APEM journal

Advances in Production Engineering & Management
Volume 13 | Number 3 | September 2018 | pp 267–278
https://doi.org/10.14743/apem2018.3.289

ISSN 1854-6250
Journal home: apem-journal.org
Original scientific paper

Design, finite element analysis (FEA), and fabrication of custom titanium alloy cranial implant using electron beam melting additive manufacturing

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ABSTRACT

Skull defect reconstruction is one of the most difficult challenges faced by the surgeons because of the complex shape of the skull. Skull defects are dramatically increasing with the increase in road accidents, tumors, and wars, thereby increasing the demand for reconstruction of skull. It is difficult to manufacture standard implants for skull defects especially for large and complex defects, due to the complexity and the difference in anatomy of skulls. Design and fabrication of custom cranial implant is required in these cases. The conventional technologies face multiple challenges in fabricating lightweight custom cranial implants closer to that of bone in terms of weight; the difference in the weight introduces stress-shielding effects onto the surrounding bone. In order to overcome this problem, several researches proposed lattice structure implants fabricated by additive manufacturing. However, lattice structure implants are difficult to remove later when some problems are encountered. This paper presents a methodology of design analysis and fabrication of solid lightweight custom cranial implant using additive manufacturing. A Case study is presented where, a custom cranial implant is designed and analysed using finite element analysis (FEA) and then fabricated using electron beam melting (EBM) additive manufacturing. The titanium alloy Ti6Al4V which is biocompatible and non-toxic is used as the implant material. The functionality, fitting, and aesthetic of the proposed design are evaluated. The results show the successful fabrication of thin custom cranial implant for skull defect reconstruction via EBM technology. The fabricated implant has sufficient strength, weight close to the weight of the removed bone portion while maintaining a good fit and aesthetics.

ARTICLE INFO

Keywords:
Additive manufacturing;
Cranial implant;
Titanium alloy (Ti6Al4V);
Electron beam melting (EBM);
Finite element analysis (FEA)

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Article history:
Received 17 July 2018
Revised 13 August 2018
Accepted 24 August 2018

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