Constitutive Modelling of Sintering Processes Using the Discrete Element Method

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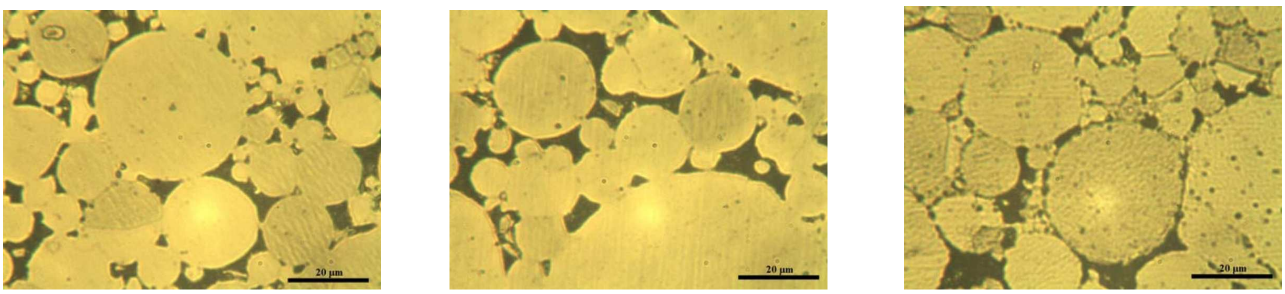
1. Basic information about sintering

Sintering is a manufacturing process used for making various parts from metal or ceramic powder mixtures. This is a complex process affected by many factors. Modelling can be used to optimize and to understand better the sintering process and improve the quality of sintered components. Modelling of sintering process is still a challenging research task. The aim of the work presented in this article is numerical modelling and simulation of a sintering process using the discrete element method.

Sintering consists in consolidation of powder mixture at elevated temperatures, close to the melting temperature with or without additional pressure. During sintering particulate material is converted into polycrystal. Evolution of the microstructure during sintering is shown in Fig. 1. In the initial stage (Fig. 1a) cohesive bonds are formed between particles. The main driving force of sintering is reduction of the total surface energy of the system. When the sintering process is continued (Fig. 1b) the necks between particle grow due to mass transport by different mechanisms. Surface and grain boundary diffusion are important mass transport mechanisms in many sintering processes. As a result of the stresses in the neck and the surface tension the particles are attracted to each other leading to shrinkage of the system. The described processes, shrinkage and mass transport, lead to the reduction of material porosity (Fig. 1c).



a) b) c)

Figure 1. Microstructure evolution during sintering of NiAl: a) early stage, b) intermediate stage, c) final stage (experiments performed at Institute of Electronic Materials Technology).

2. Numerical model of sintering

There are different approaches in modelling of sintering processes, ranging from continuum phenomenological models to micromechanical and atomistic ones. In this work the discrete element method is adopted as a modelling tool. Discrete element method assumes that material can be represented as a collection of spherical particles interacting among one another [1]. The numerical model of sintering has been implemented in the finite/discrete element code Simpact [2]. The particle interaction model assumed for sintering (Fig. 2) employs the equation derived in [3]:

(1)
$$F_n = \frac{\pi a^4}{8D_b} V_n + \pi \gamma_S \left[4R \left(1 - \cos \frac{\Psi}{2} \right) + r \sin \frac{\Psi}{2} \right]$$

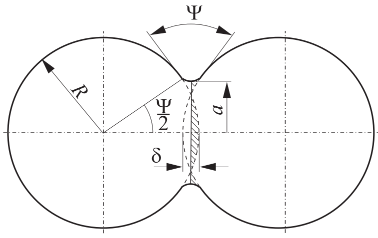
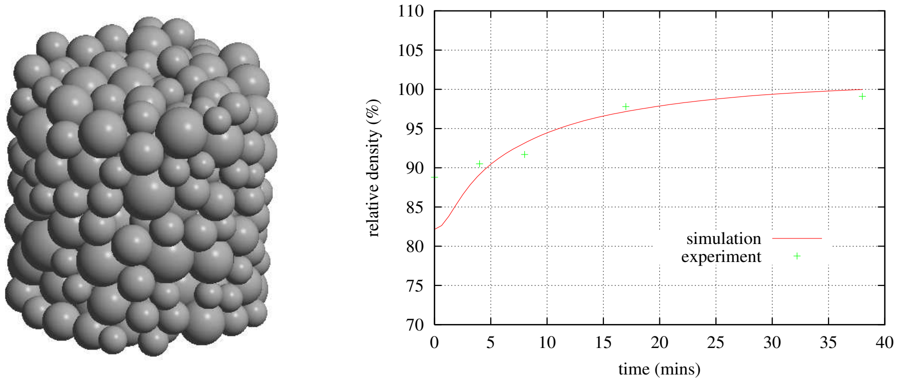


Figure 2. Two-particle model of sintering.

where F_n is the normal force between two particles, V_n – the normal relative velocity, R – the particle radius, a – the sintering contact radius, Ψ – the dihedral angle, γ_S – the surface energy and D_b – the grain boundary diffusion coefficient.

Sintering of the NiAl powder has been analysed. The discrete element model of a sintered specimen is shown in Fig. 3a. The relative density evolution obtained in the numerical simulation has been compared with experimental measurements (Fig. 3b). Quite a good agreement can be observed.



a) b)

Figure 3. Numerical modelling of sintering: a) two-particle model of sintering, b) discrete element model of a sintered specimen, b) evolution of relative density during sintering process.

3. Concluding remarks

The discrete element method takes explicitly into account the particulate nature of the sintered material. Presented results show a big potential of the developed numerical model in modelling of sintering processes.

Acknowledgement

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4. References

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