Development of a compact micro machine for the machining of powder-injection moulded (PIM) green compacts

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Abstract

Micro powder injection moulding belongs to the group of primary shaping methods. The advantages of the method include the almost unlimited range of options to choose from in terms of metallic or ceramic materials, the high level of achievable complexity, and the good automation capability. The method is highly suitable for high-volume production. [2] However, it is only suitable for large lot sizes because of the high costs incurred for tools. An increase in the complexity of the moulded component requires a more complex injection-moulding tool.

wbk Institute of Production Science has developed an innovative approach for the flexible and yet profitable production of PIM components that is based on the machining of PIM green compacts prior to sintering. This way, the number of varieties of PIM parts can be increased, and it is possible to manufacture PIM parts also in small volumes. A chip-removing CNC controlled micro machine for green compact machining was developed. The paper describes the development of a 2-axis machine with small installation space and its integration into the existing µ-PIM process chain at wbk Institute of Production Science.

1 Introduction

The micro powder injection moulding process is used to produce solid metal or ceramic components with the same level of complexity as plastics-injection moulded parts. Firstly, the feedstock, a granular material made from a binder system on a plastics basis that includes metal or ceramic particles is moulded. Afterwards the moulded parts, which are referred to as PIM green compacts, are debindered thermally, catalytically, or through the use of a solvent. After debindering, the components are compacted by being subjected to another thermal process, i.e. sintering. During sintering, the powder particles combine, and the components reach their ultimate consistence. The complex metallic or ceramic components resulting from the sintering process have very small tolerance deviations. Because of the high tool costs the method is only suitable for high-volume production. The quantity is generally higher than 10,000 units per year.

Research conducted at wbk is looking into green compact machining so as to ensure that a high diversity of variants can be provided for small volumes. PIM green compacts with the same basic shape are moulded with the same tool. The following machining process serves to provide the parts with different detailed structures. Contrary to the machining of sintered parts, less machining force is required to machine green compacts because they have lower resistance, so that it is possible to use a machine tool with a compact design.

1.1 Development of the chip-removal tool for green compact machining

The machine was developed following the development methodology defined in VDI 2221 “Systematic approach to the development and design of technical systems and products”.

1.1.1 Process requirements

Firstly, the process requirements for the machine were derived. The green compacts, which measure between 1-10 mm typically, are produced within the wbk µ-PIM process chain. They will then be machined. The target structures are detailed structures such as grooves, chamfers and bores that are machined with µm accuracy. The machining forces can be considered negligible in relation to the driving forces required for axes travel because of the low strength of the feedstock. Preliminary milling trials have shown that the best parameters for the machining of green compacts are a tool rpm of 9000 rpm and a feed of 0.5 mm/min [1]. The process is supposed to be automated and integrated into the existing wbk µ-PIM process chain.

1.1.2 Definition of functions

Secondly, functions are identified on the basis of the process requirements. The overall function of the machine, i.e. “green compact machining", was broken down into the required subfunctions such as travel, positioning and chip removal and the resulting functional requirements (table 1).

Table 1: Process and functional requirements

Process requirements	Functional requirements
Machining of grooves, bores and chamfers	≥ 2 Machine axes
Component dimensions: 1 – 10 mm	Operating range: 10 mm
Machining accuracy: high - machining with µm accuracies	High positioning accuracy Low-vibration operation → High machine stiffness → High running smoothness
Machining forces < 20 N	External forces: negligible
Tool feed: 0.5 mm/min	Straight line velocity: 0.5 mm/min
Tool rpm: 9000 rpm	Spindle speed > 9000 rpm

2 Results

According to the functional requirements the machine concept was developed (Fig. 1, left). The machine has two axes, a vertical machine bed (stiff welded construction), and two sliding carriages which hold the tool spindle. The two carriages are guided on roller-type anti friction guideways, which provides for the required stiffness. The drive of the sliding carriages is composed of servo motors and prestressed ball screw assemblies that are free of backlash.

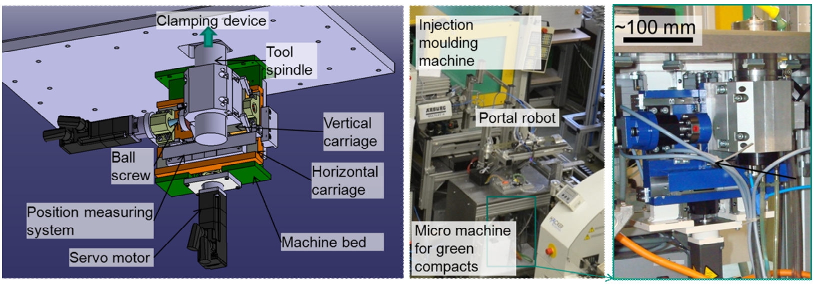

Figure 1: left: Machine design, right: Machine, integrated into the µ-PIM process chain

Low-vibration operation is ensured by the vertical, aerostatic high-speed spindle for component overhead machining, the feed axes and the stiff machine bed. A control loop with an integrated magnetic position measuring system provides for precise positioning. The reference values are provided by a Siemens Simumeric 802 C CNC control. For integration into the existing process chain (Fig. 1, right) the machine was set up on a stiff rack made from aluminium profiles. The green compacts are loaded by a portal robot. After the machine had been set up, and after the components had been aligned, the control systems were put into operation. During the process, the drive controls were parameterised, and the machine data were entered. Finally, a sample machining process was implemented during which a chamfer (to be used as a joining surface) was machined into a cylindrical green compact. The chamfer that was cut into the cylindrical sample (2.5 mm outer diameter) with a single-edge cutter, has a taper angel of 11°. Fig. 2 illustrates the machining of the first green compact, a hollow-bored sample before and a tapered sample after the machining process shown.

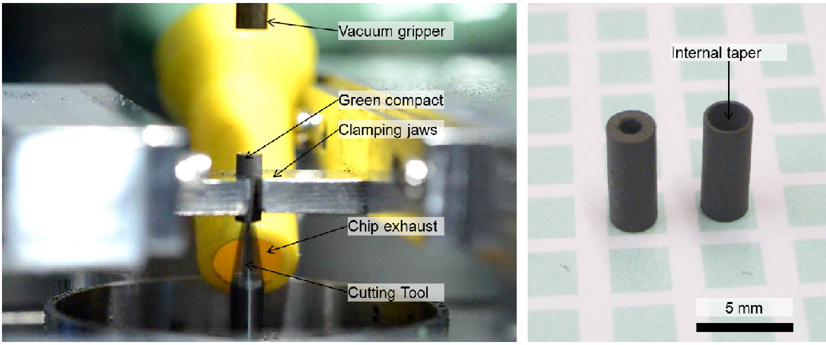

Figure 2: machining of a green compact; hollow-bored and tapered sample

5 Summary and Outlook

The paper describes the development, implementation and first operation of a 2-axis machine tool for PIM micro and miniature parts in the green state. Further research will look into the characterisation of the machine regarding its machining accuracy.

Acknowledgements

The authors gratefully acknowledge the support of the German Research Foundation (DFG) within the Collaborate Research Center 499 (SFB 499).

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