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Revolutionizing Technology Adoption for the Remanufacturing Industry

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Abstract

Remanufacturing serves as a key enabler for sustainable manufacturing, by closing the loop of material flow and increasing the efficiency of material usage. However, high labour intensity and inconsistency in remanufactured parts' quality remain vital issues to address in order to increase the remanufacturing uptake across different industry sectors. This paper presents the use of advanced manufacturing techniques for the development of remanufacturing applications. The on-going world-wide 4th Industrial revolution, related to the deployment of cyber-physical systems in industries, will be discussed in relation to its impact, opportunities and challenges for remanufacturing industries.

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1. Introduction

Remanufacturing is the process of returning a product to a serviceable condition, through the steps of disassembly, cleaning, inspection, restoration and reassembly. Often a warranty is offered to provide the customer reassurance as to the quality of the remanufactured product [1]. Remanufacturing is considered one of the key enablers for sustainable manufacturing and key strategies within circular economy, by closing the loop of material flow, reducing energy use and waste disposal [2]. It is particularly attractive for industries that produce high-value and durable products, such as aerospace, Heavy-Duty Off-Road (HDOR) vehicles, automotive parts, machinery and Information and Communications Technology products.

Remanufacturing is rising in the Asia-Pacific region and has been discussed in Asia-Pacific Economic Cooperation (APEC) meetings since 2006. Eleven economies including Australia, Brunei Darussalam, Canada, Japan, Korea, Malaysia, New Zealand, Philippines, Singapore, Chinese Taipei and the United States have committed not to apply measures specifically concerning used goods or remanufactured goods, and are fully participating in the pathfinder initiative to facilitate the trade of remanufactured goods between Asia-Pacific economies [3]. The rise of remanufacturing would potentially bring greater investment opportunities, create highly skilled jobs and promote green growth in the Asia-Pacific region. Besides an open policy for trading of remanufactured goods, remanufacturing would not be sustainable without effective business models, proactive design for remanufacturing and strong technology support. Studies show that remanufacturing is still challenged by low customer recognition, lack of volume /availability of 'cores', low consistency of remanufactured parts quality and high labour costs, which have limited the uptake of remanufacturing across various industries [4].

To tackle some of these concerns, this paper will present the use of advanced manufacturing technologies for development of remanufacturing applications. The parallel introduction of new digital technologies, to prepare remanufacturing for the upcoming Industry 4.0 trend, is also introduced. The impact, opportunities and challenges associated with this industrial revolution will be discussed in this paper.

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2. Advancing Manufacturing Techniques for Application in Remanufacturing Operations

Singapore has developed significant industrial sectors related to Maintenance, Repair & Overhaul (MRO) within high value added industries such as aerospace, marine and oil & gas. Over the years, experience in remanufacturing has been gathered, which provides a fertile ground for bridging technological gaps in remanufacturing. To bring remanufacturing into large scale, transforming best-in-class competencies, capabilities and innovations into high value added customer solutions for companies in the remanufacturing and manufacturing industries become one of the key strategies. Examples of the technology solutions that could be utilized for remanufacturing operations are illustrated as follows:

2.1 Laser Metal Deposition (LMD)

Laser metal deposition is the process of using a laser beam to melt metal filler wire or powder and form a deposit fusion-bonded on a metallic substrate with controlled heat input. A wide-range of materials including titanium, nickel, cobalt and steel alloys can be deposited onto a substrate to create a brand new feature, to restore worn surfaces or to apply material to clad a specific area of a component. The equipment is computerized, thus all movements and parameters are numerically controlled, to ensure the precision and accuracy of the deposition process. The technique lends itself extremely well to applications within the aerospace, machinery, marine and oil & gas sectors. One prominent application is to employ LMD for repairing high-pressure compressor blades in aircraft engines.

Employing the LMD process opens new technological opportunities for repairing components which were considered non-repairable by conventional high heat input methods and could achieve up to 50-70% cost saving compared to the cost of a new component.

Novel technology developments include the combination of LMD with conventional machining processes in the same machine, creating a hybrid additive-subtractive process which allows material to be added and removed in a single set up, leading to greater flexibility and savings in terms of time and cost [5].

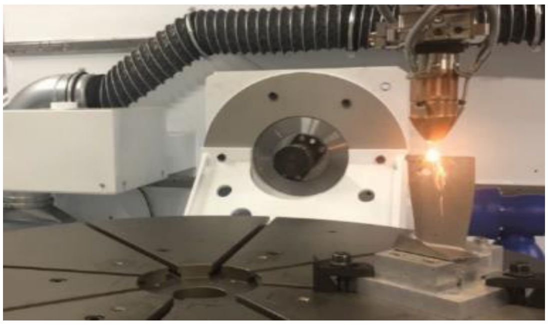

Figure 1: LMD for blade tip repair.

2.2 Robotic High Pressure Cold Spray (HPCS)

Conventional thermal spray processes have been used for many years for the restoration of surfaces on worn components. However, the use of such processes was limited due to the inherent high heat input, which introduced residual stress in the coatings and limiting the thicknesses that can be attained. Cold spray is a high kinetic energy coating processes which addresses the issue of high heat input [6]. During the cold spray process, powder particles, typically in the size range of 10 to 50 µm, were accelerated to very high velocities (200 to 1000 m/s) by a supersonic compressed gas jet at temperatures well below their melting point. Upon impact with the substrate, the particles deformed, creating an adiabatic shear instability bonded coating. As the particles remain in the solid state and are relatively cold, they impart little oxidation to the substrate material. Meanwhile, low temperature also resulted in compressive residual stress, low porosity and little thermal degradation of the coating and substrate materials, which are all desirable characteristics that cannot be achieved using thermal coating processes.

Recent development looked at repair and manufacturing applications using a robotized cold spray cell equipped with a 6 Axis Robot and Turn-tilt table, to address complex part repair requirements, such as cast iron cylinder heads or aluminium mould tools repair [7].

Figure 2: Cold spray with 6 Axis robot and turn-tilt table [7]