Densification mechanism during Spark plasma sintering of SAF 2205 Composite

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Highlights

- Duplex stainless steel reinforced nano–sized TiN was successfully fabricated via SPS
- Improved hardness and density with sintering temperature up to 1150 °C.
- Shrinkage rate showed 3 peaks of particle rearrangement, localized and bulk deformation.

1. Introduction

This study presents an investigation into the mechanisms involved during the densification of SAF 2205 and TiN powder particles by the spark plasma sintering (SPS) technique. SPS is a pressure assisted sintering techniques and has been widely applied for the fabrication of various materials such as metals and alloys, intermetallic, ceramics, metal–ceramic and ceramic–ceramic composites [1-2]. SPS have gained attention due to its advantages of high heating rate, lower sintering temperature and shorter holding time as compared with other conventional sintering process [3-4]. The densification data obtained during SPS of powders can be utilized to have a thorough grasp of the underlying deformation/densification mechanism during SPS. A previous study by Bernard-Granger and Guizard formulated a hypothesis based on creep deformation to understand the controlling mechanisms during the densification of the SPS process [5].The creep model have been utilized to predict the densification mechanism of metal matrix composites during the SPS process but the understanding of the fundamental microscopic mechanisms of densification is still largely unexplored. From our previous study, SAF 2205-TiN composite have shown promise to be materials of choice for wear and high temperature application, an attempt is made in this study to provide information on densification behaviour of the composite using the creep deformation model.

2. Methods

The starting materials are Duplex stainless steel powder grade (SAF 2205) with average particle size of 22 µm and TiN nanopowders with average particle size of 20 nm. The powders were mixed in a Turbula Mixer T2F at a speed of 72 rpm for 8 h to ensure thorough mixing of powders. The mixed powders (SAF 2205 and 5 % TiN) were poured and pressed in a graphite die and then sintered using a spark plasma sintering machine (model HHPD-25, FCT GmbH Germany). To study the densification mechanisms and to evaluate creep parameters using analytical model during SPS of powders, the parameters chosen are as follows. The sintering temperatures of 1000, 1100, 1150 and 1200 ^{o}C. Uniaxial applied pressure of 50MPa was kept constant throughout the experiment. Analysis was done for isothermal holding/soaking time of 10 min at all above mentioned temperatures.

3. Results and discussion

The results show gradual change in the microstructural morphology of the stainless steel/TiN composite with an increase in the percentage of ferrite phase relative to the austenite phase with an increasing sintering temperature. Improved density and hardness was noted with increase in sintering temperature up to 1150°C. A decrease in density and hardness was observed when sintering temperature was increased to 1200 ^{o}C. The decrease in density and hardness could be attributed to localized melting of powders. The densification phenomena taking place during sintering was studied. There was an increase in shrinkage rate and localized

deformation with increase in temperature up to 1150 °C, however a slight drop in peak was observed with further increase of sintering temperature. The deformation process followed an initial rearrangement of the powder particles, localized deformation at contact of powders and bulk deformation of the sintered product. The degree of densification is a function of the intensity of the peaks and the extent of deformation of the particles. Extensive study on the sintering kinetics was carried out using the creep model. The proposed model identified pure diffusion, grain boundary sliding and dislocation-climbing as the three dominate densification mechanisms that occurs during sintering of the composites.

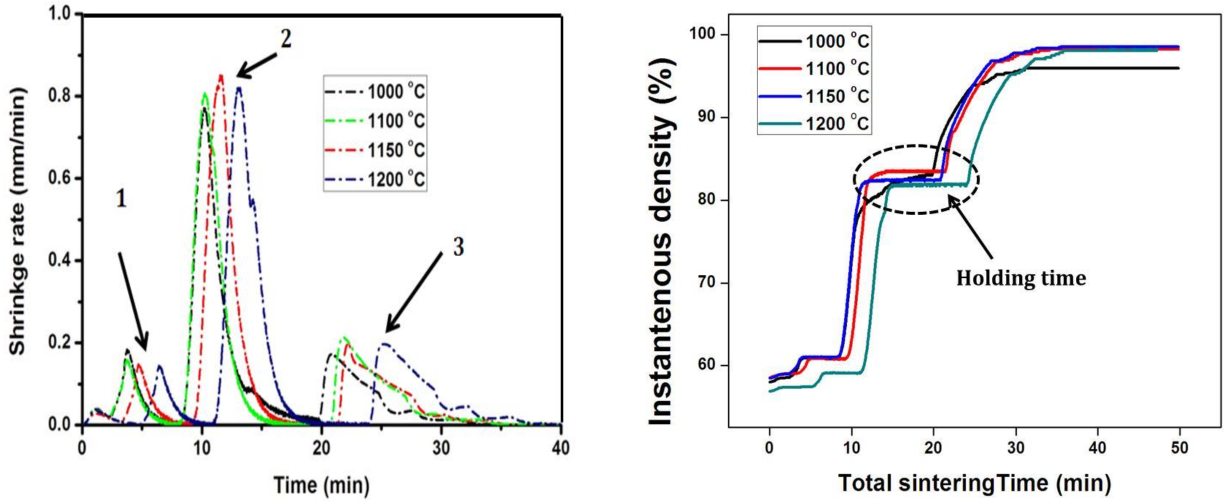

Fig 1 and 2: Shrinkage rate versus time and instantenous densification curves at different temperatures for the 2205 DSS/TiN respectively

4. Conclusions

DSS 2205-5%TiN composite has been synthesized by SPS. The influence of sintering temperature on densification mechanism and microstructure was studied. The results show that hardness, density and microstructure of the sintered composites largely depend on the sintering temperature. The SEM/EDS revealed the presence of nano ranged particles of TiN evenly distributed at the grain boundaries of DSS matrix. A decrease in densification and hardness was observed when sintering temperature is 1200°C. All composite grades displayed similar shrinkage behavior irrespective of the sintering conditions with three distinctive deformation peaks. The dominant densification mechanisms are grain boundary sliding and dislocation-climbing.

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Keywords

Densification; Spark plasma sintering (SPS); Duplex stainless steel (SAF 2205); Particle-reinforcement