Accepted Manuscript

A combined model to simulate the powder densification and shape changes during hot isostatic pressing

C. Van Nguyen, Y. Deng, A. Bezold, C. Broeckmann

PII: S0045-7825(16)30662-4
DOI: http://dx.doi.org/10.1016/j.cma.2016.10.033
Reference: CMA 11194

To appear in: *Comput. Methods Appl. Mech. Engrg.*

Received date: 1 July 2016
Revised date: 22 October 2016
Accepted date: 24 October 2016

Please cite this article as: C. Van Nguyen, Y. Deng, A. Bezold, C. Broeckmann, A combined model to simulate the powder densification and shape changes during hot isostatic pressing, *Comput. Methods Appl. Mech. Engrg.* (2016), http://dx.doi.org/10.1016/j.cma.2016.10.033

A combined model to simulate the powder densification and shape changes during hot isostatic pressing

C. Van Nguyen, Y. Deng†, A. Bezold†, C. Broeckmann†*

* Sinterwerke Herne GmbH, Forell 100, 44629, Herne
† IWM, RWTH Aachen, Augustinerbach 4, 52062 Aachen, Germany

Corresponding author: Chung, Van Nguyen
E-Mail: Chung.VanNguyen@sinterwerke.com
Phone: +49(2323) 201307; Fax: +49(2323) 201422

Abstract

Under high temperature and pressure during Hot Isostatic Pressing (HIP), various deformation and sinter mechanisms such as plastic yielding, power law creep, and diffusion occur. They contribute either simultaneously or consecutively to the densification process depending on temperature and pressure levels. Some published works have shown that neither the pure plastic model nor the pure viscoplastic model sufficiently model the densification process during HIP, therefore a combined model which includes both a time independent plasticity and a rate dependent plasticity (creep) should be used. An innovative aspect of this work in comparison with available models in literature is the accommodation for model inaccuracies in the initial creep stage. The densification model incorporates the initial creep mechanism which occurs for a short time with a higher rate as compared to the steady stage creep rate. In this study, a combined model which consists of the influence of plasticity, primary creep, and secondary creep mechanisms is used. The authors believe that this approach can improve the quality of “near-net-shape” simulation.

Innovative Aspects: The proposed model is more robust and predicts the final shape of HIP-ed components better which will support the production of Selective Net Shape or Net Shape HIP components. The reported results are of importance for companies producing big and complex shaped components through powder-HIP.

Keywords: Hot Isostatic Pressing (HIP); Combined Model; Numerical Simulation; Densification; Final Shape Prediction.

1. Introduction

Powder Hot Isostatic Pressing (PM HIP) is a modern manufacturing process for the production of complex and highly specified components made from a wide range of metals and/or ceramics. The use of PM HIP parts increases quickly nowadays in markets such as oil industry, chemical industries, tooling, energy etc [1] [2]. One important advantage of PM HIP is the possibility to produce large and massive near-net-shape metal components such as parts applied in the oil and gas industry weighing up to 30 metric tons, or net-shape impellers up to one meter in diameter. The use of HIP increases thanks to its advantages compared to other conventional manufacturing methods such as forging, casting etc [3] [4]. The Principle of the powder HIP process (PM HIP) is described as follows: a steel capsule, with a thickness typically ranging from 2 to 4mm, is filled with powder. Tapping and vibration are usually used as a pre-consolidation process in order to increase the initial relative density of the powder compact. In the next step the capsule is out-gassed, sealed, and placed into the HIP device where it is submitted to an inert gas pressure of about 100 MPa and temperatures higher than 70% of the absolute melting temperature of the metal powder for several hours. After HIP 100% material density is obtained. In theory, hot isostatically pressed components should have isotropic shrinkage under isostatic pressure load but in practice this is often not the case. Non-uniform shrinkage of components and even high distortion have been observed in [5] and in our previous works [6] [7]. This problem leads to high cost for post processing and longer delivery time. In order to improve cost efficiency, near net shape HIP parts must be produced from the first shot with the minimal geometrical allowances. This challenge can only be done with the support of a HIP simulation tool. Many different constitutive densification models and simulation tools have been reported, which relate to two different approaches to simulate the densification process of porous powder during HIP: mesoscopic and macroscopic approach as summarized by Jinka and Lewis [8] and Nohara et al [9]. In this study, a macroscopic-continuum modelling approach is chosen for further study because it has fewer parameters compared to the mesoscopic approach. Additionally, it can predict the shape changes and is convenient to use for complex geometrical component as concluded in in the work of Svoboda et al. [10] and Häggblad et al.