Additively manufactured femoral stem topology optimization: case study

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Abstract

The main problem of femoral stem prostheses is their primary stability after implantation, that is assured by the so-called press-fit implantation, but immediately after that it is to install a secondary stability, due to the best osteo-integration of the prosthesis in the bone of the femur. Additive manufacturing (AM) allows the designer to create tridimensional models that can have a diffused porosity in the contact area with bone, which confers to the femoral stem significantly higher osteo-integration. Furthermore, through topology optimization, the shape of the prosthesis can be improved, in conjunction with significant mass reduction. This work presents our results concerning the topology optimization of a medium length femoral stem, intended to be manufactured by powder bed fusion. The CAD models have been analyzed through computer-aided simulations concerning their mechanical characteristics, according to ISO 7206, and were topologically optimized using commercially available software. The CAD models, both original and optimized, have been built by selective laser sintering and analyzed concerning their mechanical characteristics. An optimized femoral stem has been obtained, which answers to the ISO 7206, but with a 15% mass reduction.

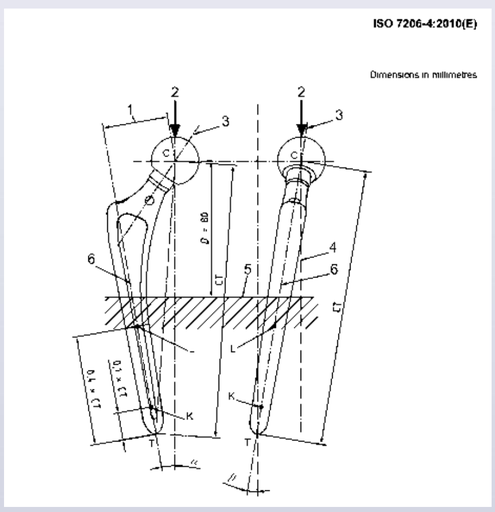
Introduction

In the field of prosthetic components, in particular those intended for hip and knee reconstructive surgery, PBF processes are already applied, roughly since 2007, for the production on Titanium alloy parts. The stems are classified as short, medium or long depending on the dimensions. While short stems are successfully produced by PBF, medium and long ones are still challenging.

Objectives

- higher strength-to-weight ratios;
- 15% weight reduction of parts;
- optimization for Aditive Manufacturing;

Topology optimization of the prosthetic part



Femoral stem loading point, according to ISO 7206/4

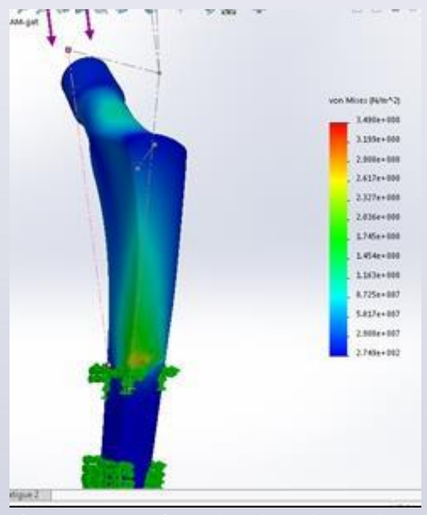
In order to realize the strain simulation on the femoral stem the SOLIDWORKS software package was used.

The topology optimization was conducted with TRUFORM (GRM Consulting) software as an extension of SOLIDWORKS.

The work was carried out taking into account all the stipulations of the ISO 7206/4 and ISO 7206/6 standards

Non-optimized femoral stem

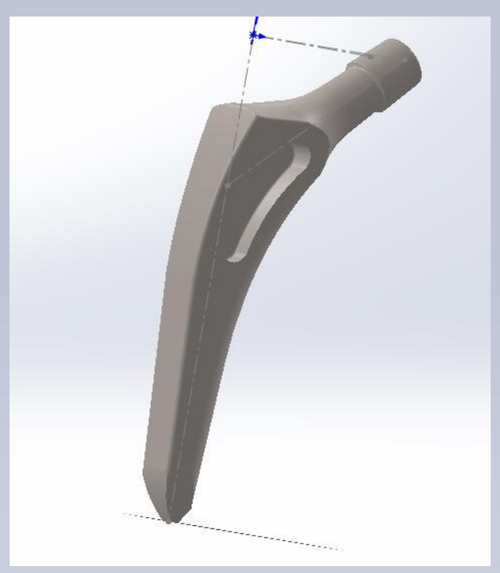
On the base of the model created started the simulations in order to then move to the next step: topology optimization. The simulations conducted have shown that the prosthesis not only fulfills the ISO 7206/4 and 7206/6 requirements but a significant reserve of strength is available. The simulations took into account the characteristics of EOS Titanium Ti64 powder.



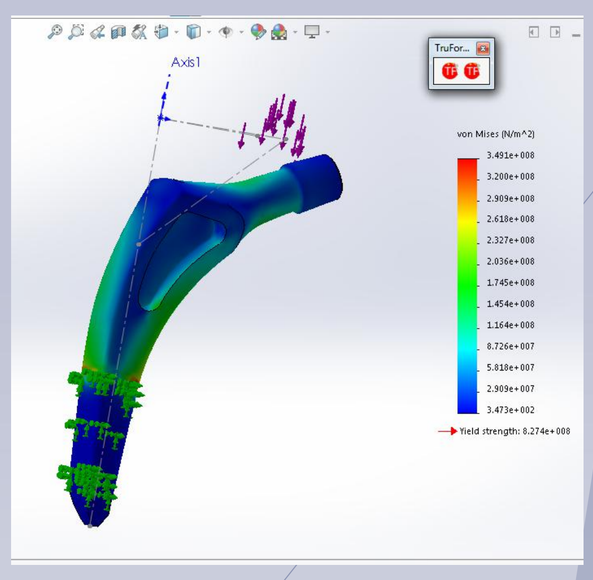
Simulation results obtained on the non-optimized femoral stem

The simulation results showed a maximum strain value of 405.9 MPa, much lower compared to the permissible resistance of the material, which is 860 MPa.

TruForm-generated optimized femoral stem



Weight optimized femoral stem



Acknowledgment:
This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 723699.