COMPUTER SIMULATION OF NECK GROWTH
DURING SINTERING PROCESS

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INTRODUCTION

Modeling and simulation of sintering process offer better possibilities in comparing theoretical to experimental results. Very often it is impossible to obtain, especially by investigating a time depended process through experiments, relevant parameters by which the process can be described either quantitatively or qualitatively.

The great complexity of the sintering process and the impossibility of following the action of its main mechanisms have encouraged interest in an investigation of this process by both modeling and simulation. At that, the efficiency of simulation is determined, most frequently, by the very manner and quality of consideration of physics of both elemental processes and phenomena that condition the quality of their modeling, as well.

In an earlier paper the neck growth kinetics was determined by a modified model of the sintering diagram. The dependence of a neck radius on temperature and on sintering time was obtained by numerical integration of rate equations of the mass transport mechanisms. The suggested method is particularly suitable for the prognosis of the sintering process, as enabling definition of the basic parameters of the process in question.

The purpose of this paper was to solve the problem of modeling and simulation of neck growth kinetics during sintering process. Having defined the total process rate as well as the conditions of its action, we suggested the simulation method for the neck growth during sintering process. The main characteristic of the method is to take into account an arbitrary number of mechanisms and analyze their simultaneous and successive action. Numerical integration of rate equations represents the basis of this method. Process simulation could be done under conditions of either constant or changeable temperature. We also defined functional dependence for the determination of contact surface as a 3-D function of topological parameters for the model of two spheres or for the model of an aggregate of spheres. In some cases polyhedral approximation instead of spheres is acceptable too, where the polyhedron can be constructed as a 3-D graph.
NET SINTERING RATE

Let

\[
\left( \frac{dx}{dt} \right)_k = f_k(x, T; A, B) \quad (k = 1, 2, \ldots, m)
\]

be the equations that define the rates of elementary transfer mechanisms as a function of neck radius \((x)\) and sintering temperature \((T)\), where \(A = (a_1, \ldots, a_r)\) and \(B = (b_1, \ldots, b_s)\) are system state vector and process parameters vector, respectively. As the sintering process is characterized by simultaneous and successive action of these mechanisms, then the net sintering rate during this process can be calculated as a sum of the form

\[
\frac{dx}{dt} = f_1(x, T; A, B) + \cdots + f_m(x, T; A, B).
\]

NECK GROWTH KINETICS

Let \(\{x_i\} x_{i+1} - x_i = const\}_n\) and \(\{T_i\}_n\) be arranged, according to increasing values, as sets of neck size values and sintering temperature respectively. Let the sintering process is defined by points \((x_i, T_i)\) by that the increment in temperature from \(T_i \rightarrow T_{i+1}\) will cause a neck size growth \(x_i\) for \(\Delta x\). At that, the total rate value in each point \((x_i, T_i)\) will be

\[
\frac{dx}{dt}(x_i, T_i) = \sum_{k=1}^{m} C^i_k = C^i \quad (C^i_k = f_k(x_i, T_i; A, B)),
\]

where \(C^i\) is the corresponding numerical rate value. When approximating the first derivative of the last equation by difference

\[
\frac{dx}{dt}(x_i, T_i) \approx \frac{x_i - x_{i-1}}{\Delta t},
\]

we obtain an expression that defines the corresponding time steps as follows

\[
\Delta t_i = \frac{x_i - x_{i-1}}{C^i} \quad (\Delta t_1 = \frac{x_1}{C^1}).
\]

When we apply the last expression, the time dependence of a neck radius can be defined with a set \(\{t_i\}_n\) obtained on the basis of the relation

\[
t_i = t_{i-1} + \Delta t_i \quad (i = 1, 2, \ldots, n; t_0 = 0)
\]

and added to the set \(\{x_i\}_n\), where \(\Delta t_i\) is a function of a neck radius and of sintering temperature, i.e.

\[
\Delta t_i = \Delta t_i(x, T, A, B).
\]

The sintering process is carried out within time intervals \(\{\Delta t_i^*\}_n\) at temperature \(\{T_i\}_n\) stepwise heating, when both time and temperature steps

\[
\Delta t_i^* = t_i^* - t_{i-1}^* \quad (t_s = 0)
\]

\[
\Delta T_i = T_{i+1} - T_i
\]