Structure and properties of Co-Cr-Mo alloy manufactured by PM, PIM and SLM methods

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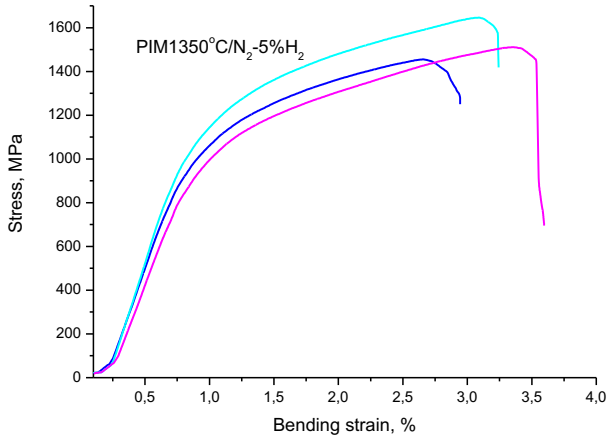
Abstract

Statement of the Problem: The main aim of the research in this work was to determine the influence of manufacturing technology on the structure and mechanical properties of Co-Cr-Mo alloy used as a biomaterial. The Co-Cr-Mo alloy is used to produce several types of dental screws, stabilizers and implants. For all manufacturing methods the same powder was used but for PIM the powder was sieved through a sieve with a mesh size of 25μm. The pressing and injection molding powders had to be properly prepared in advance. For additive manufacturing, the powder only needs to be loaded into the hopper of the machine. However, in SLM technology, sample models should be designed in advance in an appropriate program. In a AM125 machine Renishaw company for SLM the powder container is equipped with automatic valves that deliver powder doses throughout the manufacturing process. The materials produced by PM and PIM methods, respectively, after dewaxing or debinding of the binder, were sintered in a tubular furnace under atmosphere of N2-5% H2 or Ar-5% H2 at the temperature of 1300 to 1380ºC during 30 minutes. The mechanical properties of PM and PIM samples, including hardness, three-point bending and tensile strength tests showed that the use of nitrogen rich atmosphere increases the mechanical properties as compared to the material manufactured in Ar-5%H2. This is due to the precipitation of numerous fine nitrides and intermetallic phases that strengthen the ductile γ -phase matrix. The structure of obtained samples were assessed by X-ray diffraction and scanning electron microscopy. Materials manufactured by SLM method under N2 are free from nitrides but despite the lack of these precipitates, they have the highest mechanical properties.

Conclusion and significance: The use of the Ar-5%H_2 mixture results in a high proportion of ε phase fraction in relation to γ. This structure makes the material ductile. On the other hand, selection of the N_2-5%H_2 gas mixture as a sintering atmosphere cause multiple intermetallic phase precipitation in the material structure. Nitrogen makes the sinters hard while stabilizing the γ phase matrix, as confirmed by the structural tests. The use of nitrogen during the production by the SLM method does not give such effects. In this method, the local melting of the material in micro-regions in the atmosphere of Ar allows to achieve the highest mechanical properties.

Image



Mechanical properties of 3 samples of Co-Cr-Mo manufactured by PIM and sintered at 1350°C under N_2-5%H_2

Recent Publications

1. J. Zuchuat, et al., CoCrMo alloy as biomaterial for bone reconstruction in oral and maxillofacial surgery, Journal of Oral Research, Vol 9 No 4 (2020), p. 336-349
2. I. Peter, M. Rosso: Study of Ti-Enriched CoCrMo Alloy for Dental Application, IEEE Access, 2015
3. O. D. Neikov, S. S. Naboychenko, I. B. Murashova, Handbook of Non-Ferrous Metal Powders 2nd Edition: Chapter 22– Production of Cobalt and Cobalt-Alloy Powders, Technologies and Applications, 2019, 669-684.
4. L. Reclaru, L. C. Ardelean, Alternative Processing Techniques for CoCr Dental Alloys, Encyclopedia of Biomedical Engineering, 2019, 1-15.
5. A. Cutulo, B. Neirinck, K. Litaert et al., Influence of layer thickness and post-process treatments on the fatigue properties of CoCr scaffolds produced by laser powder bed fusion, Additive Manufacturing, 23, 2018, 498-504.
6. Y. Ucar, O. Ekren, Effect of layered manufactirung techniques, alloy powders and layer thickness on mechanical properties of Co-Cr dental alloys, The Journal of Prosthetic Dentistry, 120(5), 2018, 763-770.
7. Y. Zhao, Y.Koizumi, K. Aoyagi, et al., Manipulating local hrat accumulation towards controlled quality and microstructure of a Co-Cr-Mo alloy in powder bed fusion with electron beam, Materials Letters, 254, 2019, 269-272.

Photograph

Biography

Prof. Grzegorz Matula is a Head of Scientific and Didactic Laboratory of Nanotechnology and Materials Technologies, Silesian University of Technology. His scientific field of activity and specialty is powder metallurgy, powder injection moulding, tool materials, sintering, composites, polymers, biomaterials, materials processing technologies, metal science research methods additive manufacturing.
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