Research on the Machining of Green Feedstock Material for Sinter Joining

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Abstract

Miniaturisation in combination with functional integration has become one of the central aspects of product engineering worldwide [1]. The need for novel procedures is particularly pressing in the field of joining methods and technology in the micro range. Sinter joining is an innovative joining method for micro engineering [2]. It comprises the assembly of green powder injection moulded parts prior to sintering and the subsequent sintering process to join the parts. Sinter joining allows for component assemblies to be moulded as separate low-complexity parts which are then joined to complex assemblies with undercuts, hollows and moveable parts.

An automated micro production chain is available at wbk Institute of Production Science of the Karlsruhe Institute of Technology (KIT) to manufacture sinter-joined micro assemblies. It is used for extensive testing of the design of micro sinter-join connections as part of the collaborative research centre SFB 499. For the optimum component characteristics along the joining zone of the so-called green parts to be identified, tests with green part samples were conducted. This procedure quickly yields the results required for the definition of the best geometry and surface characteristics of the joining zone. The first samples have been assembled, sintered and tested for resilience. The initial results show, that the sinter joining connection can withstand a pressure of 500 bar before bursting.

1 Experimental method

The design of the sample solids was based on that of a micro check valve with undercuts and moveable elements. The hollow cylindrical sample solids were turned from carbonyl iron feedstock material. The basic solids were given internal and external tapers in pairs and were then plugged into each other. The parts are joined along the tapered zone during sintering process. Geometry and surface characteristics were then varied to determine their impact on the strength of the sinter joining connection.

2 Examination of sinter joining zones

As part of SFB 499, tests were performed on machined sample solids made from carbonyl iron feedstock in order to determine a process-specific design for rotationally symmetric sinter joining zones in the micro range. These tests were considered pretests for the design of a mould insert for micro check valves.

2.1 Development and production of the sample solids

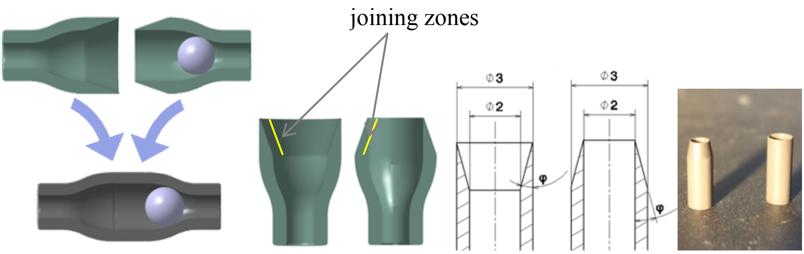

Figure 1: Micro check valve – green valve halves, blueprint, and samples

The sample solids were turned from solid feedstock as hollow cylinder pairs with internal and external tapers, respectively. The outer diameter of the circumferential surface is 3 mm with a wall thickness of 500 µm. The joining zones were geometrically varied. The taper angle was varied between 11° and 15°. The deliberate generation of different surface qualitites was achieved through the use of different machining methods and tools.

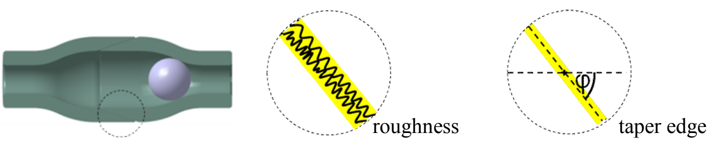

Figure 2: Considered parameters of green joining zones: roughness and taper angle φ

Table 1 specifies the used methods, machines and tools and the preset machining parameters.

Table1: List of the machining methods used

Method	Tool	Machine	Parameter		
			n_{WS} [min^{-1}]	n_{WZ} [min^{-1}]	f [mm/min]
Milling (1)	CC cutter Ø 1mm	Kugler Micromaster	10	9000	0,5
Grinding (2)	Diamond cone, #120	Precision lathe	1700	0	Manually
Turning (3)	Insert tip	Precision lathe	1700	0	Manually
Turning (4)	Single edge cutter	Precision lathe	1700	0	Manually

n_{WS} = number of revs, work piece, n_{WZ} = number of revs, tool, f = feed

A total of 186 sample solids were built. Out of those, 20 samples were machine finished by millling, 10 were machine finished by grinding, 60 were machine finished by turning, and 80 were machine finished through the use of single-edge cutters.

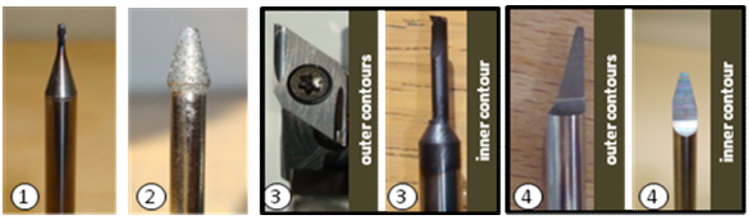

Figure 4: Tools used for the modification of characteristics at the joining zones

2.2 Determination of joining zone characteristics

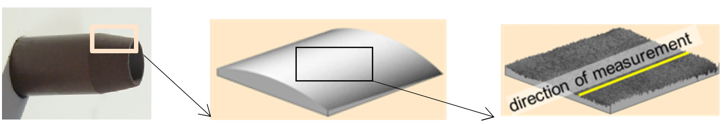

Figure 5: Determination of roughness values in joining zone

Surface roughness measurements were performed at every sample solid with the Nanofocus µ-Surf analytical topology unit in the area of the joining zone (Fig.5). The dimensions of the area under examination were 1.5 mm x 1.5 mm.

	Method	Milling	Grinding	Turning	Single-edge cutter
Rough-ness values	Ra [µm]	0,47 ± 0,1478	2,86 ± 0,4993	0,41 ± 0,1835	0,4 ± 0,0381
	Rz [µm]	3,16 ± 1,4094	13,87 ± 2,1987	2,78 ± 1,4399	2,6 ± 0,2798
Profile values	κ	0,61 ± 0,1033	0,63 ± 0,0738	0,61 ± 0,0667	0,67 ± 0,0465
	δ	0,32 ± 0,0324	0,41 ± 0,0354	0,3 ± 0,0374	0,36 ± 0,0244

Figure 4: Means and standard deviations for the different methods

From the above values, the coefficients of fineness κ and the form factors δ are calculated in order to characterise the profile shape. The roughnesses determined for the methods milling, turning and turning with single-edge cutters are almost identical. The samples machined by grinding show considerably higher roughnesses. In conclusion it can be stated that no significant impact of the parameters feed, number of revolutions and tool on the surface roughness has been identified for machining of the green carbonyl iron feedstock with geometrically defined cutting edges. Generally, the best surface qualities and the lowest fluctuations thereof are achieved by machining with single-edge cutters. Surface roughnesses of the ground samples are higher by a factor of 4-7. Roundness accuracy and angle accuracy are very good for all methods except grinding (i.e. $\Delta\varphi_{max}$ = 4.14°, maximum roundness deviation = 0.035 µm), i.e. $\Delta\varphi < 1°$ with roundness deviations of less than 0.007 µm.

3 Conclusions

The acquired results described above are used for research dedicated to correlating the examined characteristics of the green parts at the joining zone to the quality of the sinter-joined connection. It includes tensile testing and internal pressure testing. Initial internal pressure tests have shown a resistance of up to 500 bar for the joined micro checkvalves that are designed with the aid of the acquired expertise.

References:

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