Konkova, Tatyana and Mironov, S. and Rahimi, Salah (2018) Evolution of microstructure and residual stresses in a CP-Ti bioimplant produced by incremental sheet forming. In: Ultrafine Grained and Nanostructured Materials. Bashkir State University, Ufa, Russian Federation, pp. 142-143. ISBN 978-5-7477-4721-0 ,

EVOLUTION OF MICROSTRUCTURE AND RESIDUAL STRESSES IN A CP-TI BIOIMPLANT PRODUCED BY INCREMENTAL SHEET FORMING

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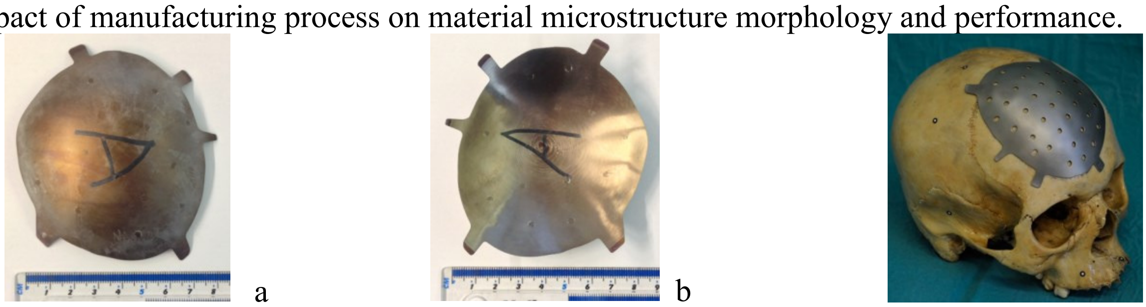
Investigation of material behaviour under different schemes of deformation process is one of the important tasks of modern materials science. Metal manufacturing methods, such as metal forming, related to methods by which material of a simple geometry is transformed into a component of specific shape without any change in mass or chemical composition of the initial material [1]. Metal forming process where the deformation is three-dimensional in nature, is known as bulk deformation [2]. Bulk deformation includes processes such as rolling, extrusion, cold and hot forging, bending, and drawing, where metal is formed by plastic deformation. The term bulk deformation is used to distinguish it from sheet-forming process. In sheet-forming, such as brake forming, deep drawing, and stretch forming, the stresses are usually in the plane of the sheet metal unlike all three coordinate directions of components in bulk deformation.

A new class of forming processes known as Incremental Sheet Forming (ISF) has shown an increasing interest from both academia and industry during last decade. In an excellent overview presented by W.C. Emmens and co-authors, they defined ISF as: a family of sheet forming processes where the deformation is highly localized, without drawing in of material from a surrounding area and using a fully clamped blank, where the final shape is determined by the xyz movement of some tool part without the need for a die [3]. Producing parts with ISF is a major interest for medical applications for both engineers and physicians as complicated components with delicate features can be manufactured in a short period of time. The objective of this work was to obtain knowledge on the component produced by ISF. For that purpose, a cranial implant was produced (Fig.1), and material microstructure and properties were analysed to understand the impact of manufacturing process on material microstructure morphology and performance.



a b c

Fig 1. Cranial implant made by ISF: a) front side of the implant; b) back side of the implant; c) human skull.

The CP-Ti sheet (base sheet) material with initial thickness of 0.6 mm was used for the ISF. Although the ISF is often carried out without the need for dies, higher geometrical accuracy was achieved when a die was used in combination with the stylus. In accordance with the selected geometry, a die was created using polymer material. The ISF part of CP-Ti was manufactured with support of CNC machine, and subjected to the following heat treatment to reduce the level of residual stresses.

Non-homogeneity of the material response to the manufacturing process parameters was found in the ISF sample. Stages of microstructure transformation were specified for the formed part. Progress in recrystallization was noticed in the ISF part and resulted in increase of fraction of recrystallized material. The ISF part had higher microhardness values than those in the as-received sheet material, i.e. ≈175HV and ≈161HV respectively. A nonhomogeneous character of the microhardness distribution of the ISF part was observed. A significant reduction in microhardness to ≈160HV appeared almost symmetrically with regard to the sample's axis. Residual stress distribution in the ISF sample was not homogeneous throughout the surface and characterised by prevalence of tensile stresses.

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