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Spark plasma sintering: Comparison between a fully coupled process numerical simulation and experimental data

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SPARK PLASMA SINTERING: COMPARISON BETWEEN A FULLY COUPLED PROCESS NUMERICAL SIMULATION AND EXPERIMENTAL DATA

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INTRODUCTION

Spark Plasma Sintering (SPS) is a process for powder compaction for which the number of studies is constantly increasing due to promising results. It consists in concurrently applying a load, and a pulsed direct current of very high intensity through graphite tooling in order to sinter powders. Regarding its application to metals, its growing popularity lies in the very fast temperature increase and short cycle time driven by the Joule's effect, which limits grain growth. However, the different and strong interactions between the different physical phenomena make the process difficult to develop and apply for routine industrial production. That motivates the development of numerical simulation in view of better understanding and optimization of the process. Up to now, very few models integrating the coupling between heat transfer, electric transfer and mechanics have been proposed.

In this study, results coming from a fully coupled numerical computation and experimental data are investigated in detail.

METHODS

A 3D finite element model has been developed, with three interacting modules. First, a compressible viscoplastic model (Abouaf type) was implemented in the finite element code FORGE® for the mechanical part, which provides the evolution of the spatial distribution of the relative density (porosity). Second, a new electrical solver has been developed and added to FORGE®. The third module is the pre-existing thermal solver of FORGE®, which was complemented to take into account the heat source associated with Joule effect. In addition, the dependence of electrical and rheological parameters with temperature (Molenat *et al*) and with the relative density for the powder is taken into account. In the present version of the numerical code, thermal dilatation, and the electro migration (Milligan et al*)* have been ignored.

The experimental data come from simple test cases of compaction of cylinders made from TiAl powder and sintered in a SPS machine (Sinter 2080, SPS Syntex Inc). The material used is an intermetallic TiAl with an initial relative density equal to 0.63. The temperature cycle is controlled by a PID procedure monitoring the current density, while a time dependent axial force is applied. The aim of this study is to validate the numerical model by comparing the evolution of relative density, height and temperature.

RESULTS

The viscoplastic compressible model and the thermoelectrical solver were successfully implemented using linear tetrahedral elements. Both of them were validated by using analytical solution for simple cases. During the computation of the full process, the temperature and the potential field are an important output for the validation (fig.1).

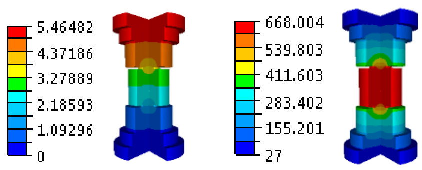

Figure 1: Electrical potential in Volt (left) and temperature induced in °C (right)

The powder sintering can be followed by the relative density value, the temperature and the displacement of the punches.

DISCUSSION

Using this new numerical model, the shape of evolution of the temperature and the displacement of the punches with time are in agreement with the experimental measurements. So the sintering of the sample can be predicted.

REFERENCES

Abouaf, Modélisation de la compaction de poudres métalliques frittées, PhD, 1985.

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