DEBURRING AND SURFACE CONDITIONING OF MICRO MILLED STRUCTURES BY ABRASIVE AND NON-ABRASIVE MICRO PEENING

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ABSTRACT

Micro milling is an economically interesting process for manufacturing of micro injection moulds for small and medium batches. In contrast to other manufacturing processes, like the LIGA-technique, it allows real 3-dimensional piece structures. However, moulds obtained by micro milling of hardened steels often show burrs that have to be removed. Additionally, the typical surface textures due to the milling process can obstruct demoulding.

Micro peening with abrasive blasting agents allows deburring and removing of the surface textures due to the milling process. Edge rounding can be almost avoided using appropriate peening parameters and the use of appropriate blasting agents.

Micro peening with non-abrasive blasting agents such as glass or ceramic beads allows a removal of surface textures by plastic deformation. Surface roughness can be significantly reduced by levelling of profile peaks.

In the work presented here the influence of the micro peening process on micro milled structures was studied for different blasting agents in different single-step and double-step processes. This included the investigation of deburring effect, edge rounding and the influence on the surface topography.

SUBJECT INDEX

Micro peening, smooth finishing, micro moulding, deburring, surface conditioning

INTRODUCTION

Micro powder injection moulding is a high precision manufacturing process for micro parts with 3-dimensional structures. It allows the use of ceramic and metallic materials with high mechanical and chemical resistance such as ZrO_2 or stainless steels (Piotter, 2000). The use of ceramic feedstocks requires mould materials with a high resistance to abrasion, such as tool steels. In contrast to other manufacturing processes for micro-moulds, like the LIGA-technique, the utilisation of milled steel moulds allows real 3-dimensional piece structures (Weule, 2001). Furthermore, micro-milled moulds make injection moulding economically interesting for short and medium batches.

However, surfaces made by milling usually show striations in their topography which result from the cutting process. When milling hard material states, burrs appear on the mould edges. In injection moulding, these surface states lead to a bad removability of parts with a low flank inclination from the mould. Additionally, burrs deteriorate the tightness between mould parts, leading to flashes on the workpiece in the joint level. For these reasons, a direct use of milled injection moulds is often not possible and a smooth finishing is necessary.

For smooth finishing and deburring of micro moulds, peening offers the following advantages : As peening processes do not require form tools that could only be used for one type of mould, precision problems in tool manufacturing can be avoided. Thus, tool costs are very low. By variation of the peening parameters and the peening agents, the process can be adapted to a wide range of materials and surface states.

METHODS

The specimens for micro peening were cuboids of 66 x 30 x12 mm^3 made of quenched and tempered X38CrMoV5-1 VMR (German grade 1.2343) with a hardness of 52 HRC, in which micro-cavities as shown in Fig. 1 were manufactured by micro end-milling. The prismatic part of the cavity, that is milled with the same milling parameters used for steel micro moulds in SFB 499 (Weule, 2001)is essentially used for deburring experiments. The straight groove which is machined by one single tool pass is mainly used for investigations on the roughness development due to peening processes since its surface state is homogeneous over the whole length. A SEM-view of the inner edge of a milled cavity is shown in Fig. 2. Burrs with a height of about 10 µm can be seen on the upper edge. The milled surfaces show striations characteristic for the manufacturing process. For determining peening parameters for these microstructures, cuboids of 30 x 10 x 10 mm^3 were used. A a roughness comparable to that found on the micro milled specimens was created by grinding with wet silicon-carbide paper 320.

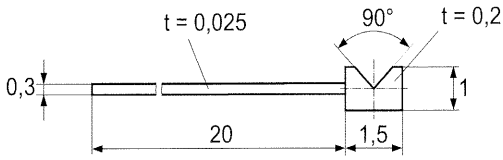

Fig. 1: Geometry of the micro-milled cavity at the peening specimen.

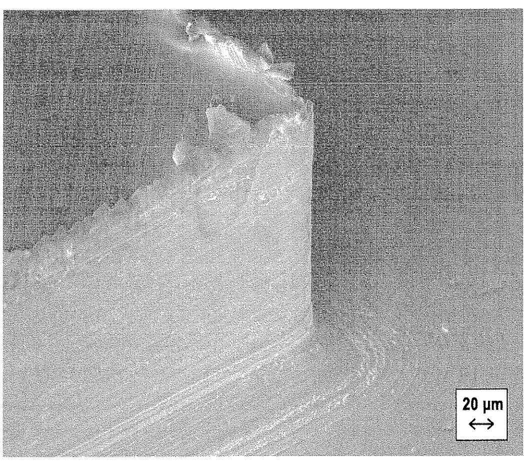

Fig. 2: SEM view of burrs on a micro milled cavity

The peening device used was of the type IEPCO Micropeen 200 with a nozzle diameter of 800 µm. The blasting shot used consisted of a mixture of alumina, silicon carbide and glass beads with a grain size between 10 and 20 µm for abrasive blasting, and glass beads with a diameter between 20 and 30 µm for non-abrasive peening. For roughness analysis, the surfaces were investigated using a confocal white-light microscope (Nanofocus µSurf). The roughness values Rz were determined according to ISO 4287 on 25 profile lines, their mean values and standard deviations were calculated.

