A STUDY OF THE MICROSTRUCTURE PROPERTIES OF COLD SPRAYED 6061 AL ON 7075-T6 ALUMINUM

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Faculty of Mechanical and Manufacturing Engineering Technology

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DECLARATION

I declare that this project entitled "A study of Microstructure Properties Of Cold Spray 6061 AL on 7075-T6 Aluminum" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Logentharan a/l Ganasan

Date : 19/01/2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

Signature :

Supervisor Name : Dr. Noor Irinah Binti Omar

Date : 19.1.2023

DEDICATION

This dissertation is dedicated to my beloved parents, my supervisor Dr. Noor Irinah Binti Omar and to those who are unwavering affection, guidance and encouragement have enriched my soul and driven me to undertake and complete this work.

ABSTRACT

Deposits are created in the cold spray (CS) process by depositing powder particles at high velocity onto a substrate. CS-deposited powders do not melt before or after contacting the substrate. Because of this property, CS is useful for the deposition of a wide range of materials, most notably metallic alloys, but also ceramics and composites. The particles undergo extreme plastic deformation during processing, resulting in a stronger mechanical and less metallurgical connection with the underlying material. An individual particle's deformation behaviour is determined by a number of material and process factors, which are categorised into three broad groups: powder properties, geometric parameters, and processing parameters, each having their own subcategories. Changing any of these factors causes the microstructure to evolve and, as a result, the mechanical characteristics of the deposit to vary. While cold spray technology has advanced over the last decade, the process is intrinsically complicated, thus the effects of deposition parameters on particle deformation, deposit microstructure, and mechanical characteristics are yet unknown. The goal of this research is to investigate the microstructure characteristics of cold sprayed 6061 Al on 7075-T6 aluminium. The resistance, physical, and microstructure characteristics of 7075 Al-T6 are affected by factors such as coating temperature, pressure, coating thickness, and particle size. In this study, there is FIVE Testings have been carried out which are Scanning Electron Microscope analysis (SEM), Energy Dispersive X-Ray Spectroscopy (EDX), Tensile strength testing, Microhardness testing and Transmission Electron Microscopy (TEM) testing are used to assess the effectiveness of the CS coating process.

ABSTRAK

Deposit dicipta dalam proses semburan sejuk (CS) dengan mendepositkan zarah serbuk pada halaju tinggi ke atas substrat. Serbuk yang didepositkan CS tidak cair sebelum atau selepas menyentuh substrat. Disebabkan sifat ini, CS berguna untuk pemendapan pelbagai bahan, terutamanya aloi logam, tetapi juga seramik dan komposit. Zarah mengalami ubah bentuk plastik yang melampau semasa pemprosesan, menghasilkan sambungan mekanikal dan kurang metalurgi yang lebih kuat dengan bahan asas. Tingkah laku ubah bentuk zarah individu ditentukan oleh beberapa faktor bahan dan proses, yang dikategorikan kepada tiga kumpulan luas: sifat serbuk, parameter geometri dan parameter pemprosesan, masing-masing mempunyai subkategori mereka sendiri. Mengubah mana-mana faktor ini menyebabkan struktur mikro berkembang dan, akibatnya, ciri mekanikal deposit berubah. Walaupun teknologi semburan sejuk telah maju sejak sedekad yang lalu, proses ini secara intrinsik rumit, oleh itu kesan parameter pemendapan pada ubah bentuk zarah, struktur mikro deposit, dan ciri mekanikal masih belum diketahui. Matlamat penyelidikan ini adalah untuk menyiasat ciri-ciri mikrostruktur semburan sejuk 6061 Al pada aluminium 7075-T6. Ciri rintangan, fizikal, dan mikrostruktur 7075 Al-T6 dipengaruhi oleh faktor seperti suhu salutan, tekanan, ketebalan salutan, dan saiz zarah. Dalam kajian ini, terdapat LIMA Ujian telah dijalankan iaitu analisis Mikroskop Elektron Imbasan (SEM), Spektroskopi X-Ray Penyebaran Tenaga (EDX), ujian kekuatan tegangan, ujian Microhardness dan ujian Transmission Electron Microscopy (TEM) digunakan untuk menilai keberkesanan proses salutan CS.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

