

DEVELOPMENT OF CUSTOM PROSTHESES USING INCREMENTAL SHEET FORMING AND RAPID PROTOTYPING

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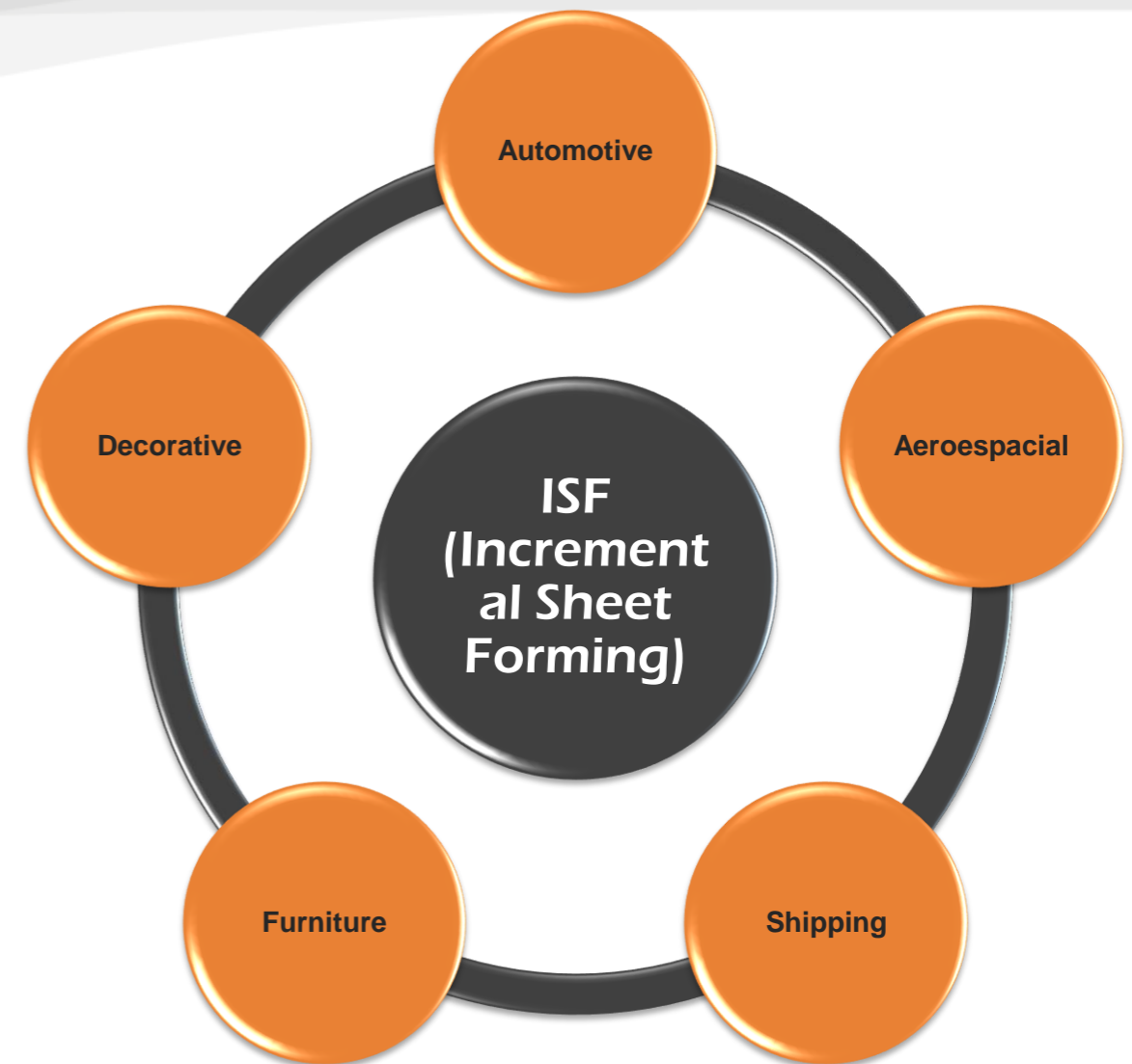


