Mold Production by Selective Laser Sintering of Resin Coated Sands

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ABSTRACT

Small sand molds for aluminum casting were produced by selective laser sintering (SLS) of pre-coated sands. A diode laser source with a rectangular laser beam spot was used to perform single and multi-layer processing tests. Subsequently, small sand molds were produced and tested in casting operations. Single layer processing was performed by changing laser power, scan rate and distance of the processed surface from the beam focus. In multiple layer processing, some process changes were made to achieve a perfect joining of adjacent layers. More changes were necessary for the mold production so as to compensate the negative cooling effect of the metallic frame during the sand laser heating. At the end of the process optimization, final molds showed good soundness even if the morphology of internal mold surfaces was affected by the layering procedure.

Keywords: Aluminum Casting, Foundry, Molds, Resin Coated Sands, Selective Laser Sintering

INTRODUCTION

Selective laser sintering (SLS) is a solid imaging technology to generate product concept models, functional prototypes, master patterns, tooling, and production parts (Goode, 2003). In the SLS process, a laser sinters powdered materials according to a pattern provided by CAD data, and a net shape part is built without the need of molds or machining in as a little as a day. However, available materials for SLS technology cannot always substitute the materials needed for product: in these cases, molds can be rapid prototyped and a small production run can be made with the same technology and materials as that of the final product. SLS technology can be used in injection molding of plastic parts (for mold inserts) in die-casting and for forming tools (Levy & Schindel, 2002).

Injection molding is the most common process for economically producing complex parts in large quantity. SLS parts can be used in applications with lower or unknown production quantities or to quickly produce a small
series of a product (Karania & Kazmer, 2007). The process optimization is not trivial and different prototyping technologies (e.g., polyjet technology, Oroszlany et al., 2010) could be preferred, in such cases, because of a higher cost efficiency. Numerical modeling has been used for a better understanding and optimization of the process: models can predict the effect of the laser-material interaction for polymer powders (Kandis et al., 1999) and metal ones (Tiebing & Yuwen, 2006). Models are also able to evaluate the effect of the dominant processing parameters, such as laser-beam intensity, scanning velocity, and number of already sintered layers underneath (Tiebing & Yuwen, 2007). However, experimental information is still fundamental to understand the feasibility of new SLS applications. Mold inserts can be produced by SLS of cooper polyamide (Dimov et al., 2001). Hybrid molds for rapid tooling of injection molds have been developed by combining conventional machining for the mold structure and SLS for the molding blocks (core and cavity), Pontes et al., 2010. Conformal cooling channels can be made as well by integrating indirect SLS and traditional powder metallurgy (Liu et al., 2010).

In metal casting, molds are subjected to more severe process conditions than in injection molding of plastics. Mechanical properties and accuracy are critical on choosing the rapid tooling die inserts as the production-grade tooling (Ferreira, 2004). SLS is used to produce tooling for gravity die casting (Pham et al., 2000) or, in combination with colloidal infiltration, for titanium casting molds, made of stabilized and unstabilized zirconium oxide (Harlan et al., 2001). Anyway, the most important application seems to be the production of sacrificial molds. By using polystyrene powder for prototyping, the plastic pattern is almost entirely removed during casting, as in the case of the lost wax casting process (Liu et al., 2005). SLS is not the only prototyping technology to produce plastic patterns: stereolithography and fused deposition modeling can be used as well (Gibbs & Winkelmann, 2006). Recently, also 3D printing has been investigated as a valid alternative to SLS for producing sacrificial molds in aluminum casting (Singamneni et al., 2009). However, SLS remains a leading technology due to its high potential for further developments. SLS has been used to produce micro-tools (Regenfuss et al., 2005), scaffolds for tissue engineering (Partee et al., 2006), stainless steel microlattice structures (Tsapanos et al., 2010), CU-AISI304 parts in combination with combined with cold and hot isostatic pressing (Lu et al., 2009), piezoelectric ceramics in combination with gelcasting, (Guo et al., 2002). In all these applications, SLS is used to obtain durable or sacrificial molds layer-by-layer. This idea was taken by the authors who applied the concept of the SLS process to build layer-by-layer sand molds for aluminum casting. Particularly, they proposed the original combination of diode laser and pre-coated sands. A pre-coated sand is commonly silica sand lightly coated with phenolic resin; it is typically used in foundry cores and molds manufacturing through shell molding.

In the first part of the current study, the authors have studied the laser-material interaction by performing the sand consolidation under the laser source in a standstill position (Quadrini & Santo, 2009). This way, the influence of the laser power, the focusing distance and the exposure time on sand consolidation was investigated as well as the shape and size of cured samples. The laser power was changed between 20 and 50 W and the interaction time between 3 and 15 s. These parameters strongly affect the laser-material interaction and influence sand consolidation whereas the focusing distance does not seem to be relevant for small changes from the focalization condition. Five main agglomeration conditions of the pre-coated sand were observed, depending on the heating conditions, from the un-cured sand to the complete removal of the resin binder. No pre-heating effect was considered in the experimentation even if it was expected to play an important rule in the case of SLS. Anyway, those results provided important information for the definition of a layered manufacturing method which is described in the current work.
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