FABRICATION OF CUSTOM DESIGNED SPINAL DISC REPLACEMENT FOR VETERINARY APPLICATIONS

AGNIESZKA CHMIELEWSKA[1,2]*, BARTŁOMIEJ WYSOCKI[1,2], KAROL SZLĄZAK[1,2], JACEK STERNA[3], KRZYSZTOF JAN KURZYDŁOWSKI[1], WOJCIECH ŚWIĘSZKOWSKI[1]

[1] FACULTY OF MATERIALS SCIENCE AND ENGINEERING, WARSAW UNIVERSITY OF TECHNOLOGY, 141 WOLOSKA STR., 02-507 WARSAW, POLAND
[2] MATERIALSCARE LLC, 10/1 ZWIERZYNIECKA STR., 15-333 BIALYSTOK, POLAND
[3] WARSAW UNIVERSITY OF LIFE SCIENCES, WARSAW, POLAND
*E-MAIL: AGNIESZKA.CHMIELEWSKA@INMAT.PW.EDU.PL

[ENGINEERING OF BIOMATERIALS 143 (2017) 40]

Introduction

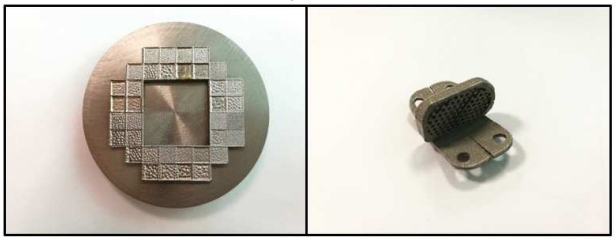
Two-phase alpha-beta titanium alloy Ti-6Al-7Nb is widely used in many industrial applications. Due to excellent biocompatibility and non-toxicity in human body environment and excellent mechanical properties it is an attractive material in medical field. Difficulties with fabrication complex shaped medical implants and gradient or lattice structures from Ti-6Al7Nb alloy lead to finding out fabrication method which allows to produce such elements. The most appropriate for mentioned applications are Additive Manufacturing (AM) techniques such as Selective Laser Melting (SLM), which enables producing any geometry directly from the Computer Aided Design (CAD) model [1]. The aim of the study was fabrication of custom designed spinal disc replacement for veterinary applications.

Materials and Methods

In our study both cuboid specimens and spinal disc replacement, were fabricated using Realizer SLM50 machine. The SLM50 is a 3D printer for metals and its alloys equipped with Nd:YAG laser with maximum power of 120 W. Cuboid shaped samples of 6x6x3mm size were fabricated with the energy densities in range from 38 to 333 J/mm^3 and scanning speeds from 125 to 375 mm/s to select the best manufacturing parameters of the Ti6Al7Nb alloy. The process was conducted in argon atmosphere. Afterwards, samples were cut perpendicularly to the platform surface. Metallography cross section related to x-z scanning plane were mechanically gridded with SiC papers with gradation from 320 to 1200 µm and polished with 0.1 µm Al_2O_3 suspension. Etching was performed with HF, HNO_3 and H_2O mixture [2]. Microstructure observation was performed using Zeiss Axio Light Microscope. Microhardness measurement was carried out on Zwick/Roell machine with load of 1.961 N. Finally, spinal disc replacement designed using a computed tomography, basing on the case of a clinical veterinary patient, was fabricated using selected manufacturing parameters. After ultrasonic cleaning in water, chemical polishing in HF/HNO_3 solution was performed to improve surface quality of the implant and remove unmelted fully powder particles from struts. Furthermore, it was confirmed in our previous study that treating titanium with solution of HF/HNO_3 has positive influence on cell response [3].

Results and Discussion

Different manufacturing parameters used for each sample fabrication had influence on their surface quality (FIG. 1a). For some samples irregular or concave surfaces were observed while for others smooth with very regular boarding. Microscopic observations showed that porosity was also determined by the manufacturing parameters. The best surface quality and the lowest porosity of about 99.7% was obtained for sample manufactured with the energy density of 50 J/mm^3 and the scan speed of 375 mm/s. The average microhardness of this sample was 368 ±12 $HV_{0,2}$ and was 26% higher than for pure titanium (CP Ti) fabricated by SLM technique [4]. Spinal disc replacement implant was fabricated using the manufacturing parameters adopted from the cubic sample (FIG. 1b). Our optimization procedure provided the high manufacturing accuracy of the CAD model. Furthermore, surface quality of the spinal disc replacement was improved after chemical polishing in a mixture of the HF/HNO_3.



(a) (b)

FIG. 1. (a) Samples produced with different manufacturing parameters; (b) Spinal disc replacement.

Conclusions

The microstructure and the mechanical properties of Ti-6Al-7Nb produced by SLM technique is determined mainly by delivered amount of energy density (J/mm^3) and scan speed value (mm/s). Selecting proper manufacturing parameters is important to obtain high manufacturing accuracy of the CAD model. Furthermore, proper chemical polishing procedure improves surface quality of elements produced by SLM technique for medical application.

Acknowledgments

The authors would like to thank the NCBiR (National Center for Research and Development) for providing financial support to project LasIMP (Grant No. PBS3/A5/53/2015).

References

[1] A. Pawlak, P. Szymczyk, G. Ziolkowski, E. Chlebus, B. Dybala, Fabrication of microscaffolds from Ti-6Al-7Nb alloy by SLM, Rapid Prototyp. J. 21 (2015) 393–401. doi:10.1108/RPJ-10-2013-0101.
[2] E. Lyczkowska, P. Szymczyk, B. Dybała, E. Chlebus, Chemical polishing of scaffolds made of Ti-6Al-7Nb alloy by additive manufacturing, Arch. Civ. Mech. Eng. 14 (2014) 586–594. doi:10.1016/j.acme.2014.03.001.
[3] B. Wysocki, J. Idaszek, K. Szlązak, K. Strzelczyk, T. Brynk, K. Kurzydłowski, W. Święszkowski, Post Processing and Biological Evaluation of the Titanium Scaffolds for Bone Tissue Engineering, Materials (Basel). 9 (2016) 197. doi:10.3390/ma9030197.
[4] B. Wysocki, P. Maj, A. Krawczyńska, K. Rożniatowski, J. Zdunek, K.J. Kurzydłowski, W. Święszkowski, Microstructure and mechanical properties investigation of CP titanium processed by selective laser melting (SLM), J. Mater. Process. Technol. 241 (2017) 13–23. doi:10.1016/j.jmatprotec.2016.10.022.