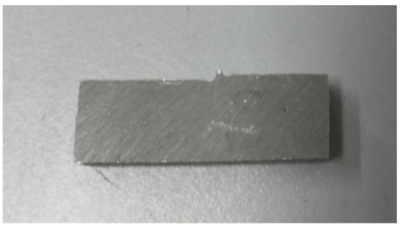


Fig. 4. Cold sprayed sample before SST

Fig. 5. Cold sprayed sample after SST

3.2. Energy dispersive X-Ray analysis (EDX)

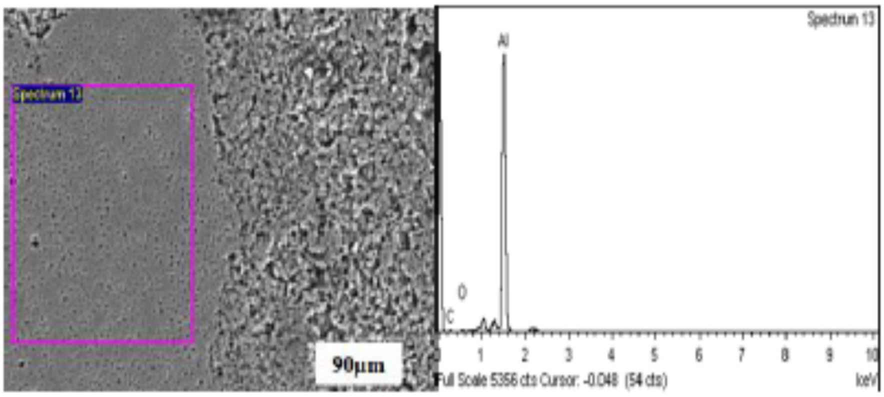
Table 2 show analysis composition deposition of Al 7075 coated with Al 6061 powder. Meanwhile Fig. 6 (a) shows the microstructure for coating area for 90µm and 6(b) X-ray diffraction pattern for coated area. Composition show Aluminum, Al is most abundant compared to Carbon, C and Oxygen,

O. This condition maybe due to the bonding between Al 7075 substrate and Al 6061 powder, create a new dense of thin layer surface on the coated area [14].

Table 3 show analysis composition of not coated Al 7075 substrate. Meanwhile Fig. 7 (a) shows the microstructure for not coat area for 90µm and 7(b) X-ray diffraction pattern for not coated area. Analysis of composition deposition show weight % of Al is 71.59, is lower compared to coated area with weight % of Al is 85.34. This decreased maybe due to contribution of Al only from Al 7075 substrate without any Al 6061 powder coated.

Table 2
Composition deposition of Al 7075 coated with Al 6061 powder

Element	Weight %	Atomic %
C	11.18	21.60
O	3.47	5.04
Al	85.34	73.37



(a) **(b)**

Fig. 6. (a) microstructure of the coating area for 90µm (b) X-ray diffraction pattern image peak for the coating area

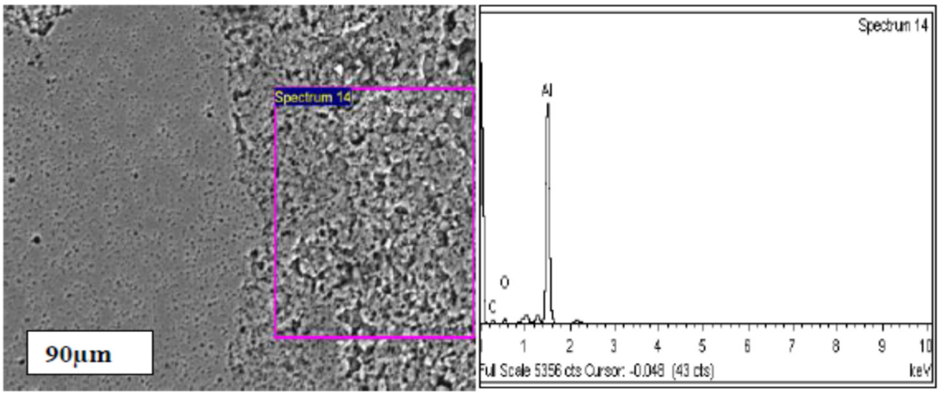
Table 3
Composition deposition of not coated Al 7075 substrate

Element	Weight %	Atomic %
C	19.89	34.20
O	3.47	10.99
Al	71.59	54.80

3.3. Field emission scanning electron microscope, FESEM

Surface morphology of coated and not coated area of Al 7075 substrate are shown in Fig. 8 and Fig. 9. Large cracks and porosity are formed on the not coated area and some tiny pores are seen on the coating area. Chemical activity on not coated area will accelerate the porosity and crack issue as well.