Polymer mold of skull and
prosthesis in titanium sheet

Introduction / Motivation

ISF - Incremental Sheet Forming

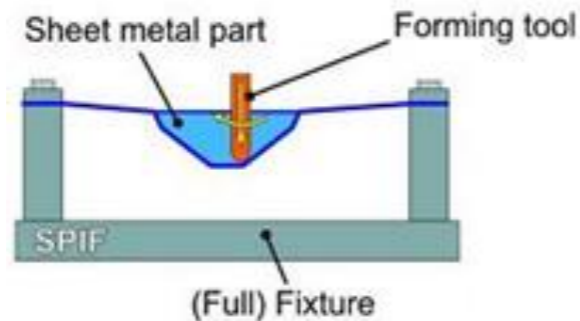
- Challenging sheet metal forming process once it is still in development;
- Increasing of the material formability;
- Applicable to different industry fields;
- Production of small batches of products or single components (prototypes);
- Use of simple forming tools;
- Could be performed at CNC milling machines, adapted robots or ISF specifically made machines.



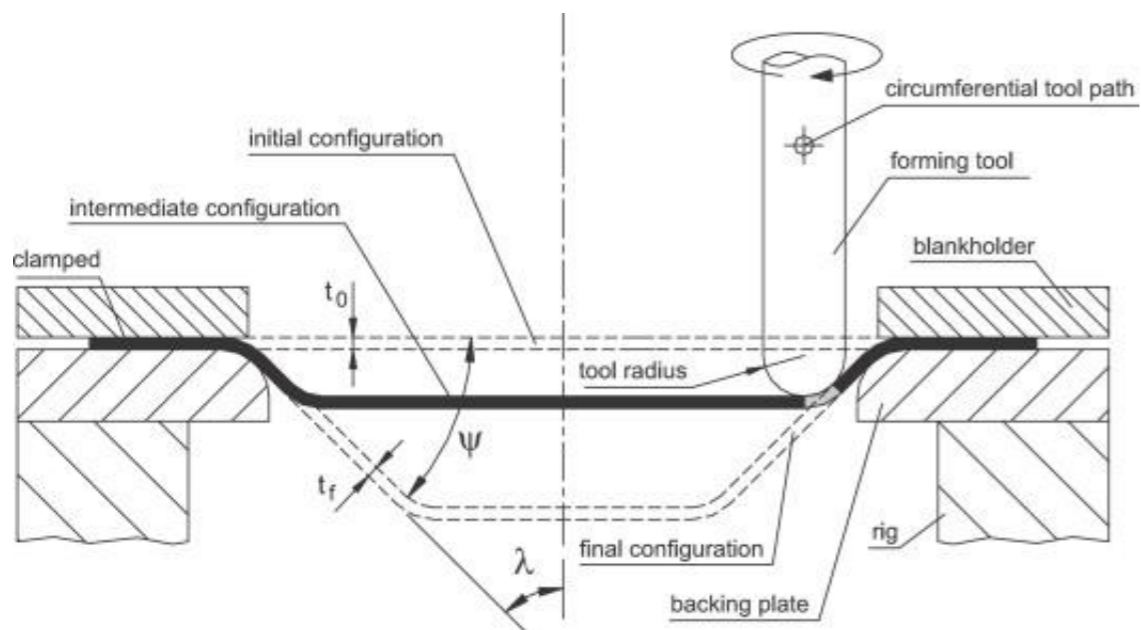
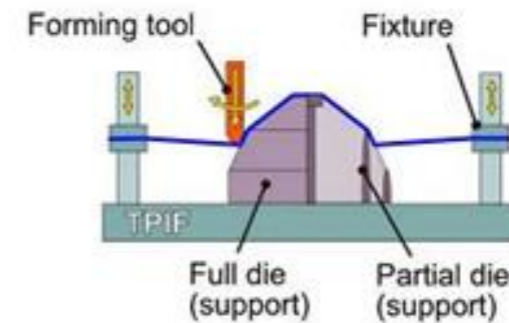
SPIF Process Principle

This process can be divided in to main forming metods:

- ➔ SPIF – Single Point Incremental Forming



- TPIF – Two Point Incremental Forming



- Produce sheet metal parts throught incremental deformation without resorting to any complex die or punch;
- It uses very simple tools with cilindrical or conical body and spherical or hemispherical tip (mostly);
- Deformation occurs due to the contact of the tool in a very small area of the sheet;
- Toolpath is controlled by a CNC numerical code.

