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Review

Development and surface improvement of FDM pattern based investment casting of biomedical implants: A state of art review

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ABSTRACT

Fused deposition modelling (FDM) is one of the additive manufacturing (AM) techniques, emerging as a favorable technique in different industries including medicine. The most distinctive purpose of AM in medical industries is to design and produce medical devices, instrumentation and implants. In association with other techniques, it leads to improvement in services offered to society for e.g., in combination with investment casting (IC) process it can produce bio-implants with complex geometries and features at a comparatively less cost and in a less interval of time. While, IC is also a very promising technique to produce net-shape parts with high accuracy and surface finish, however the surface finish of the final casting greatly depends upon the finishing quality of FDM pattern. But, due to inherent limitations of the process, FDM patterns face surface roughness issues, therefore the need of processing of patterns before/during the production or after the fabrication of the pattern, arises. So, this paper will spot a light on development of casted implants and some surface improvement techniques (pre-processing and post-processing) which can be implemented on patterns to enhance its surface properties and their effects will be studied on the pattern as well as casting. It will also focus on the implant materials, production details of implants,and their corrosion studies.

Contents

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1. Introduction

Additive manufacturing (AM) is a process by which models, parts, prototypes and tools can be made in a short span of time, economically with superior characteristics. It is also described as 3-D printing, layer based manufacturing, laser prototyping, rapid prototyping and digital fabrication [1]. Prototypes and Solid models are built up by the data obtained from 3D CAD files. There are two methods (i.e. by using additive and subtractive approach) to produce models. Additive approach is that in which building material is fused together to produce hard to manufacture products with internal cavities, features that are difficult to do manually and it falls under the category of AM. On the flip side, the physical model is attained by the removal of material from solid product in Subtractive approach and cutting processes such as: drilling, reaming, turning and shaping etc. are examples of the subtractive method [2,3]. The most common processes of AM are such as: Laminated object manufacturing (LOM)), 3-D printing (3DP), Fused deposition modelling (FDM), stereo-lithography (SLA), Selective laser sintering (SLS). 3-D CAD models are first sliced into thin layers with minimum layer thickness up to 0.0254 mm in these techniques and later, according to the design of the model; building material is deposited layer by layer on one another to fabricate the part [3]. Until the invention of AM technologies, it was very difficult to produce low volume of components by investment casting process. Because, the cost associated for tooling to produce IC wax patterns was very high, so due to this limitation, it was feasible for high production volume only. But, additive technology completely eliminated the requirements of costly tooling. Thus, it makes possible to produce low quantity of parts with IC process at low cost. And, due to the combination of these two processes the lead time to obtain a casting greatly reduces [4–6]. Reduction in lead time to obtain pattern with the help of AM and the attributes of IC parts such as, ability to make complex designs and fine details, profoundly acknowledged by the medical field. Ultimately, IC has become the preferable choice in medicine industry to obtain bio-implants and additive technology satisfactorily supports this process. As implants are generally obtained for specific patients so the combination of both these processes fulfills the requirements of implants, i.e., specific anatomy, size, tolerances, finish and quantity [7–11].

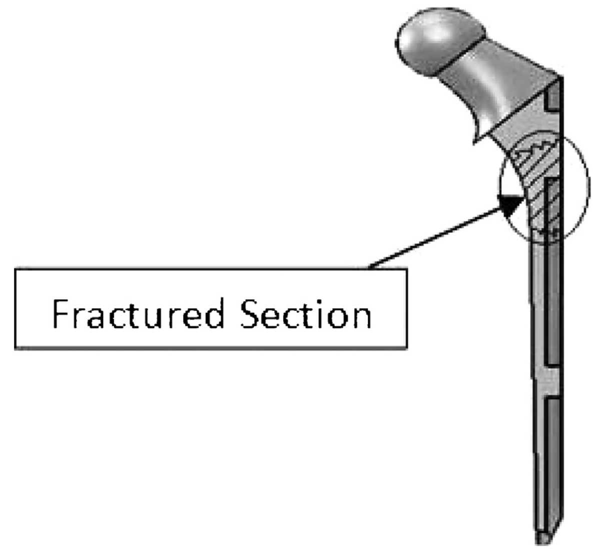

Fig. 1. Hip joint with fractured section.

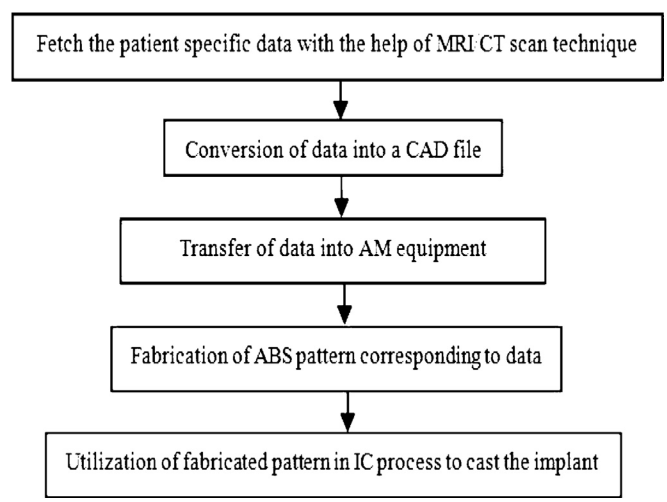

Fig. 2. Step by step procedure to fabricate implant with support of AM and IC.

1.1. Relationship between AM, IC and biomedicals

Figs. 1 and 2 can be helpful to understand the application of AM and IC process in biomedical field. In Fig. 1, a hip implant can be seen in a fractured state, shown with section lines. So, the need of replacement of whole implant or fractured section arises. In one condition, patient can be operated and replaced with readymade implant, having shape and size near to the fractured implant. But, replaced implant may not work efficiently inside the body being a standard shape and size implant, create problems to the patient and have cost issues.

Secondly, only fractured portion of the implant can be replaced. In a traditional manner, in order to cast the fractured section of implant with the help of IC process, there is a need of metallic dies/moulds to produce sacrificial wax patterns having patient specific cavities. This will definitely be a time consuming and high cost (material cost, labor cost, wastage associated cost etc.) affair because, it will not be justified to make costly dies for treatment of individual patient which can make parts of specific shape and size.

So, here the application of AM emerges. Due to which medical industry became able to produce patient specific implants at fast rate and comparative less cost. The procedure to obtain patient specific implants can be noticed in Fig. 2.

As far as finishing of casted implants is concerned, it highly depends upon the surface quality of pattern. But, due to the inherent shortcoming of FDM, the surface of patterns is built with asperities those can not be removed by controlling the parameters of IC itself. So, FDM patterns require special attention and they must undergo surface improvement methods before casting in order to save the time and money to finish the final cast. [12]

It has been found from literature that many studies have been reported related to application of surface finishing methods on FDM patterns. But, there are very few comprehensive studies that explore the effect of finishing methods on FDM pattern and its impact on IC.