Chapter 10
Laser Additive Manufacturing in Surface Modification of Metals

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ABSTRACT

Additive Manufacturing (AM) offers lots of advantages when compared to other manufacturing processes, such as high flexibility and ability to produce complex parts directly from the Three Dimensional (3D) Computer-Aided Design (CAD) model. Producing highly complex parts using traditional manufacturing processes is difficult, and it requires it to be broken down into smaller parts, which consumes lots of materials and time. If this part needs to have a surface with improved property or a surface made of composite materials, it has to be done by employing another manufacturing process after the parts are completed. AM, on the other hand, has the ability to produce parts with the required surface property in a single manufacturing run. Out of all the AM technologies, Laser Additive Manufacturing (LAM) is the most commonly used technique, especially for metal processing. LAM uses the coherent and collimated properties of the laser beam to fuse, melt, or cut materials according to the profile generated from the CAD image of the part being made. Some of the LAM techniques and their mode of operations are highlighted in this chapter. The capabilities of using LAM for surface modification of metals are also presented in this chapter. A specific example is given as a case study for the surface modification of titanium alloy (Ti6Al4V) with Ti6Al4V/TiC composite using laser material deposition process – an important LAM technology. Ti6Al4V is an important aerospace alloy, and it is also used as medical implants because of its corrosion resistance property and its biocompatibility.

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INTRODUCTION

Additive Manufacturing (AM) is also referred to as 3D printing technology according to the international standard organization (ISO) F42 committee on AM standard (Scott et al., 2012). AM is defined as a layer by layer fabrication method of producing parts directly from the CAD model of the part being produced. Additive manufacturing is a revolutionary (Mahamood et al., 2013a) and a promising technology especially for the aerospace industry because of it flexibility and its capability of reducing the buy-to-fly ratio (Allen, 2006; Richter et al., 2004). Buy-to-fly ratio is the ratio of weight of the raw material bought for the manufacturing of a part, to the weight of the final component produced. The difference in these sizes has gone into scrap. In some aerospace parts, the buy-to-fly ratio can be as high as 80% (Bryant et al., 2012; Mahamood et al., 2013b), that means, only about 20% of the material invested made it to the final part produced which is responsible for the high cost of the airplanes.

For a technology that is able to reverse this trend by reducing the buy-to-fly ratio to about 20% or less is very promising and AM technology can do just that. AM can achieve this objective in two different ways, namely 1) The ability to produce complex part in one single step by adding materials layer by layer, as against removing material that later become scrap in the traditional manufacturing methods. 2) Less materials are used up during the material processing. This is because, assembly of smaller parts is eliminated in additive manufacturing method and the overall weight of the component becomes lighter as a result of the extra weight from bolt, nut, rivets etc. that are eliminated. This weight saving comes with two advantages: reduced material cost and reduced running cost in terms of routine maintenance, energy saving (especially in the aerospace industry) and reduction of carbon foot print. AM technology can be referred to as a ‘green’ technology because it uses less energy intensive processes (Lewis, 2012).

Additive manufacturing technologies are classified based on the energy system used, which are laser based system or non-laser based system. Laser based additive manufacturing system is the most popular additive manufacturing technologies (Wohlers, 2012). They took the advantage of the highly coherent characteristics of laser beam that makes it possible to produce a very fine detail part with intricate shapes, and with minimum dilution as well as with minimum heat affected zone. LAM technologies are capable of producing composite materials which are useful in various applications such as aerospace, defense, and medicine. In traditional manufacturing process or processes, when parts that required improved surface properties need to be produced, the parts are first made in a separate manufacturing process, and the surface modifications are done in another manufacturing process. The case is different with LAM technology because, part with the required surface properties can be produced in one manufacturing run which can be programmed at the onset of production process.

This chapter presents a brief review of additive manufacturing. Some laser additive manufacturing technologies that are used in the production of metallic parts with improved surface and surface made of composite material to improve the surface property of the parts are explained. Ti6Al4V, an important aerospace material, is briefly reviewed and why it requires surface modification for applications demanding better wear performance behaviour is also explained. A section is devoted to a research work conducted on surface modification performed on a Ti6Al4V substrate with Ti6Al4V/TiC composite using laser material deposition (LMD) process, a laser additive manufacturing technique. The chapter ends with concluding remarks.