Chapter 3

Recent Advancements in Customized Investment Castings Through Additive Manufacturing:

Implication of Additive Manufacturing in Investment Casting

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ABSTRACT

Conventional investment casting (IC) has suffered from numerous limitations such as rigidity of the process, longer production cycles, higher tooling cost, and waste during different manufacturing stages. With the invent of additive manufacturing (AM) technologies, it is now possible to overcome the aforesaid issues along with additional benefits in terms of comparatively better quality characteristics of the resulting castings. The collaboration of AM and IC provided numerous avenues, specifically in biomedical, aerospace, and automobile sectors. AM technologies supported the IC process both in direct and indirect ways where these systems can be used for both job and mass production applications, respectively. In the chapter, the author will try to discuss the assistance of AM process to IC in detail. Each and every step to be followed will be supported with the practical findings, either by the contributing author or published somewhere else. Moreover, some of the case studies will be discussed in detail to highlight the practical importance of the duo.

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INTRODUCTION

The casting industry is a vital segment of the manufacturing sector which produces intricate parts, blends, internal features and varying thickness with excellent surface finish with negligible metallurgical limitations, (Pal et al., 2002). In this today's manufacturing era, we rely on conventional investment casting (IC) process for hundreds and thousands of objects that we need for various end user applications. This method of casting is one of the most ever-present manufacturing processes we are utilizing, since 300 BC, before our civilization. The ancient expertise in casting resided among several cultures such as Mesopotamians, Egyptians, Chinese, Thai and Indians (Greer, 2008). However, the basic principles of IC can be traced back to 5000 BC when the early-men employed this method to produce rudimentary tools (Taylor, 1983), followed by jewellery and artistic products (Träger & Bührig-Polaczek, 2002), and the development of aerospace and subsequently engineering components during the 2nd world war (Barnett, 1988). The IC process, often known as lost-wax or precision casting process, is one of the manufacturing processes that have capability to produce high accuracy, intricate shapes and fine impression with tight geometrical tolerance. This is an alternative approach to produce parts that are hard to machine (Singh & Singh, 2016). IC process has numerous applications that includes agricultural equipments, automobile components, aircraft engines, air frames, fuel systems, computer hardware, electrical equipment, electronic hardware and radar, making jewellery, statues and art castings, dentistry and dental tools, prosthetics, guns and armament, hand tools, machine tool components etc. (Pattnaik et al., 2014). The working procedure of conventional IC process is given in Figure 1. The first step of IC process: (a) the injection of molten wax (at about 150°C) inside the precisely machined metallic die (usually split one) with help of an injection machine; (b) patterns are then safely ejected out of the metal cavity; (c) patterns let for strengthening in air conditioned environment so that the geometrical dimensions get fixed, afterwards, the pattern is assembled with another wax assembly that consisted of pouring sprue, runner and gate as integral parts; (d) this tree like structure is dipped into clay and stucco coatings are performed repeatedly to get the required mould is attained (e); (f) de-waxing is carried out to create a hollow cavity; (g) baked to increase hot strength; (h) molten metal is poured into the cavity and part is separated from the tree once solidify and (i) finally the refractory layers are removed on pneumatic vibration system (Singh & Singh, 2013, 2016). The key requirements of an investment casting mould are (Jones & Yuan, 2013): sufficient green (unfired) strength, sufficient fired strength, sufficiently weak to prevent hot-tearing, high thermal shock resistance, high chemical stability, and low reactivity with the metals, sufficient mould permeability and thermal conductivity, low thermal expansion to limit dimensional changes.

Problems associated with ceramic shell materials have been exacerbated following the introduction of the Environmental Protection Act (Jones & Yuan, 2013), wherein fix degree of emissions allowed and this has boosted the use of water-based shells within industry. Moreover, improvements in the quality, reduction in manufacturing costs and explores new markets for the process are the hot topics amongst current research area. Along with this, numerous tools and software are currently being used for the optimization of the mechanical and physical properties at various stages of the casting. The troubles like: long lead time and high tooling costs for low-volume IC production runs is still present in the conventional process. Wax, as pattern material, is suspect of shrinkage that affects the dimensional and surface features of the casting, and various researches has been carried out to control the shrinkage rate (Taşcıoğlu & Akar, 2003; 2007). However, the critical barrier in prototype development and production time could be easily reduced with the introduction of additive manufacturing (AM) technologies. The AM technologies allowing the designer to work more comfortably with the geometrical complexities,

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