RESULTS AND DISCUSSION

Deburring

By abrasive peening, the burrs shown in Fig. 2 could be totally removed of the specimen after blasting as can be seen in the SEM-picture in Fig. 3 left. For that purpose, the nozzle was inclined by 75 degrees to the vertical, the horizontal projection of the peening direction was perpendicular to the cavity edge and a peening pressure of 2 bar was applied. As shown in the metallographic section in Fig. 3 right, the edge radius after blasting with total removal of the burrs is smaller than 5 µm.

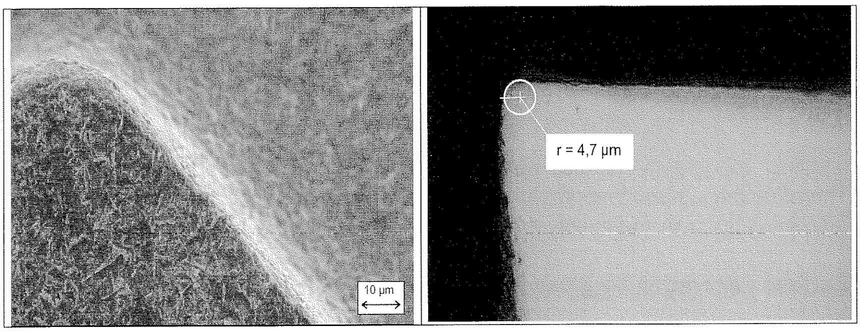

Fig. 3: SEM-view (left) and metallographic section (right) of the deburred edge

Thus, abrasive micro peening allows a reliable deburring of micro milled structures without generating excessive form errors such as big edge roundings.

Surface generation by abrasive peening

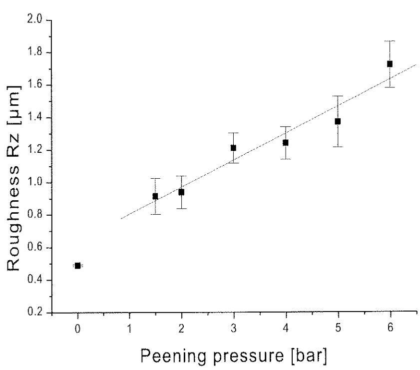

Fig. 4: Roughness Rz vs. peening pressure for abrasive peening of a ground cuboid

The roughness values obtained by abrasive peening of ground cuboids are shown in Fig. 4. A nearly linear increase of the roughness values is observed with increasing peening pressures.

With peening pressures superior to 2 bar, the surface striations due to the grinding process can be removed. The roughness obtained for this pressure is 0.94 µm. As can be seen in Fig. 5, an isotropic surface topography is obtained. It shows sharp peaks generated by the impingements of the sharp-edged silicon-carbide particles.

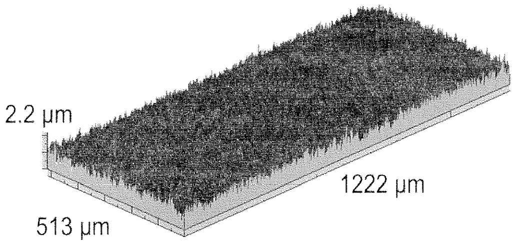

Fig. 5: Surface topography of a ground cuboid after abrasive peening at 2 bar

On a micro milled groove, abrasive peening at 2 bar could completely remove the feed marks due to the milling process. Hereby, roughness increased from 0.53 to 0.92 µm, which is similar to the results obtained on the ground surfaces. The resulting topography is also similar to that obtained at the ground specimen. Therefore the surface topography seems to be mostly independent from the previous machining process and mainly determined by the abrasive peening process.

Surface generation by glass bead peening

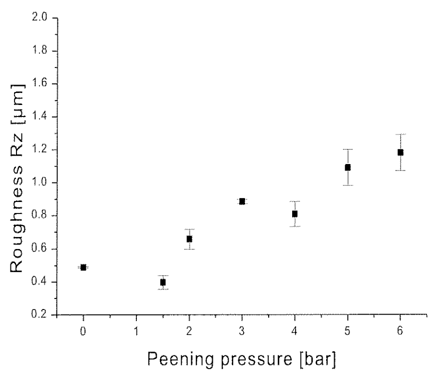

Fig. 6: Roughness Rz vs. peening pressure for glass bead peening

The roughness values obtained by glass bead peening of ground cuboids are shown in Fig. 6. At a peening pressure of 1.5 bar, the roughness Rz is reduced from 0.5 to 0.4 µm by plastic deformation of the profile peaks. Higher peening pressures lead to an increasing roughness. Applying peening pressures superior to 3 bar, the surface striations due to the grinding process can be removed. The best roughness value obtained for texture removal by glass bead peening is 0.8 µm at a peening pressure of 4 bar. The surface topographies obtained at pressures of 1.5 and 4 bar are exemplarily shown in Fig. 7.