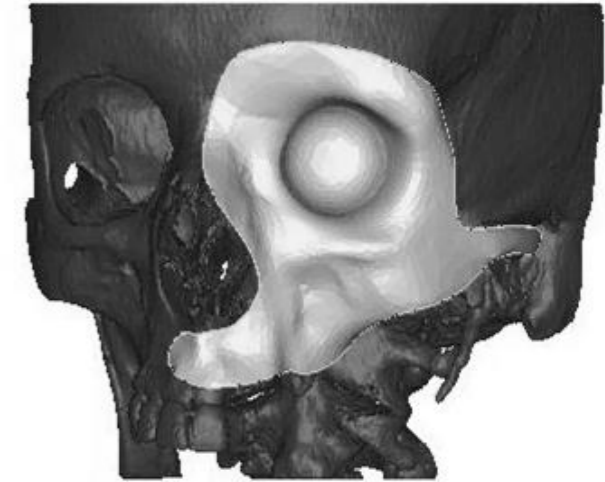
SPIF Advantages

- a) Setup time reduction;
- b) Flexibility;
- c) Increased formability;
- d) Works without specific tools;
- e) Possibility to use conventional CNC milling machines;
- f) Possibility to form parts of several sizes;
- g) Process without intense noises;
- h) Possibility to perform irregular and asymmetric shapes;
- i) Surface finishing is improved by the use of lubrication;
- j) Energy economy;
- k) Easier transport and allocation on the factory layout;
- l) Low cost to obtain small batches or single products.

SPIF Limitations

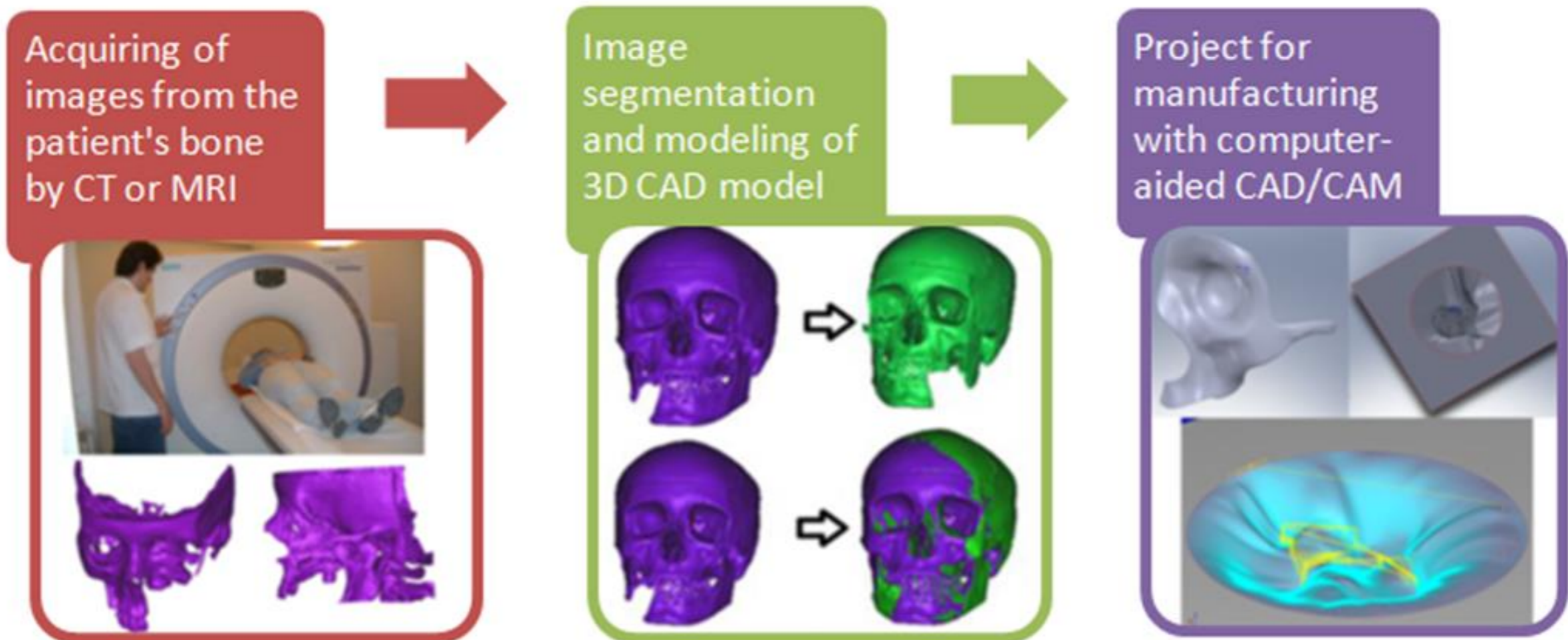
- a) High manufacturing time of the parts;
- b) Non-compliance of geometry dimensions;
- c) Impossibility to perform vertical walls or very pronounced drawing angles (Ψ);
- d) Deformation of the parts after removing the blankholder.

