BioForming Innovative stamping process for fully-customized prosthetic implants

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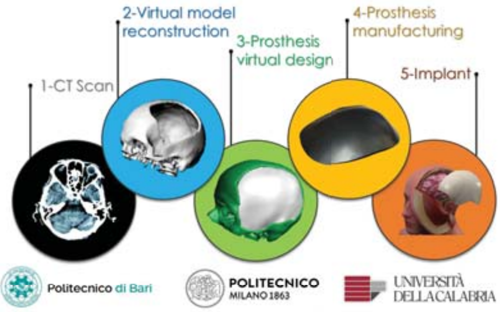
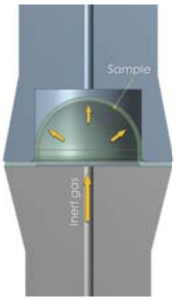
BioForming Project. The research project "BioForming" (*www.bioforming.it*), funded by the MIUR, aims at the realization of titanium alloy custom-made prostheses by means of unconventional sheet metal forming processes such as SuperPlastic Forming (SPF) and Single Point Incremental Forming (SPIF); in particular, in the SPF a metal sheet is deformed using the action of inert gas in pressure at a high temperature and in the SPIF a tool rotating at high rpm deforms the sheet locally.



Background. When it is necessary to ensure complex geometries or integrated structure, SPF is reported to be the most suitable manufacturing process [1]. Numerical simulation plays a fundamental role in the process design, and reliable results can be obtained only if a proper material characterization is carried out. The characterization of the superplastic behaviour of the **Ti6Al4V-ELI alloy** was carried out by means of **free-inflation tests** [2].

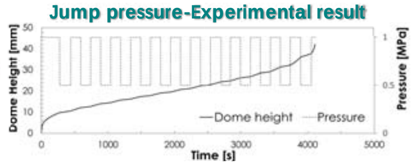
Methodology. Circular Ti blanks (D=80mm, s=1mm) were deformed at high temperature (T=850° C) by the action of pressurized argon according to both a constant value (0.5 and 1.0 MPa) and a pressure profile based on jumps between 0.5 and 1.0 MPa. Evolution of the dome height with the time was recorded and subsequently adopted for the inverse analysis approach.