SEM	-	Scanning Electron Microscope Analysis
EDX	-	Energy Dispersive X-Ray Spectroscopy
TEM	-	Transmission Electron Microscopy
CGDS	-	Cold Gas Dynamic Spray
HPCS	-	High Pressure Cold Spray
LPCS	-	Low Pressure Cold Spray
ASTM	-	American Society for Testing and Material
NHT	-	Non Heat-Treatable
HT	-	Heat-Treatable
kV	-	Kilo Volt
HV	-	Vickers Pyramid Number
PSI	-	Pound per Square Inch
kN	-	Kilo Newton
GPa	-	Gigapasccal
MPa	-	Megapascal
Al	-	Aluminium
C	-	Carbon
O	-	Oxygen
CNC	-	Computer Numerical Control
HVOF	-	High Velocity Oxyfuel
CS	-	Cold Spray
Ø	-	Diameter
%	-	Percentage
σ	-	Stress
ε	-	Strain
K	-	Kelvin
Mg	-	Magnesium
Zn	-	Zinc

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

The cold gas dynamic spray (CGDS) technique is commonly referred to as 'Cold Spray.' Dr. Anatolii Papyrin and his colleagues in Novosibirsk, Russia, invented it in the mid-1980s (Papyrin et al. 2006). This cold spray procedure is ideal for applications where high-temperature spraying processes such as plasma, arc, flame, and HVOF (High Velocity OxyFuel) spray are ineffective due to concerns such as oxidation, coating porosity, and low adherence (Srikanth & Bolleddu, 2020).

Cold Sprayed Coating comes in two types. The first is high-pressure cold spray coatings, in which powder particles are injected into the throat of the spraying nozzle from a high pressurised gas supply, resulting in particle velocities of 800–1400 m/s. For high-pressure cold spray coatings, helium or nitrogen are the recommended propellant gases. The second type of coating is low-pressure cold spray coatings, which involve injecting powder particles from a lower pressurised gas through the diverging section of the spraying nozzle.

A high-pressure supersonic gas jet is used in the CS process to accelerate fine powder particles to or above a critical velocity (500–1200 m/s) for coating deposition. The kinetic energy released by the particle upon impact with the substrate ruptures any surface oxides and plastically deforms the particle as it approaches the clean surface of the substrate, promoting coating bonding (Singh et al., 2021).

A CS coating is formed in two steps: (i) initial particle-substrate contact, followed by (ii) particle-particle interactions. Bonding/adhesion is achieved at the interface of the substrate and the first layer of particles in the first step, followed by the formation of subsequent layers by particle-particle interactions (Singh et al., 2021). Layer-by-layer formations create thick coatings.

The existence of residual stress in the coating and near the coating/substrate interface can influence the mechanical performance of CS deposits, as it does in all thermal spray processes. In the case of HPCS, SPD creates residual stress in the CS deposition, and microscopic evaluation of the residual stress profile (on a particle size) is difficult and needs understanding of various deposition process features, such as non-uniform local deformation and recrystallization. The particles deposited by cold spraying distort initially on collision, resulting in adhesion to deposited particles, followed by subsequent deformation produced by the impacts of incoming particles, resulting in a tamping action. This mechanism explains why the coatings are dense and compact. (Rokni et al., 2017)

1.2 Problem Statement

Fitting sponson spar is often the main structural member of the wing, running span wise at right angles to the fuselage of Nuri Helicopter. 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 spars, with stressed skin construction also sharing the loads where it is used (Bruce,2006). Fitting sponson spar Nuri helicopter is made from aluminium 7075-T6 but premature failure due to corrosion is one of the main challenges associated with this alloy and the most common effect of corrosion on aluminium alloys is called pitting. It is first noticeable as a white or grey powder deposit, like dust, which blotches the surface (Noor irinah, 2012). Beside corrosion problem, structural restoration that involved mechanical and microstructure properties also another problem to be considered. To date, there has been no detailed investigation of application high pressure cold spray process as dimensional restoration for Malaysian aging aircraft in term of microstructure properties toward adhesion bonding mechanism.

