MOLDING COMPOUNDS BASED ON PARTIALLY WATER-SOLUBLE ORGANIC BINDER FOR PRODUCTION OF COMPLEX SHAPED CERAMIC MICRO PARTS

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Keywords: *powder injection molding, zirconia, water-soluble polymer, binder system*

1 Introduction

Micro-powder injection molding (µ-PIM) allows for industry-related and low-cost production of small complexly shaped ceramic or metallic micro parts with high sintered density. The process consists of feedstock compounding from fine powder and thermoplastic polymers, shaping to a green body via micro-powder injection molding and two post processing steps namely solvent and/or thermal debinding and sintering [1].

The quality and stability of each production step as well as the properties of final micro parts depend on the choice of the suited binder system [2]. In addition to two important requirements on binders such as the high feedstock flowability for a complete mould filling and the sufficient stability during demolding and solvent debinding, there is also an environmental aspect. Conventional wax-polyethylene-based binders are widely used, but have a disadvantage, that toxic and high flammable hexane [3] or heptanes have to be applied as organic solvent to extract the wax. In order to overcome this problem, this research work deals with the development of a new binder composition based on common water-soluble polyethylene glycol (PEG) and polyvinyl butyral (PVB), which is well-known from tape casting. The results presented in this paper cover the compounding of homogeneous zirconia feedstocks, their rheological properties, moulding capability, water debinding mechanisms as a function of temperature and time as well as quality characteristics of sintered micro parts.

2 Experimental and Results

A multi-component binder system was used to fabricate injection molded specimens. In addition to the major portion of PEG und PVB mixture stearic acid was used as surfactant for improving feedstock flow behavior. The binder components were mixed with commercially available zirconia powder (Tosoh Corp., TZ-3YS-E) in a mixer kneader (Brabender W 50 EHT). The compounding of homogeneous feedstocks as well as their rheological properties were studied for various filler loadings of sub-micrometer zirconia, where a critical filler loading of 56 vol% was observed. Fig. 1 shows the recorded torque during compounding under ambient conditions for one hour at a temperature of 125°C with a constant rotation speed of 30 rpm. The influence of solid load on the feedstock viscosity of ceramic compounds was measured at 160°C using a high pressure capillary melt rheometer from Goettfert and is presented in Fig. 2.

Shaping experiments were carried out using a Microsystem 50 injection molding machine (Battenfeld) using either isothermal or variothermal process control. To test the basic process ability of the prepared feedstocks several specimen geometries such as tribological disc, flexural micro part and micro gear housing were chosen.

After shaping the green bodies were subjected to successive treatments of solvent and/or thermal debinding and sintering. The solvent debinding was performed in de-ionized water at different temperatures for 16 h with continually stirring of the liquid. This step allows removing most of the water soluble binder component in the investigated

PVB/PEG binder systems, which simplifies the later thermal process steps. These experiments showed that the best dimensional stability was found at room temperature where about 94% of the PEG-content can be extracted after only 4 hours. The remaining binder constituents were burned out by following thermal treatments in air.

To characterize possible potentials of the new binder system completely the probability to debinde the micro parts just thermally was investigated, too. A concluding sintering step at 1450°C led to final parts with a high relative density close to hundred percent in both cases.

Fig. 3 exemplarily shows a photographic image of a greenbody of micro gear housing (left) and sintered parts without (middle) and with a solvent debinding step in water (right).

3 Acknowledgements

The authors thank the Deutsche Forschungsgemeinschaft (DGF) for financial support within the Collaborative Research Centre SFB 499 and all colleagues at KIT Campus North involved in this work.

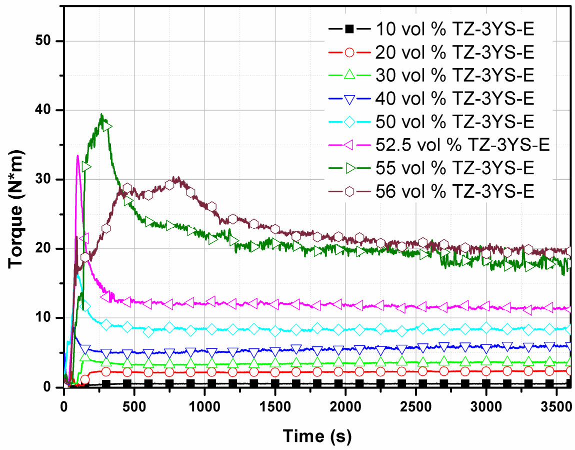

Fig.1. Torque during compounding under ambient conditions of increasing zirconia contents, dispersed in PVB/PEG mixture, including stearic acid as surfactant.

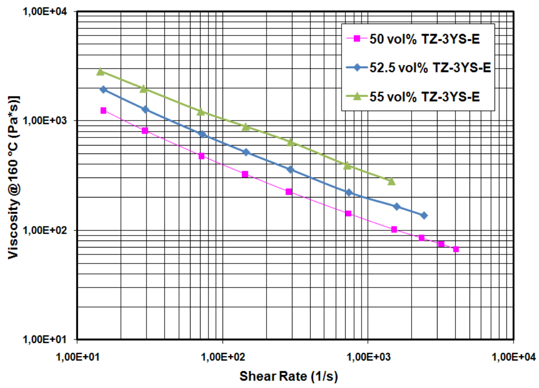

Fig.2. Influence of solid load on feedstock viscosity of ceramic compounds using PVB/PEG as binder system including stearic acid as surfactant.

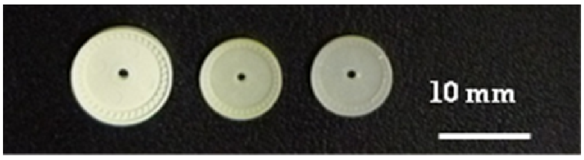

Fig.3. Greenbody of gear housing (left) realized with 55vol% zisconia feedstock and sintered parts without (middle) and with the solvent debinding step (right).

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