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MACROSCOPIC CONSTITUTIVE MODEL OF SINTERING PROCESSES AND ITS NUMERICAL IMPLEMENTATION

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1. Introduction

This paper presents macroscopic model of single-phase powder sintering processes and its numerical implementation within the framework of a MUSINT project which is carried on in Institute of Fundamental Technological Research, Warsaw, Poland. The overall objective of the MUSINT (Multiscale numerical modelling of sintering processes) is development of numerical models allowing us to analyse at various scales manufacturing processes employing sintering as the main technological stage. In order to provide high efficiency model, numerical predictions will be validated by comparison with experimental results.

2. Constitutive model of single-phase sintering

Sintered material is treated as continuous medium at the macro scale. Its constitutive model is tightly related to observations done at the micro scale (single grain level) and fully consistent with the model describing the microscopic mechanical phenomena of the sintering process. Such a model, proposed by Nosewicz [1], is schematically depicted in Figure 1. The macroscopic model is derived

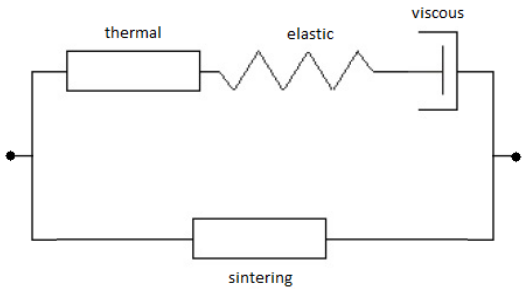

Figure 1. Mechanical scheme of the constitutive model of sintering[1]

with the use of methodology known from works of e.g. Zhang [2]. The total strain rate is a sum of three parts: thermal, elastic and viscous, as follows:

$$\dot{\boldsymbol{\varepsilon}} = \dot{\boldsymbol{\varepsilon}}^{th} + \dot{\boldsymbol{\varepsilon}}^{e} + \dot{\boldsymbol{\varepsilon}}^{visc} \tag{1}$$

Thus, the constitutive equation has the form:

$$\dot{\boldsymbol{\sigma}} = \mathbf{D}\left(\dot{\boldsymbol{\varepsilon}} - \dot{\boldsymbol{\varepsilon}}^{th} - \dot{\boldsymbol{\varepsilon}}^{visc}\right) + \dot{\boldsymbol{\sigma}}^{s} \tag{2}$$

where:

- thermal strain

$$\boldsymbol{\varepsilon}^{th} = \alpha T \mathbf{I} \tag{3}$$

- viscous strain rate

$$\dot{\boldsymbol{\varepsilon}}^{visc} = \frac{\boldsymbol{\sigma}'}{2\eta_s} + \frac{tr(\boldsymbol{\sigma}) - 3\sigma_s}{9\eta_b}\mathbf{I}, \tag{4}$$

- sintering stress

$$\boldsymbol{\sigma}^s = \sigma_s \mathbf{I} \tag{5}$$

$$\sigma_s = \frac{\beta\gamma_s\hat{\rho}^2}{r_0}\frac{1}{\left[(1+\varepsilon_1)(1+\varepsilon_2)(1+\varepsilon_3)\right]^2} \tag{6}$$

All parameters of the above equations — viscosity η_s, η_b, relative density $\hat{\rho}$, surface energy γ_s etc. are related to microscopic material properties. They may also be functions of temperature. These relations are subject to investigations in our research.

The model is implemented in the form of a user subroutine in ABAQUS [3]. Numerical results will be presented on the Conference.

3. Acknowledgements

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4. References

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[3] Abaqus FEA v. 6.13-3. Dassault Systèmes Simulia, 2013