8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

SUPERPLASTIC FORMING OF PATIENT-SPECIFIC DENTAL AND MAXILLOFACIAL PROSTHESES

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Key Words: *Patient-Specific Modelling, Dental and Maxillofacial Prostheses, Superplastic Forming, Incremental Flow Formulation.*

ABSTRACT

There is a growing demand for dental and maxillofacial prostheses resulting from both disease and trauma. Specifically, the main causes of skull defect requiring implants have been reported to be severe intracranial traumata, tumours, cerebral infarcts and osteomyelitis [1]. The customisation of prostheses has been increasing in the last decades and as with many products, the demand and the requirement for items that are unique to the individual has become considerable.

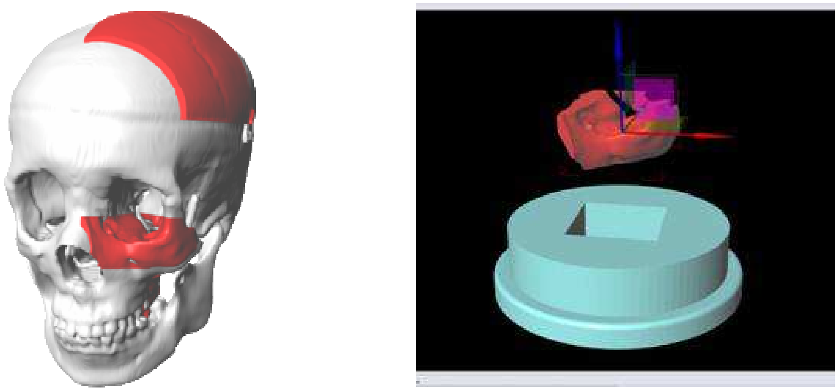

Figure 1: Construction of a 3D SPF die using Simpleware tools.

In recent years, more technological approaches to customisation have emerged within the medical arena, driven by advances in scanning technology, manufacturing technology, numerical modelling and computational resources. One example of the use of computational analysis to achieve customisation involves the use of SuperPlastic Forming (SPF) for the manufacture of titanium alloy dental and maxillofacial devices [2]. Indeed, SPF introduces interesting new possibilities of creating prostheses at a lower

cost and with more complex shapes than the usual cold forming processes. Crucial to the effectiveness of this technique is its ability to efficiently simulate patient-specific problems. An on-going collaborative project is currently investigating the use of scanning technology based on Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) in association with commercial image-based mesh generation tools (Simpleware Ltd.) and in-house cutting edge numerical simulation software to efficiently and accurately construct and model patient-specific dental and maxillofacial prostheses.

A mesh generation technique based on an in-house developed multi-part marching cubes scheme with specifically designed multi-part smoothing algorithms is employed [3] (see Figure 1). The incremental flow formulation, originally developed to model the forming of components in the aerospace industry [4], is extended to the application of patient-specific prostheses. SPF is an inelastic large deformation, incompressible process with deformation dependent pressure loading. In addition, the constitutive equations involve a nonlinear viscous behaviour dependent upon an evolving grain size, the latter requiring an evolution law. The success of SPF is strongly dependent on maintaining an optimal strain rate, which can only be achieved by varying the pressure with respect to time [5]. Pressure cycle calculations employ a variety of formulations usually based on a maximum allowed desired target strain rate occurring anywhere within the forming material. In this paper, a general algorithm whereby the rate of work done by the pressure is equated to the rate of energy dissipated in the forming material enables a direct calculation of the pressure evolution with respect to time (see Figure 2).

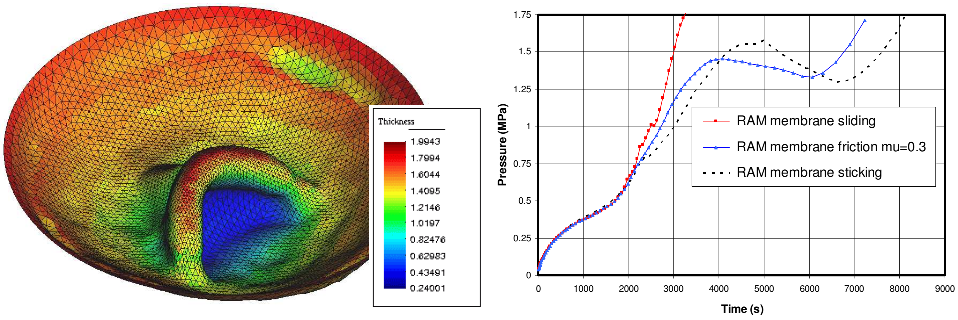

Figure 2: SPF numerical simulation of a dental prosthesis.

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