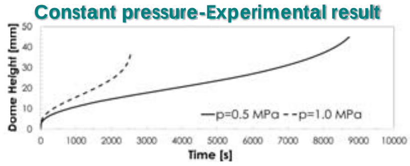
Scheme of test

Experimental equipment

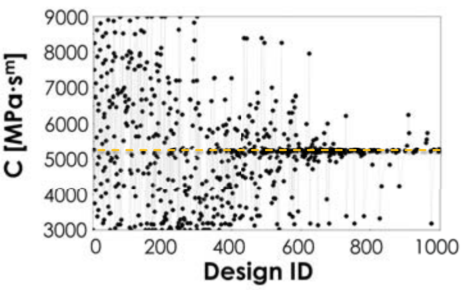
Jump pressure-Experimental result

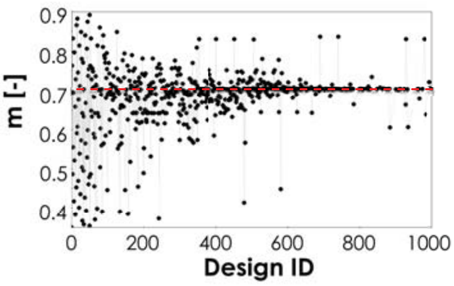


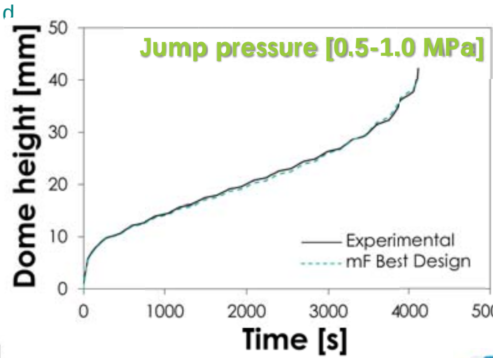
Constant pressure-Experimental result

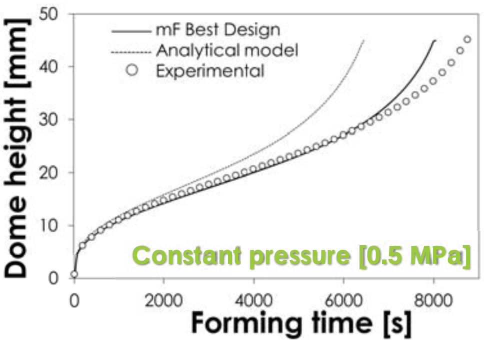


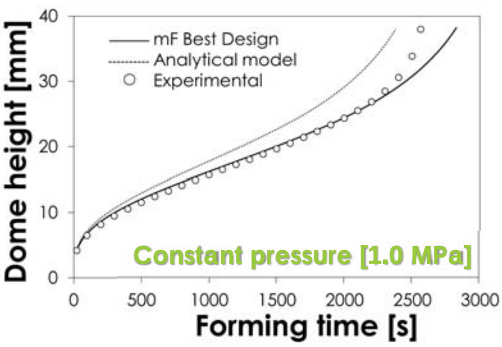
Inverse analysis. Experimental tests conditions were re-created within a CAE environment with a 2D FE model. Material elasto-viscoplastic behaviour was modelled according to Backofen law $\sigma=C\dot{\varepsilon}^m$. The values of the strength coefficient **C** and the strain rate sensitivity index **m** able to minimize the error between the numerical and the experimental dome height evolution with time were obtained coupling the 2D model with modeFRONTIER within an optimization procedure driven by the MOGA-II algorithm [3]. A total number of 1000 designs (20 successive generations, each composed of 25 designs) were run on a Xeon 3.47 GHz dual processor with 40 GB RAM installed. The whole optimization procedure took less than one day to get completed.





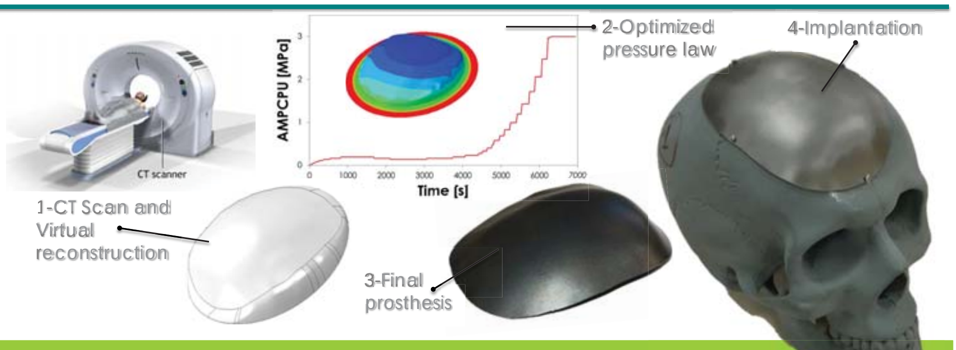






Validation. The material constants obtained from the inverse analysis were validated with further numerical simulation regarding free inflation tests under constant levels of pressure equal to 0.5 and 1.0 MPa. Comparison with experimental data confirmed the accurateness of the determined constants even when compared with those determined with the analytical model [5].

Prosthesis manufacturing design. Once properly determined the material constants, the design for the skull prostheses manufacturing can be carried out by means of numerical simulations [4]. Prostheses geometry is virtually re-constructed from CT scans (1), then the optimized pressure law is obtained by means of FE simulations (2). The final geometry of the prostheses is thus obtained by means of 3D laser cut (3) and finally implanted on a demonstrative skull (4).



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