Medical Application: Maxillofacial Prosthesis



For its characteristics, SPIF should, eventually, be an adequate process to perform the complex geometry of an implant with thin walls.

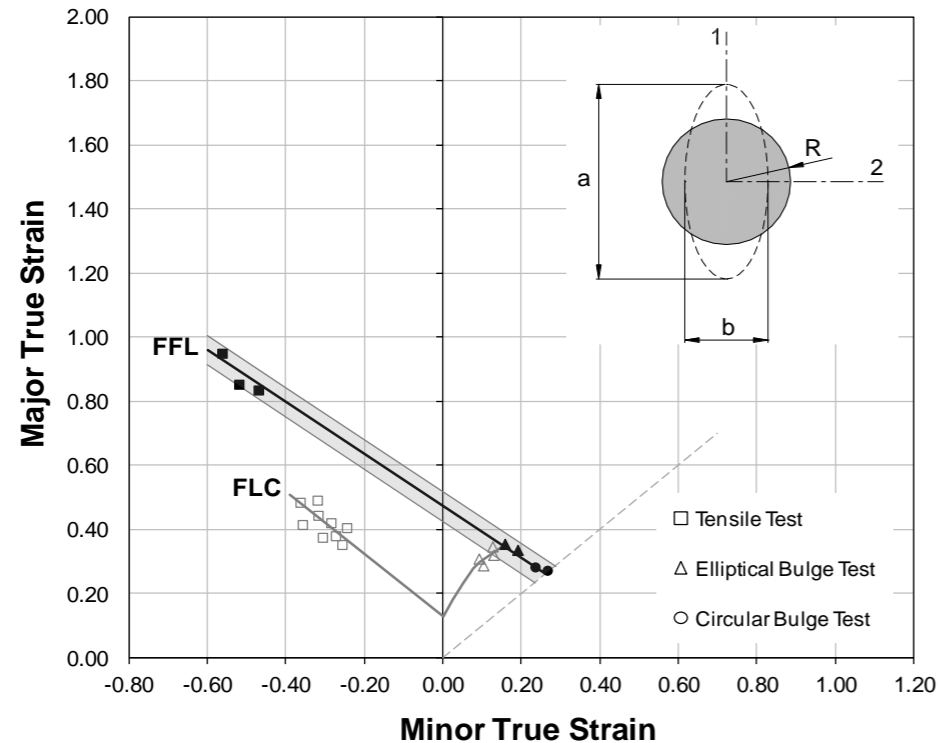
Thus, it was followed a maxillofacial defect of a patient.



