International Conference on Engineering Education 2013
Madinah, Kingdom of Saudi Arabia, 25-27 December 2013

REVIEW ON HIGH PRESSURE COLD SPRAY (HPCS) PROCESS AS CORROSION TREATMENT FOR AGING AIRCRAFT PART

Nooririnah Omar[1], Rohana Abdullah[2], Muhamad Azwar bin Azhari[3], Nuzaimah Mustafa[4]

[1,2,4]Department of Manufacturing Engineering Technology,
Faculty of Engineering Technology,
University Teknikal Malaysia Melaka,76100, Durian Tunggal, Melaka, Malaysia.
Phone: +606-2346512, Fax: +606-2346973
. [3]Department of Mechanical Engineering Technology,
Faculty of Engineering Technology,
University Teknikal Malaysia Melaka,76100, Durian Tunggal, Melaka, Malaysia.

Email:
Nooririnah@utem.edu.my,rohana_abdullah@utem.edu.my,azwar@utem.edu.my,nuzaimah@utem.edu.my

ABSTRACT

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 increase confident level of user. Malaysia forecast to become regional maintenance, repairing and overhaul (MRO) hub to be worth US$65 billion by 2020.Corrosion treatment is one of the MRO services that utmost concern in the aircraft industry. Many techniques been used to control corrosion in aviation industry ; grease, application of advanced composite material, DOW 17 process and thermal spray. DOW 17 process issued with OSHA and thermal spray technology will create internal stress lead to fatigue failure due to application of heat on aircraft part. There is keen interest to explore potential applications of high pressure cold spray (HPCS) process onto aircraft structure for corrosion treatment. One of the characteristic of cold spray process is creates a negligible heat-affected zone in the as-deposited material and substrate, therefore generating layers that exhibit excellent fatigue characteristics and spray efficiency in HPCS reaching up to 90%. Due to this features, cold spray is potential solution for corrosion treatment to be applied on aircraft part.

Keywords: *Cold Spray, Pitting, HPCS, Reusability, LPCS*

INTRODUCTION

Asia Pacific is now considered a key location for growth potential not only in aviation but in business, tourism, trade and communications. Asia Pacific is predicted to have the second highest fleet growth at 6.6% over the next 10 years. To meet the growth in passenger numbers, the growth in aircraft movement is forecast to be equally significant over the next 20 years [1]. Malaysia ultimately aims to capture at least 5 percent of the global maintenance, repairing and overhaul (MRO) market by 2015, as well as positioning itself to capture substantial aero-structures work packages for next-generation aircraft programmes.Corrosion treatment is one of the MRO services that utmost concern in the aircraft industry. 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 [2]. 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 [2]. The potential for corrosion of aircraft structures is a major consideration in the design of aircraft. Corrosion can be related to various types of material deterioration. Corrosion phenomena often occur on the surface of aircraft structures is 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 [2]. 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 greases to bearings in aircraft control mechanisms, wheel, rudder posts. Other approach is application of advanced composite materials to secondary airframe structures [2]. Sikorsky Aircraft Corporation is a world leader in the design, manufacture and service of military and commercial helicopter. For original equipment manufacturer, OEMs such as Sikorsky, current method to provide corrosion protection to aluminum or magnesium aircraft structure using DOW 17 process or thermal spray technology. DOW 17 process involved with sodium dichromate containing hexavalent chromium that very dangerous in case of skim contact, ingestion and over expose by inhalation may cause respiratory irritation. This will address with occupational safety and health administration, OSHA and on top of this, even with chromoted surface treatment, Al and Mg components suffer severe degradation in service [3]. Issue with thermal spray coating application involved with heat to the substrate, it will build internal stress in substrate that lead to fatigue failure. Cold spray is one of the many names for describing a solid-state coating process that uses a high-speed gas jet to accelerate powder particles toward a substrate whereby metal particles plastically deform and consolidate upon impact. The term "cold spray" refers to the relatively low process temperature involved, which is typically much lower than the melting point of the spray material, commonly less than 500°C. This creates a negligible heat-affected zone in the as-deposited material and substrate, therefore generating layers that exhibit excellent fatigue characteristics. Deposited layers are generally compressive in nature, which is also beneficial for fatigue resistance. Types of CS system are low pressure cold spray, (LPCS) and high pressure cold spray, (HPCS). The spray efficiency in this HPCS system is very high, reaching up to 90% as compared to 50% in LPCS system. Objective of this paper to study high pressure cold spray (HPCS) process as corrosion treatment method for aging aircraft structure.