1.3 Research Objective

The main objectives for this project are:

1. To investigate microstructure properties of 7075-T6 cold sprayed 6061Al via Scanning Electron Microscopy (SEM-EDX).

2. To study the correlation between microstructure properties and adhesion bonding mechanism of cold sprayed 6061 Al on 7075-T6 Al substrate.

1.4 Scope of Research

The scope of this research is shown in figure 1 below. The objectives of this research to investigate the microstructure properties of cold sprayed 6061-Al powder on 7075-T6 substrate and to relate the properties with bonding mechanism involved. The scope of this project is to study the properties of sample after undergo cold spray treatment. Aging aircraft part (Fitting sponson spar of Nuri Helicopter) is used as a sample in this project. It is made from Aluminium 7075-T6 but premature failure due to corrosion effect. Besides corrosion, dimensional restroration that involved mechanical and microstructure properties also another problem to be considered. Therefore, the substrate will be coated by using High Pressure Cold Spay (HPCS) process whereby, Aluminium 6061 powder (Valimet 6061 Al) is deposited onto the surface of the substrate. In this process, powder feestock material (Valimet 6061) with nominal particle size 3 microns is injected into the gas stream and accelerated towards the substrate (Al 7075-T6).

In general, this work study is more focused on the characterization and measurement of the sample after the CS process. The evaluation of this research is based on five standard tests which are Scanning Electron Microscope analysis (SEM), Energy Dispersive X-Ray Spectroscopy (EDX), Tensile strength testing, Microhardness testing, Transmission Electron Microscope (TEM). All the tests are a fundamental of material testings. Hence, the result from the test are commonly used for quality control and used to predict how the material will react under these type of many condition such as forces.

