Procedure to Measure Reliable Thermophysical Data during Debinding and Sintering using Thermo-Kinetic Process Modelling

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Both, the prediction of the net shape of sintered part and the estimation of stress during the sintering process are based on the knowledge of the transient spatial densification. The transient spatial densification itself can be described with a thermo-kinetic model of the sintering process which is strongly determined from the local transient temperature history within the sintered part. The required thermophysical data: density ρ, specific heat c_p, and thermal conductivity λ have to be determined from a "material in progress" regarding that a sintering material is a continuously transforming material. The measurement of thermal density intrinsically captures the significant densification of the sintered material and the thermal response thereof. To obtain reliable data from specific heat, the characteristics of mass loss during the debinding process must be considered. When starting with chemically de-waxed green parts in a first approach decomposition enthalpy can be neglected. And specific heat of the transforming parts is calculated with the rule of mixture – using measured data from the constituents, and considering process relevant mass loss from a kinetic model derived from thermo-gravimetric measurements: geometrically stepped heating rates are applied. The use of flash methods to determine the thermal diffusivity requires the exact knowledge of the actual thickness of the measured sample. The shrinkage of the sample has to be taken into account to obtain sufficient diffusivity data. Hence for diffusivity measurements a temperature history regarding to the production routine is used. Transient shrinkage is calculated from a kinetic model which is established from a set of dilatometer measurements: once more geometrically stepped heating rates are applied. The procedure leads to corrected thermal diffusivity data which are correlated with the actual density of the part during sintering. Based on these optimised thermophysical data, a realistic transient temperature field can be calculated. This provides a significant improvement in the through-process-modelling of any powder-metallurgical based technology. The validity of the thermo-kinetic models is confirmed from rate controlled mass loss experiments (RCM) and sintering experiments (RCS) under laboratory conditions and production conditions as well. Maximum correction of diffusivity and conductivity data at maximum sintering temperature was about 50% referred to the corrected value.