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High pressure cold spray (hpcs) process as coating treatment for magnesium chassis: an overview

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Abstract: Magnesium, Mg and its alloys have excellent physical and mechanical properties for a number of applications. Mg approximately 35% lighter than aluminum and has exceptional stiffness and damping capacity. Disadvantage of this metal and its alloys are highly susceptible to corrosion, particularly in salt-spray conditions and very susceptible to surface damage due to impact. This paper is an outcome of project to address corrosion problem at Mg chasis part in walkie talkie radio using cold spray technique. Current practise of corrosion treatment for Mg chassis structure is using organic coating contains no heavy metals, fluorides with no effect on the alloy composition upon recycling. Disadvantage of this technique is galvanic corrosion at Mg chassis part after 48hrs of salt spray testing and dull finishing. There is keen interest to explore potential applications of high pressure cold spray (HPCS) process onto Mg 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 Mg chassis structure.

Introduction

Two-Way Radios are designed to provide affordable and dependable communication, ideal for the outdoor enthusiast, oil and gas field and etc. Radios work in remote areas, are rugged and convenient to use and provide instant access without using our cell phone. This phenomena required robustness structure and radio able to be use and still could survive to function regardless under which severe environments it would be. Chassis structure can full fill this requirement. On top of that, weight also is another concern for radio structure. Magnesium is the 8th most abundant element on the earth making up approximately 1.93% by mass of the earth's crust and 0.13% by mass of the oceans [1]. It also has some advantageous properties that make it an excellent choice for a number of applications. Magnesium has a high strength: weight ratio with a density that is only 2/3 that of aluminum and 1/4 that of iron. Magnesium also has high thermal conductivity, high dimensional stability, good electromagnetic shielding characteristics, high damping characteristics, good machinability and is easily recycled [1]. These properties make it valuable in a number of applications including automobile and computer parts, aerospace components, mobile phones, sporting goods, handheld tools and household equipment. Magnesium has even been suggested for use as an implant metal due to its low weight and inherent biocompatibility [2].

Unfortunately, magnesium has a number of undesirable properties including poor corrosion and wear resistance, poor creep resistance and high chemical reactivity that have hindered its widespread use in many applications. One of the main challenges in the use of magnesium, particularly for outdoor applications, is its poor corrosion resistance. Magnesium and its alloys are extremely susceptible to galvanic corrosion, which can cause severe pitting in the metal resulting in decreased mechanical stability and an unattractive appearance. Corrosion can be minimized by the use of high purity alloys that maintain heavy metal impurities such as iron, nickel and copper below a threshold value. The elimination of bad design, flux inclusions, surface contamination, galvanic couples and inadequate or incorrectly applied surface protection schemes can also significantly decrease the corrosion rate of magnesium alloys in service [3]. One of the most effective ways to prevent corrosion is to coat the base material. Coatings can protect a substrate by providing a barrier between the metal and its environment or through the presence of corrosion inhibiting chemicals in them. In order for a coating to provide adequate corrosion protection, the coating must be uniform, well adhered, pore free and self-healing for applications where physical damage to the coating may occur. One of the problems with magnesium is its chemical reactivity. As soon as it comes in contact with air or water an oxide/hydroxide layer forms on the surface which can have a detrimental effect on coating adhesion and uniformity. Thus, the pre- cleaning process plays a critical role in the development of a good protective coating on magnesium and its alloys. An organic conversion coating is designed for Mg chassis [4]. This organic coating contains no heavy metals, fluorides with no effect on the alloy composition upon recycling. On top of that, no acid for etching process involve and it is a simple process at waste disposal. Coating shall at least be able to withstand 48hrs Salt spray test in accordance to ASTM B117. Apart from that, it must be conductive coating for EMI shielding as well as for grounding purpose. The coating hardness is just another needs so as to ensure the coating is able to withstand minimum 6.5K cyclic test, this is to simulate the battery latching in and out during application by users. Problem with this type of coating is galvanic corrosion at Mg metal part after 48hrs of salt spray test and dull finishing. Objective of this paper to introduce High pressure cold spray as alternative coating process for Mg chassis part.