The coating dense as shown in Fig. 9 (c) and (d) maybe due to powder particle Al 6061 impacting well on Al 7075 substrate but pores or pin holes still can be seen as Fig. 9 (a) and (b) due to factors like differences of particle impact velocities or the distance between the substrate and gas nozzle [15,16].



(a) (b)

Fig. 7. (a) microstructure of the not coated area for 90µm (b) X-ray diffraction pattern image peak for the not coated area

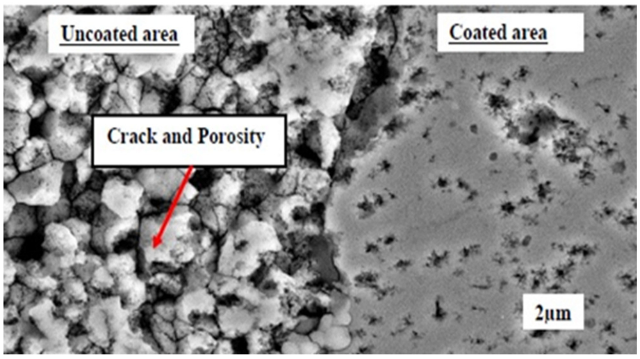
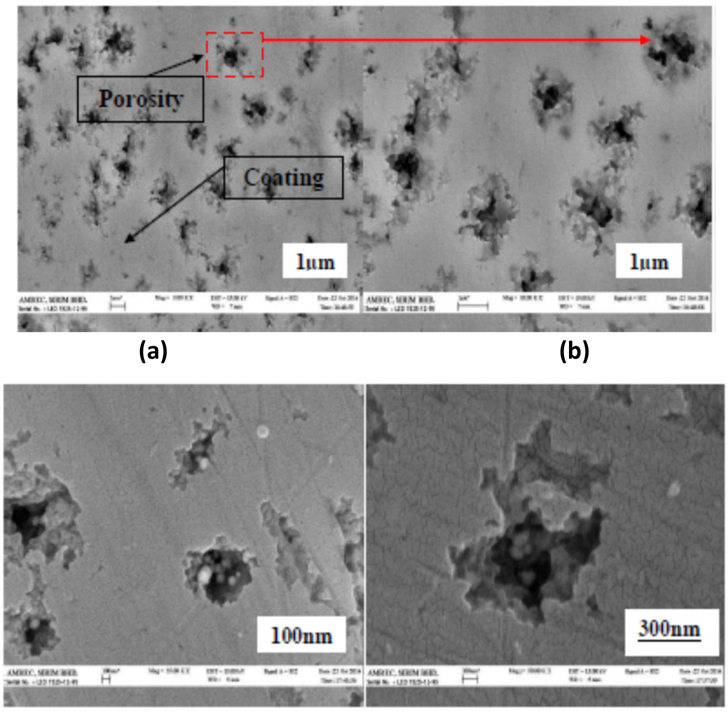


Fig. 8. FESEM images of reference (uncoated area) and Cold sprayed sample (coated area) at magnification 2000x



(c) (d)

Fig. 9. FESEM of Al 7075 coated with Al 6061 powder at different magnification (a) 5000x (b) 10,000x (c) 25,000x (d) 50,000x

4. Conclusion

This study set out to examine the relationship between corrosion properties of 7076-T6 fitting sponson spar and Cold Sprayed process. This study has identified that Cold sprayed process shows a significant corrosion treatment. The main findings can be summarized as follows, no localized corrosion shown on coated area after 48hours salt spray testing and only tiny pores are seen on coating area compared to not coated area.

Acknowledgments
The authors would like to thank University Technical Malaysia Melaka for the financial assistance PJP/2-13/FTK (4B)/S01166. The authors would also like to express their gratitude to the Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM) for the facilities provided during the research.

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