Mechanical Characterization and Formability Limits

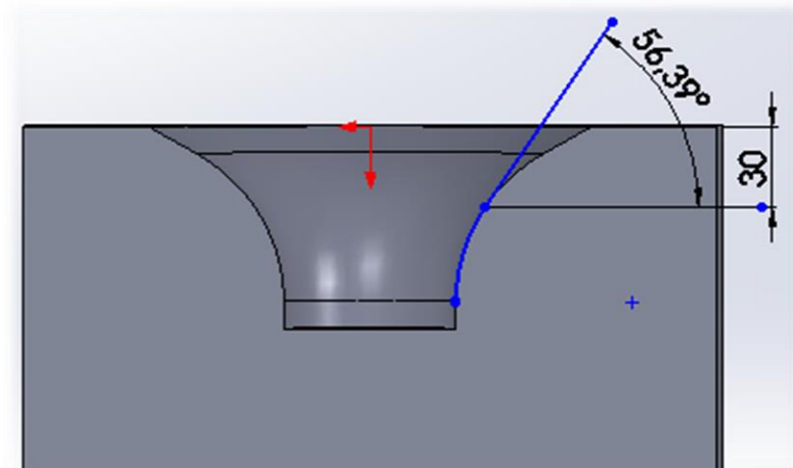
Due to biocompatibility issues, the material selected for this research was the commercially pure titanium (TiCp Gr2).

Uniaxial tensile tests and hydraulic Bulge tests were performed in order to find out the hardening and anisotropy behavior, the forming limit curve (FLC) and the fractureforming limit line (FFL).



Mechanical Characterization and Formability Limits

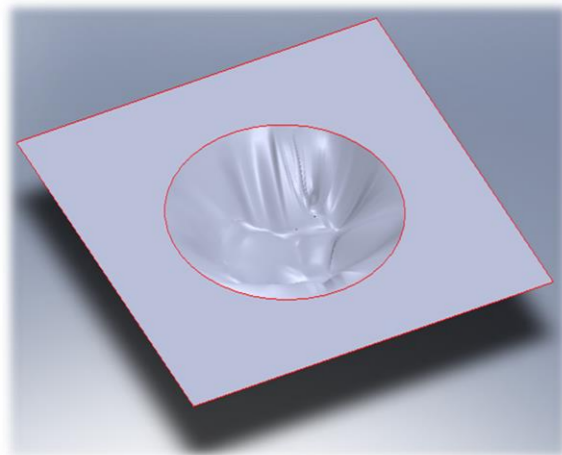
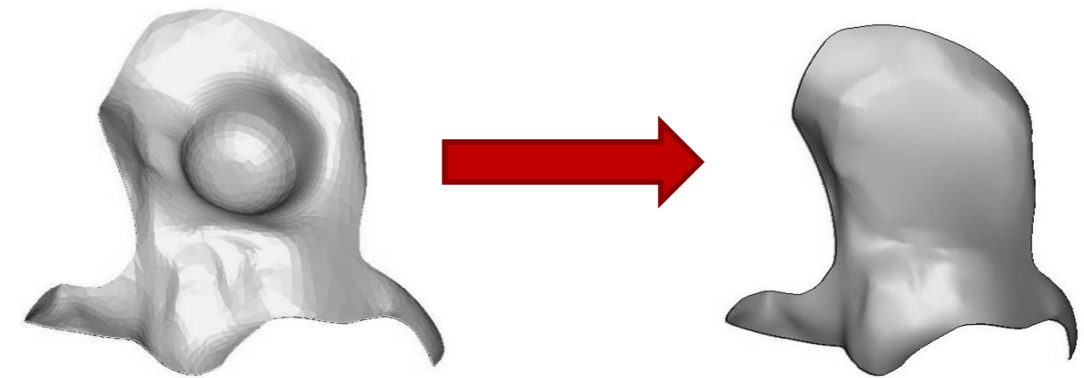
There were also performed single point incremental forming (SPIF) tests, consisting in the drawing of a tronco-conical shape with variable wall angle, with the objective of determine the maximum drawing angle (Ψ_{max}).