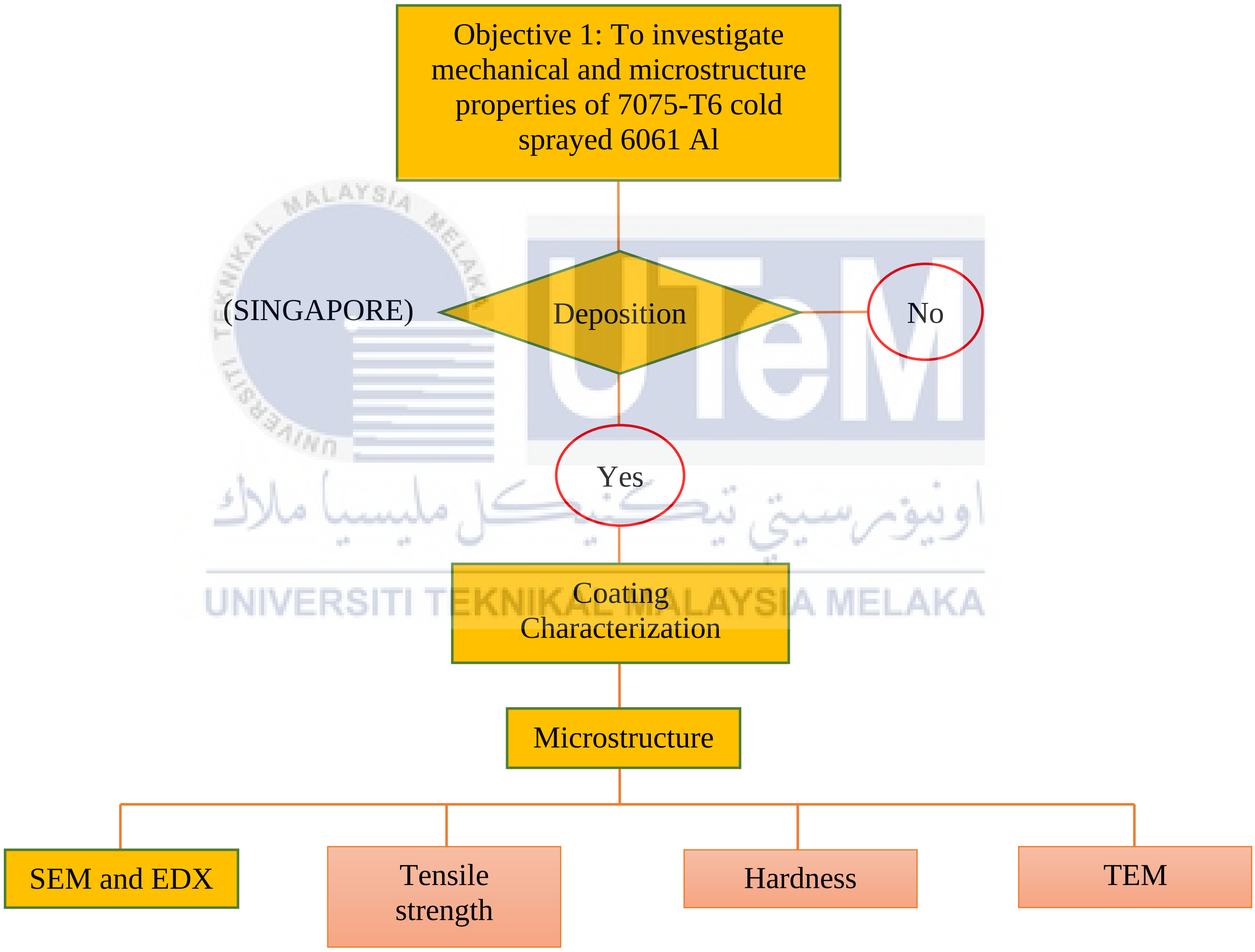

Figure 1: Project Work scope

1.5 Conclusion

This chapter covers the research background, problem statement, objectives and scope of the research. The following chapter will consist review of main theories and describe previous works related to this research.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a review of the concept of microstructure properties of 7075-T6 cold sprayed on 6061 aluminium by using high pressure cold spray process. This chapter will also include the information about parameter involves to be exposed to the concepts and theories. The main sources of information are taken from books and journal articles. Each source was selected based on the similarity with the scope of study. The elements will be narrowed down to the analysis of the characterization and measurement of coating specimen.

2.1 Cold spray process

In this chapter, the basic principle, invention of cold spray technology and advantages of cold spray system will be explained to give some practical information on technologies and equipment's as well as to present the current state of the research and development in this field.

2.1.1 Introduction

Cold spraying, CS is becoming increasingly important due to its superior qualities over other thermal spraying methods such as flame spray, plasma spray, HVOF, and arc spraying, among others. The fundamental distinction between cold spraying and other methods is that it uses kinetic energy rather than thermal energy for powder deposition, and the operating temperature is always kept below the melting point of the powder particles (Srikanth & Thalib Basha G A, Venkateshwarlu, 2019).

The cold spray procedure is also known as solid-state coating deposition because the powder particles remain solid throughout coating deposition, eliminating the production of defects due to thermal distortion. Temperatures in this method are typically below 8000 °C, although temperatures in other thermal spraying processes can occasionally exceed 20000 °C. The impingement velocity of the powder particles on the substrate, on the other hand, is about more than 1200 m/s. Cold spray is preferred for depositing materials with lower heat capabilities, are softer, and are oxygen sensitive, such as copper, aluminium, and titanium. This approach can reduce oxidation, coating porosity, phase transitions, heat affected zone (HAZ) development, and thermal residual stresses, all of which are significant issues in traditional thermal spray coating procedures. This cold spray method may also deposit highly dense and thick coatings with thicknesses ranging from 100 m to 1500 m (Srikanth & Thalib Basha G A, Venkateshwarlu, 2019).

