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Ni based powder reconditioning and reuse for LMD process

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Abstract

LMD is an additive manufacturing process based on the injection of metallic powder into a melt-pool created by a heat laser source on a substrate. One of the benefits of this technology is the reduction of the wasted material since it is a near-shape process. Moreover one of the main drawbacks is the relatively low efficiency of the trapped powder, which can be loss than 5% in some cases. The non-trapped powder represents a significant cost in the LMD process, since powder metal material is very expensive and usually is not reused.
This article proposes a methodology of the reconditioning and posterior reuse of a nickel base powder commonly used in the aerospace industry, with the main objectives of cost saving, higher environmental cleanup and increase of the overall efficiency in the LMD process. The results are checked by the development of a prototype part built up from reused powder.

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1. Introduction

The laser metal deposition (LMD) process is based on the injection of a metallic material into a previously melted pool of substrate material. The surface of the part where the material is being deposited is melted by a laser and an external material (usually a powder stream) is deposited and melted together with the base material (Toyserkani et al. 2005). This process allows produce a metallic component layer by layer from a 3D CAE geometry file. Moreover, when a coaxial or multi-jet nozzle is being used to inject metallic powder coaxially to the laser, the geometries created can be almost freely defined. One of the main drawbacks of the process is the trapped powder efficiency. The powder needs to be injected into the melt pool but a high ratio of the particles hits against an

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unmelted area and directly bounces off the deposited area. The efficiency ratio of trapped particles can drop to 40% depending on the configuration and laser spot size (Arrizubieta et al. 2014). Therefore, a relatively high waste of metallic particles is generated in some cases as high as 95% (Carrol 2006).

Taken into account the specific characteristics that metallic powder used in LMD process should provide as size (the typical size of powder recommended for LMD and EBM technologies is located between 50 and 100 to 150 µm), that differentiates it from other additive manufacturing laser processes (powder bed systems), with finer powder particles below 10 to 20, (EPMA, 2015), in addition to requirements of spherical shape or plane grain surface originate that the cost of the powder is higher than other raw geometries as wire or sheet (another problem is that the powder used in LMD is not interchangeable due to problems of flowability with powder for powder bed systems). On the other hand, cost of powder cladded material is usually three or four times higher than casted material. Moreover it must be taken into account that metallic powder is a hazardous and difficult to treat waste. It is also important to consider the typical powder size in LMD process ranges from 15 to 150 microns, and there are associated health and safety issues (Benson 2012).

Industrial advantages of the recovery of the non deposited powder are clear. In fact, there are several works that evaluate the impact of this recovery. However most of the research in LMD has been focused on the parameters of the process like overlap distance (Liu 2014, Kamara 2014), laser power, feed rate (Tabernero 2011) or the metallurgical properties of the manufactured components. Besides these studies, some research can be found published on the recycling of particles in other processes of additive manufacturing where a Ti6Al4V titanium alloy has been studied, as electron beam melting (EBM) process (Petrovic 2015), and selective laser melting (SLM) process (Strondl 2015). Ardila et al. (2014) published a work reporting IN718 powder recycling in SLM process. However, powder recycling for LMD process has not been studied by many authors. Carroll et al. (2006) published a methodology to reuse Waspaloytm powder, apparently without compromising the integrity of the manufactured parts, Slotwinski et al. (2014) have developed a methodology based on an exhaustive analysis based in variation of physical and chemical properties of stainless steel and cobalt-chrome powder after a certain number of cycles of use in an effort to determine standards for characterizing powders used in additive manufacturing.

On the one hand powder reuse is a hot topic for SLM based processes since powder cost is significantly higher and the amount of reused powder is also much higher than LMD process.

Therefore this works presents a methodology to recover, treating and reusing the non deposited powder in the LMD process. This methodology has been adapted to a nickel base alloy IN718, an alloy widely used in aeronautical and energy applications. Metallic powders have been reused up to four times and a test part has been built layer by layer. The results obtained with the test part show a sound microstructure from reused powder.

2. Materials and methodology

2.1. Material

The present methodology has been prepared for one of the most used superalloys, IN718, widely employed in many aeronautical applications such ass turbine blades, compressor blades and combustion chambers. It is a nickel-based heat resistant alloy difficult to forge and machine. It is considered a good candidate to be processed by additive manufacturing processes mostly in repairing operations due to the high cost of the IN718 components. The LMD, unlike other methods such as SLM requires a substrate or base to begin the process of deposition of material. In this study, the substrate or support material has been C45E steel. An atomized IN718 alloy powder from Oerlikon Metco Company (Metcoclad 718 powder) with spherical shape and particle size ranging from 45 to 90 microns has been supplied and used. Its chemical composition is shown in Table 1.

Table 1. Chemical composition of Metcoclad^{tm} 718 powder.

Elem.	Al	C	Co	Cr	Cu	Fe	Mn	Mo	Nb+Ta	Ni	P	S	Si	Ti
wt.%	8.38	0.02	<0.01	18.15	0.02	17.57	0.08	3.00	5.05	54.7	<0.01	<0.01	0.02	0.92