Electric Field Assisted Sintering and Related Phenomena Far From Equilibrium

Proceedings

Spring 3-6-2016

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Spark Plasma Sintering of a Functionally Graded Material Consisting of a High-Alloyed CrMnNi-Steel and Varying Mg-PSZ Content

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A functionally graded material (FGM) consisting of a TRIP steel matrix (**TR**ansformation **I**nduced **P**lasticity) and a varying Mg-PSZ particle reinforcement (**Mg**O **P**artially **S**tabilized **Z**irconia) was sintered by Spark Plasma Sintering (SPS). The used steel is high-alloyed (16 wt.% Cr, 7 wt.% Mn, 3 wt.% Ni) and the Mg-PSZ content decreases along the sample height from 100 vol.% to 0 vol.%. Hence, the bottom of the sample consists of a pure ceramic layer. Due to the different melting temperatures and therefore different optimal sintering temperatures of steel and Mg-PSZ, it is challenging to densify the FGM in one sintering step. A temperature gradient has to be created along the sample height. To achieve a temperature gradient, the sample was shifted 3.5 mm upwards from the die centre on the one hand. On the other hand, two additional layers of graphite foil were placed either on the pure steel side of the FGM or on the pure Mg-PSZ side. In all cases, the sintering temperature was controlled by a vertical pyrometer, measuring the temperature in the graphite punch. The sinter temperature was set to 1100 °C. All tool set up options led to the formation of a temperature gradient along the sample height. Especially the pure Mg-PSZ layer exhibited a higher density, compared to samples sintered by a symmetric tool set up. Furthermore, the steel phase locally melted in particular if additional graphite foils were placed on the pure steel side of the FGM. Thus the steel melt infiltrated the pure Mg-PSZ layer of the FGM. Larger sintering temperature were achieved in the ceramic rich area of the FGM sintered with additional graphite foils on the FGM sample side consisting of pure Mg-PSZ and within the FGM sintered eccentric in the die, compared to samples sintered in a symmetric tool set up. Hence, these samples exhibited a larger density and hardness. However, the FGM sintered eccentric in the die exhibited cracks due to high thermal stresses. Altogether, the FGM sintered with additional graphite foils on the Mg-PSZ side exhibited the best properties. Sintering this FGM, the temperature was determined by thermocouples and pyrometer within holes in the die, 3 mm away from the sample, in the die centre and 2 mm above and below the die centre. The temperature in the die centre deviated maximal 40 K from the measured temperature in the punch. Increasing the sinter temperature from 500 °C to 1100 °C, the temperature deviation between the die centre and the hole 2 mm below the die centre decreased from 100 K to 10 K. In contrast, the temperature deviation between the die centre and the hole above decreased from 250 K to 40 K. Hence, the die centre is still the warmest area, but the temperature distribution is not symmetrical anymore.