The cold spray procedure is employed not only for coating deposition, but also for crucial component maintenance. Thus, it is currently establishing itself as an alternative solution for difficult part repair, particularly in the aerospace, defence, and turbine industries. This process has the potential to outperform conventional technologies such as 3D printing, welding, and electro plating. The main benefits of using cold spray as a repairing solution are: (i) improved fatigue properties of the base metal, (ii) residual compressive stresses in the materials, which can prevent cracking from starting, (iii) worn out workpieces can be repaired by same deposition process and placed in the same position, (iv) on-site repairing is possible with the portable cold spray system, and (v) higher coating deposition quality (Srikanth & Thalib Basha G A, Venkateshwarlu, 2019).

As this process continues a uniform layer with little porosity and high bond strength is obtained as the particles continue to impact the substrate and a bond with the material stored has formed. The term ‘cold spray’ was used to describe this process as relatively low temperature gas flow to grow around the nozzle. In other term, it is referred to the temperature that is always lower than melting point of the material during acceleration of powder particles by the supersonic gas jet. Figure 2.1 shows the schematic diagram of cold spray process.

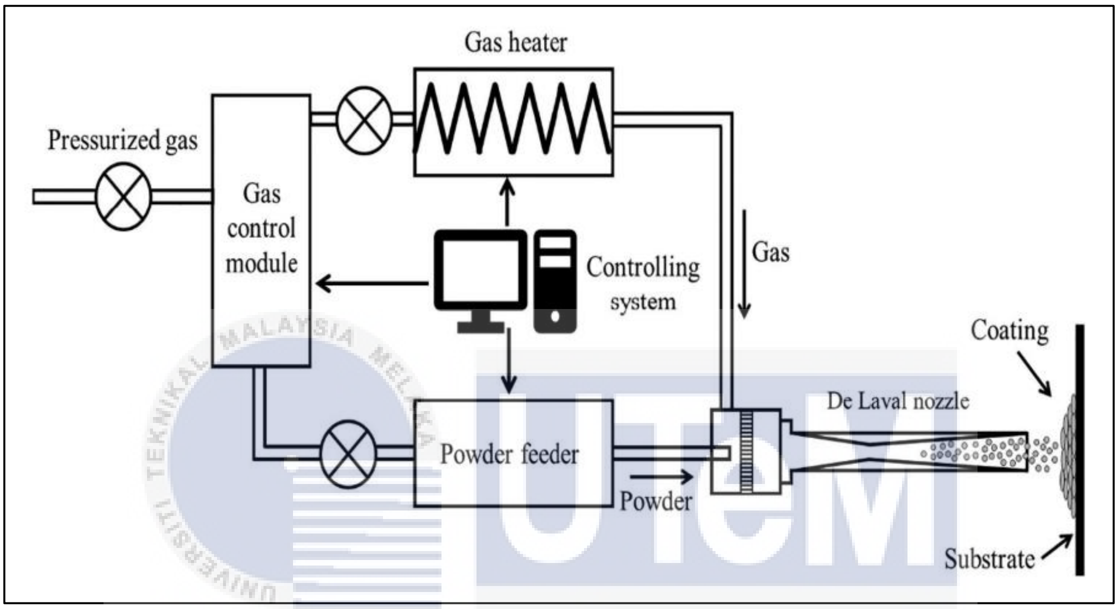

Figure 2.1: Schematic Diagram of Cold Spray Process
(Srikanth & Thalib Basha G A, Venkateshwarlu, 2019)

Like other materials processing technique, cold spray process also has its own advantages and limitations. The primary advantage of the cold spray process over traditional thermal techniques that rely on a variety of processes like laser, electron beam, plasma, or electric arc) to melt and/or soften feedstock had something to deposition is that consolidation happens in the solid state. The powder particles blasted during the cold spray process remain reasonably cool, below the melting temperature, eliminating oxide contamination, microstructure changes, and tensile stress accumulation.