Experimental Work

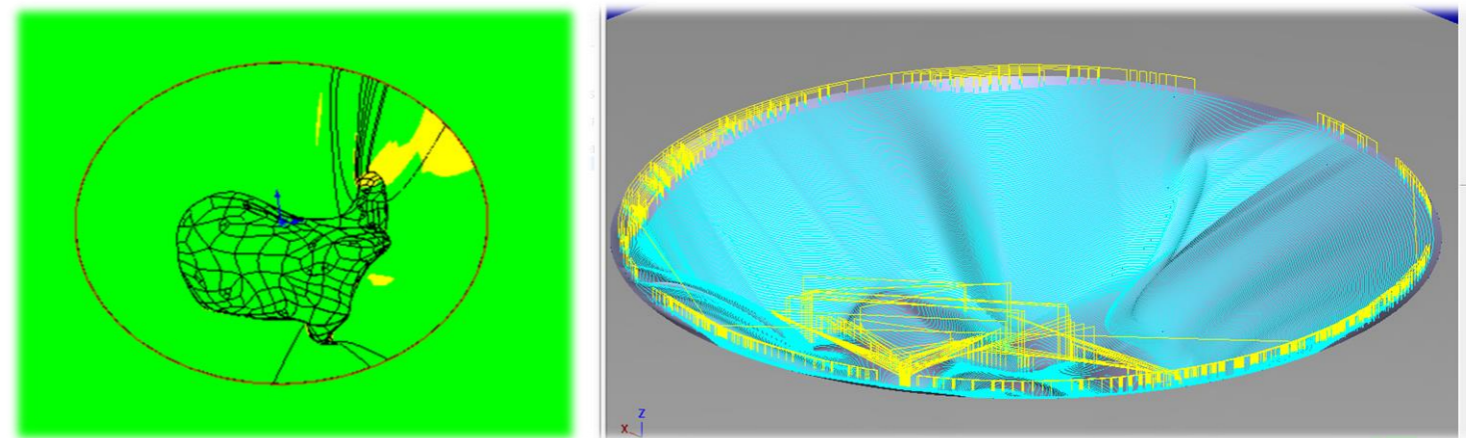
CAM preparation

- Starting from the previously found 3D model of the implant, it was realized in this work a first approach with with a simplified model, without the orbital cavity.



- In order to define the required toolpath, it was created a surrounding wall around the implant perimeter, connecting it to the initial blank position.

- It was performed a draft analysis on the geometry of the geometry, representing the yellow areas, drawing angles higher than the Ψ_{max} . It is expected fracture on those areas during a single stage strategy.
- Nevertheless, it was created a toolpath with this geometry.

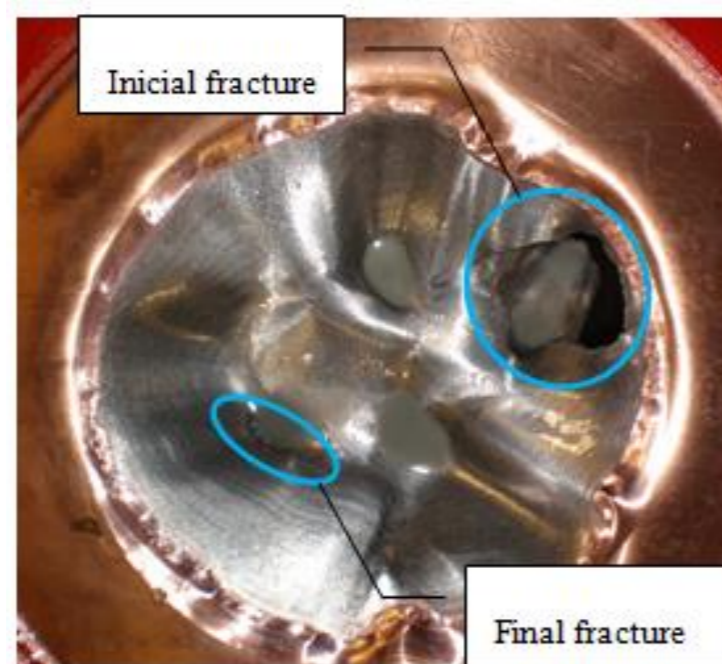


Experimental Work

Sheet forming

Forming the given geometry, it was noticed that fracture occurred in the predicted areas, as we can see in the figures:

- One first fracture happened in the outside of the prosthesis perimeter, which was enlarged as the tool went deeper, influencing the final wall angles of the part;
- A second fracture has occurred inside the part, near to the defined final depth.



Cutting of the implant model was made in the same CNC milling machine with remove the part between operations.

Conclusions/Remarks

After perform the mechanical characterization of the involved material (TiCp Gr2), and the consequent determination of the forming limits by necking and fracture, and develop a numerical model with two representative failure criteria for formmability assessement, it can be taken the following conclusions:

- Results verified by means of experimental and numerical means show that SPIF seems to be an **appropriate process to obtain medical implants.**

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