THEORITICAL OVERVIEW

Cold Spray (CS) is a relatively recent technology which falls under the larger family of thermal spray process and there are different approaches known by different names such as Cold Gas Dynamic Spraying, Kinetic Spraying and Supersonic Particle Deposition (SPD). The concept of cold spraying metallic materials onto substrates goes back to the early 1900s, it was not until the 1980s that the applicability of this technology was demonstrated at the Institute of Theoretical and Applied Mechanics of the Russian Academy of Sciences in Novosibirisk [4].Cold spray is one of the many names for describing a solid-state coating process that uses a high-speed gas jet to accelerate powder particles toward a substrate whereby metal particles plastically deform and consolidate upon impact. Bonding in cold spray process achieved by adhesion of the metal powder to the substrate and deposited material is achieved in the solid state. If the powder particles reach a critical velocity, metallurgical bonding is obtained through adiabatic sheer processes created due to particle plastic deformation on the substrate. The critical velocity is a function of the material properties of both the powder and the substrate, particle size and process conditions [4]. The common phenomena that have been observed during spraying onto various substrates are substrate and particles deformation, and substrate melting as there is evidence for the formation of a metal-jet [5,6].

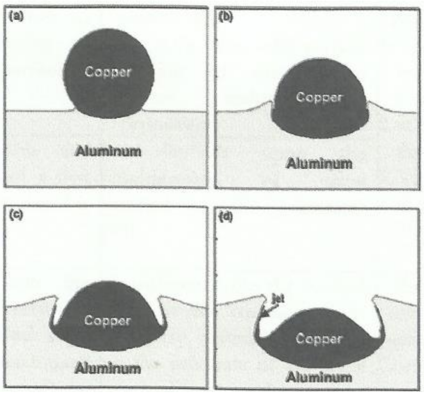

Figure 1: Impact of a Cu particle on a Cu substrate at successive time (a) 5ns, (b) 20ns (c) 35ns, (d) 50 ns [6]

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The characteristics of cold spray deposits are quite unique, making cold spray suitable for depositing a wide range of traditional and advanced materials on many types of substrate materials especially in non-traditional applications that are sensitive to the temperature of the process. Some of the characteristics of cold spray include the ability to form dense deposits with extremely low oxygen content, free of residual tensile stresses, grain growth, re-crystallization zones and phase changes. Certain materials may even experience grain refinement at the nano meter scale[4]. These attributes make cold spray uniquely suitable for depositing a range of advanced and temperature-sensitive materials. Currently, cold spray is increasingly being used in a number of industries including aerospace, energy and military. Cold spray has distinct features over powder spray methods; Materials are deposited at low temperatures, commonly less than 500°C. This creates a negligible heat-affected zone in the as-deposited material and substrate, therefore generating layers that exhibit excellent fatigue characteristics. Deposited layers are generally compressive in nature, which is also beneficial for fatigue resistance. Very thick layers of material, more than 5mm can be deposited using this technique[5].Due to these features, cold spray is an excellent choice for restoring aluminum surfaces for aerospace applications. Cold spray process is a technology in which metal, a fine solid aluminum powders particles generally 1-50µm in diameter are accelerated to velocities in a range between 500-1000 m/s by entrainment in a supersonic jet of compresses gas metal powder particles to impact a solid surface. For low pressure cold spray, LPCS process, utilizes air or nitrogen as a carrier gas with pressure ranging between 80 to 140 psi is also preheated, up to 550°C. Compresses gas of an inlet pressure enters of an inlet pressure and flows through a converging/diverging DeLaval type nozzle to attain a supersonic velocity. The solid powder particles are metered into the gas flow upstream of the converging section of the nozzle and accelerated by the rapidly expanding gas to achieve higher gas flow velocities in the nozzle, the compressed gas is often pre-heated. These droplets then impact in a substrate to give a high yield of a partially solid deposit of controlled shape. This deposit is cooled by the gas stream and solidification is completed at much slower rates than the initial cooling rates in spray. Particle bonding in cold spray process is due to high rate deformation of the particle, adiabatic shear instability and requires high particle velocity > Vcritical []. In high-pressure cold spray system (HPCS), helium or nitrogen at high pressure up to 1,000 psi is preheated up to 1,000°C and then forced through a converging-diverging De Laval nozzle. At the nozzle, the expansion of the gas produces the conversion of enthalpy into kinetic energy, which accelerates the gas flow to supersonic regime 1,000 m/s while reducing its temperature. The powder feedstock is introduced axially into the gas stream, prior to the nozzle throat. The accelerated solid particles impact the substrate with enough kinetic energy to induce mechanical and metallurgical bonding [5].

