AceGen and AceFEM in custom M5 industrial applications

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Short abstract

This paper presents some industrial software applications based on AceGen and AceFEM packages and their usefulness in developing custom made numerical solutions for niche markets. These applications provide simplified user interface, hiding complexity of advanced finite element technology from non-expert user. Properties and advantages of applications are discussed on examples of metal forming, human skin biomechanics and tissue electroporation.

Keywords industrial applications, constitutive modelling, inverse analysis, optimization

1 Introduction

AceGen and AceFEM packages are already well known in academic community for developing new constitutive models and finite element formulations. Their characteristic combination of flexibility and numerical efficiency is also valuable for development of industrial applications and custom made numerical solutions targeted at specific problems. In this paper we are going to show examples of software applications based on AceGen and AceFEM packages, discuss their advantages and explain their use for developing M5 (multi-scale, multi-body, multi-field, multi-phase and multi-objective) solutions for a range of industrial problems in the areas of advanced materials, mechanical engineering, pharmaceutics, biomechanics, etc.

2 Software applications

2.1 Radial forging application

Radial forging is a type of incremental bulk metal forming process often used for conversion of steel ingots to bars (see Figure 1). Besides changing the dimension, the goal of the process is to achieve favourable microstructural changes and closing of internal porosity. Nowadays numerical simulation of radial forging is still a challenge, due to incremental nature of the process where final shape of the product is achieved in large number of deformation steps.

We have used the flexibility of AceGen and AceFEM to develop a software application for efficient 3D simulation of hot radial forging process. The application can enhance the understanding of forging process and consequentially optimize it with respect to product quality and energy efficiency. The main assumption is that deformation fields of consecutive hammer strokes are equal in spatial coordinate system and final shape of the workpiece is obtained by superposition of deformation fields in material coordinate system. Therefore only a limited number of hammer strokes needs to be simulated. Process is also speed up by taking advantage of periodic symmetry when forging round workpieces. Adopted constitutive models include custom defined equations for describing the plastic flow curves with respect to deformation, deformation rate and temperature. Indicators of damage and internal porosity evolution are calculated for chosen locations in the workpiece.

Radial forging is usually used for processing advanced steels and high temperature alloys that need special constitutive models to capture rich metallurgical processes that happen during forging. Therefore we are developing new elements for simulation of material densification in powder metallurgy and different approaches for simulation of material microstructure evolution.

2.2 Application for suction test inverse analysis

Suction test is one of the most popular in-vivo methods to characterize the skin mechanical properties, where a skin fold is sucked into a small opening and evolution of its displacement with time is measured (see Figure 2). We have developed a software application for simple simulation of suction test and its inverse analysis, with graphical user interface. It can be used to determine the parameters of the adopted constitutive model of the skin and to improve the understanding of skin mechanics.

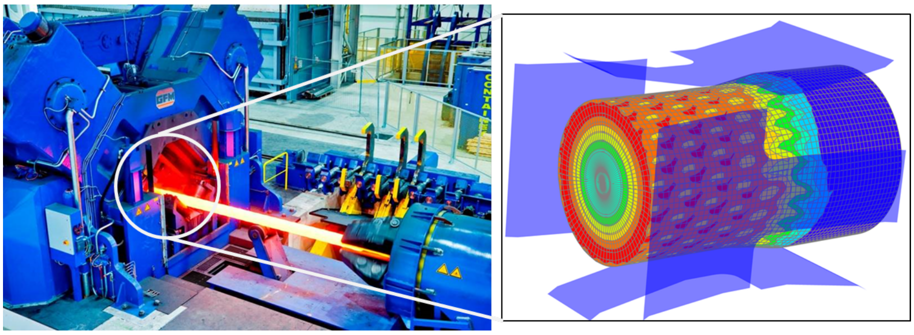

Figure 1: Radial forging process [3] with simulation mesh detail

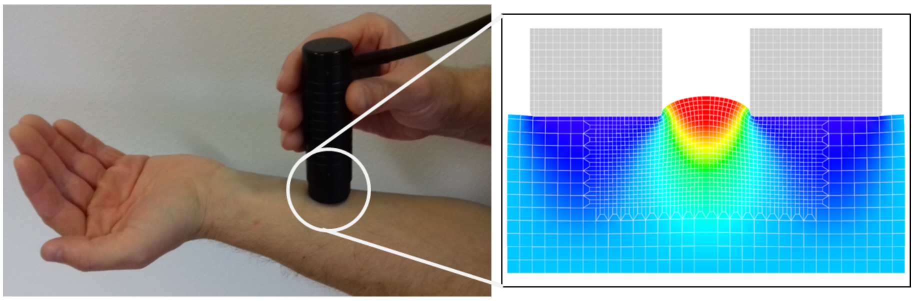

Figure 2: Suction test with simulation mesh detail

The main building block of the application is a parametric 2D axisymmetric FEM model of skin patch and experimental probe. Constitutive model for skin is visco-elastic and was chosen among many compared models in early stages of development. Response of the FEM model (time displacement) curve is then compared with experimental results and their gap represents the objective function that should be minimized in inverse analysis. Identification of optimal material parameters is significantly enhanced by exact first and second order sensitivity analysis which enables the calculation of gradient vector and Hessian matrix of the objective function.

The software has been developed within the scope of European Space Agency (ESA) founded project to evaluate human skin mechanical properties during long term space flights.

2.3 Electroporation modelling

Electroporation is a biological phenomenon where cell membrane opens due to electrical field allowing chemicals to be introduced into the cell. It is used in cancer treatment (electrochemotherapy) to deliver drugs only to the targeted tissue. Our software application which is already used in clinical practice calculates treatment plan consisting of optimal positioning of electrodes and respected voltages based on patient specific tumor shape. The current version of the software uses 2D analytical model for electric field distribution within the tumor and uses simplified geometric shapes to cover the tumor area. The new version of the software will use the FE modelling capabilities of AceFEM offering import of 3D tumor geometry and modelling of biological tissue response including time dependent effects of applied electrical pulses [1, 2]. First goal is to develop an application to support biomedical research on electroporation. In longer term we would like to push the application to clinical practice for improved treatment planning.

3 Conclusions

Using AceGen and AceFEM within Mathematica as main software development environment has numerous advantages, because it provides with rich visualization capabilities, data importing and exporting, optimization algorithms, machine learning, etc. Therefore developers can be more efficient, focusing only at modelling the physical problem. The process is fast and flexible because the models can be developed, tested and used in a unified environment. Customized solutions include a fully parametrized FEM model, graphical user interface and automated generation of results. This approach offers the possibility to provide advanced technology solutions for niche markets where the commercial codes offers rather excess functionality at high cost. On the other hand customized solutions for specific target process offers the possibility hide the numerical procedure complexity by providing a user interface containing only the relevant process parameters.

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