Theoritical overview

Cold spray as a coating technology initially developed in the mid1980s at the Institute of Theoretical and Applied Mechanics of the Russian Academy of Sciences in Novosibirisk. The Russians scientist successfully deposited a wide range of pure metals, metallic alloys, polymers and composites onto a variety of substrate materials and they demonstrated that very high coating deposition rates are attainable using the cold spray process [5]. Cold spray is 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. The term 'cold spray' has been used to describe this process due to relatively low temperature (-100 to +100°C) of the expanded gas stream that exits the nozzle. The temperature of the gas stream is always below the melting point of the particulate material during cold spray and the resultant coating and freestanding structure is formed in the solid state. Since adhesion of the metal powder to the substrate as well as the cohesion of the deposited material is accomplished in the solid state, the characteristics of the cold spray deposit are unique because particle oxidation is avoided and cold spray produces coatings that are more durable with better bond strength. The range of operation for cold spray process fall into two type; Low pressure cold spray (LPCS) and High pressure cold spray (HPCS). The principal differences separating this two systems are gas pressure and powder flow rates. 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 [5]. 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

Mg AZ91D is Chassis structure for two way radio. Chassis is needed to support the radio structure strength in the field application. Several mechanical testing will be conducted to make sure radio able to be use and still could survive to function regardless under which severe environment it would be; 6 planes drop test at certain height (normally 1.5metres), ball drop test, temperature cyclic test and salt spray test. This for robustness verification purpose.

When the severe environments come into picture, a robust coating to coat the chassis is required. It shall at least be able to withstand 48hrs Salt spray testing in accordance to ASTM B117. Apart from that, it must be conductive coating for EMI shielding as well as for grounding purpose. The coating hardness is just another needs so as to ensure the coating is able to withstand Minimum 6.5K cyclic test (abrasion test by using steel wool). This is to simulate the battery latching in and out during application by users.

Optimum conditions for coating Mg components with CP Aluminium powder by cold spray techniques is stationary system with standard nozzle using helium gas. Pressure is 2.74MPa with temperature reach 250°C. Gas flow rate is 122 m^3/ hour with powder feed rate is 3g/minute with particle mass mean diameter is 20µm. Stand-off distance is 25 mm. Expected Adhesion strength range CP-Al deposited by cold spray process is 18-20 MPa.

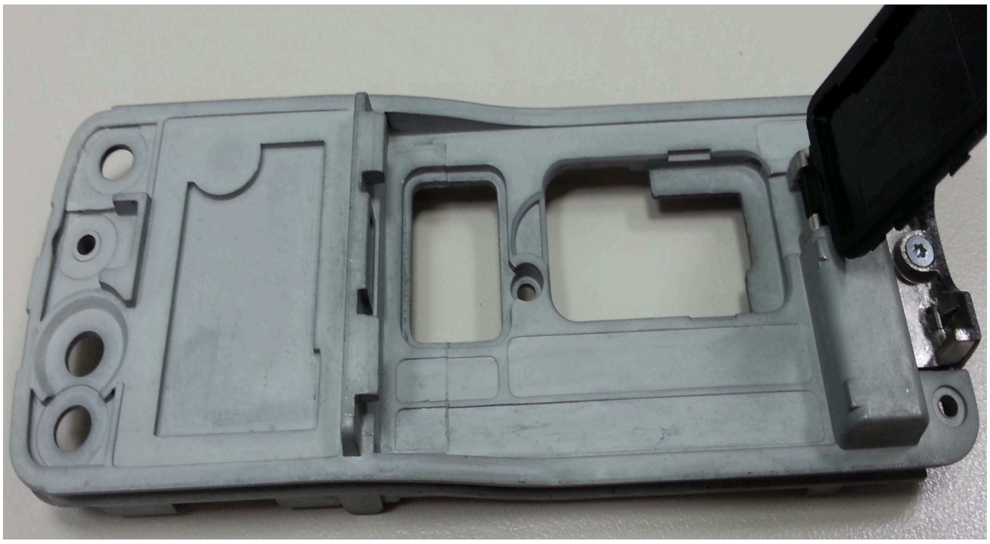

Figure 1: Mg AZ91D chassis for two way radio

Conclusions

One of the most effective ways to prevent corrosion for Mg chassis is to coat the base material and Cold spray is one of the alternative process for coating purpose. Deposited Aluminium powder with particle mean size 20µm using cold spray technique to overcome corrosion problem of Mg chassis was successful.

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