CASE STUDY

Sikorsky S16A-4, Nuri helicopter currently use for multipurpose transport, carrying troops and humanitarian aid. 30 Nuri helicopter is serviceable in Malaysia. Fitting sponson spar part is one of the Nuri helicopter structure and often the main structural member of the wing, running span wise at right angles to the fuselage. The spar carries loads and the weight of the wing while on the ground. Other structural and forming members such as ribs may be attached to the spar with stressed skin construction also sharing the loads where it is used [6]. Fitting sponson spar Nuri Helicopter is made from aluminum 7075-T6 but failure due to pitting corrosion. To overcome this problem, cold spray process using high pressure cold spray system (HPCS) choose with pressure range between 350-450 psi is pre-heated up to 1000°C to optimize it aerodynamic properties and forced through converging De laval nozzle. At the nozzle, the expansion of the gas produces the conversion of enthalpy into kinetic energy and this accelerates the gas flow to supersonic regime, 1200 m/s while reducing it temperature. The accelerated solid particles, 600-1200m/s impact the substrate with enough energy to induce metallurgical bonding. Coating materials; 6061 aluminum powder of average particle size 45µm was the chosen material to spray onto the part due to its excellent adhesion characteristics, spray efficiency and corrosion properties. On top of that, standoff distance for nozzle spray to substrate is 10 to 25mm. Feed rate for aluminum 6061 powder is 16-17 grams per-minute with gun traverse speed is 40mm per second. Nitrogen was used as the carrier gas for this process. The surface of the sponson spar was prepared by grit blasting methods that using 120 grit aluminum oxide, Al_2O_3. Aluminum thicknesses up to 4mm were deposited onto the part.

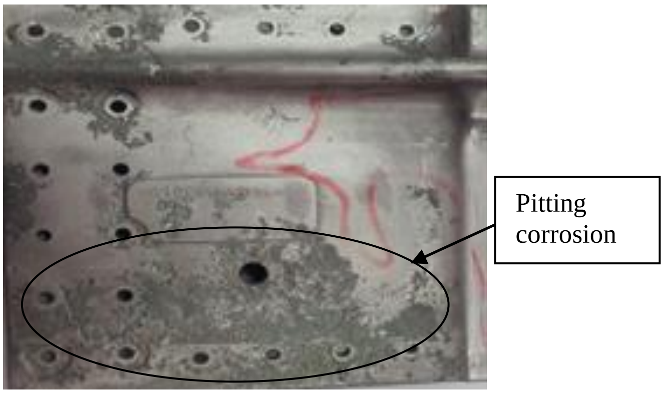

Figure 1: Fitting sponson spar; pitting corrosion, before CS treatment

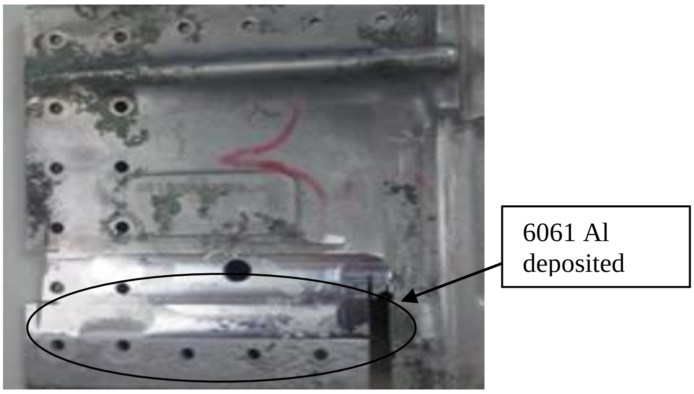

Figure 2: Fitting sponson spar; after CS and machining

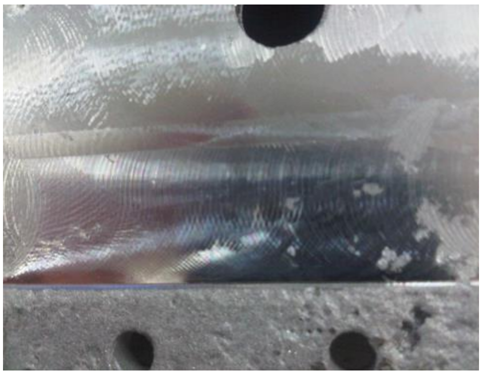

Figure 3: Close up view of machined CS surface

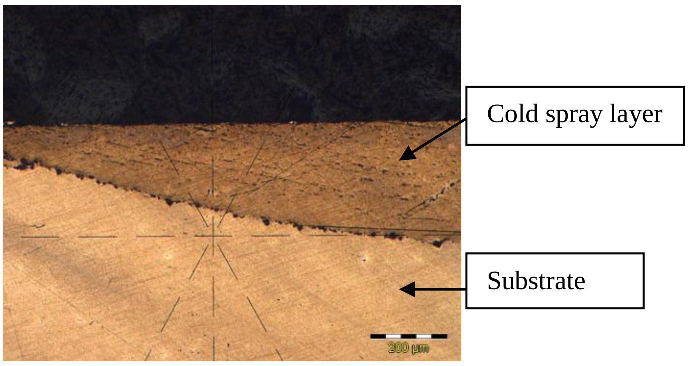

Figure 4: Cross sectional view of the cold sprayed 6061 aluminum deposited on sponson spar.

CONCLUSIONS

Corrosion treatment of aging aircraft part is utmost concern in the aircraft industry because of its potential impact on human safety and increase confident level of end user. High pressure cold spray system can provide cost saving through re-use of part by corrosion treatment process and in-haze environment by saving energy consumption.

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