On a micro milled groove, glass bead peening reduced roughness Rz from 0.53 to 0.42 µm, which is similar to the results obtained on the ground surfaces. Hereby, feed marks remain slightly visible, like the grinding striations.

A reliable deburring of milled microstructures is not possible by glass bead peening because of the high toughness of the tool steel used.

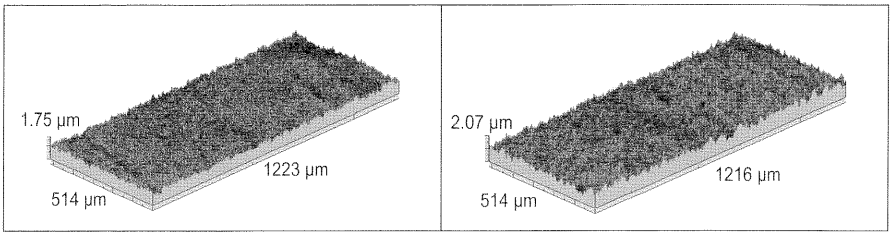

Fig. 7: Surface topographies after glass bead peening at 1.5 (left) and 4 bar (right)

Surface generation by double-step peening with an abrasive agent and glass beads

In most cases of application, a deburring of micro milled structures is necessary, which only possible with abrasive agent in a reliable way. However, abrasive peening generally leads to a roughness increase. As a roughness reduction can be obtained by glass bead peening, a combination of both processes promises the best results. In a first step, the specimens were peened with the abrasive agent at 2 bar as for this pressure the lowest roughness is obtained for total striation and burr removal. In a second step, the surfaces were peened with glass beads at different pressures between 1.5 and 6 bar. The roughness values obtained at an initially ground cuboid after the glass bead peening step are given in Fig. 8.

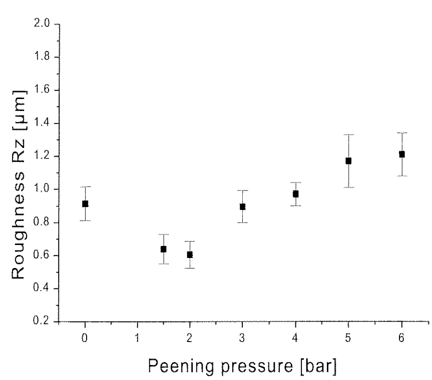

Fig. 8: Roughness Rz vs. peening pressure for glass bead peening after abrasive peening at 2 bar measured at an initially ground cuboid

At a peening pressure of 2 bar, the roughness is reduced from 0.9 µm to 0.6 µm. For higher peening pressures, a roughness increase is observed. On a micro milled groove, the second peening step at 2 bar reduced the roughness from 0.92 to 0.67 µm, which is similar to the results obtained on the ground surfaces. A smooth surface topography without textures is obtained. The double-step peening process with abrasive agent and glass beads allows a total removal of surface textures due to prior manufacturing processes. Compared to a single-step glass bead peening, the roughness values obtained for total texture removal are lower (0.6 compared to 0.8 µm), but the lowest overall roughnesses obtained are higher (0.6 instead of 0.4 µm). Compared to the initial roughness obtained by micro milling, the roughness increase due to the two step micro peening process amounts to only 0.14 µm. An isotropic surface topography is obtained, which facilitates demoulding. The topographies of the ground of a micro groove after milling and after double-step micro peening are shown in Fig. 9.

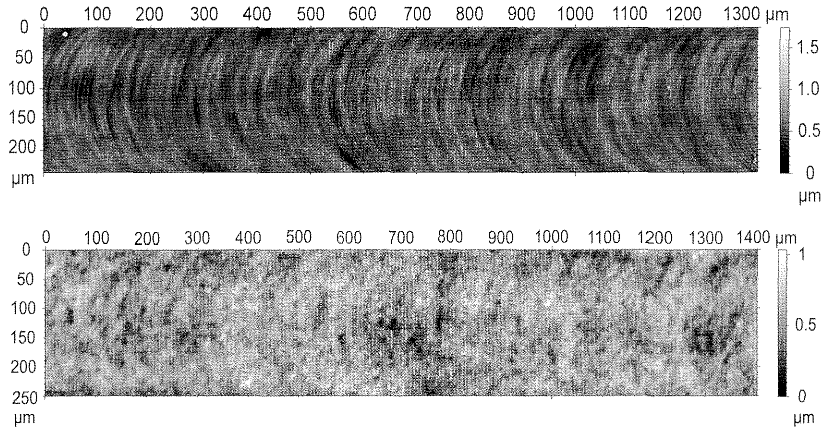

Fig. 9: Surface topographies of the ground of a milled groove before (top) and after (bottom) double-step micro peening.

CONCLUSION

Micro peening allows deburring, roughness reduction and texture removal on micro milled structures made of tool steel. A reliable deburring can be achieved by abrasive peening without generating strong edge roundings or other form errors. The roughness increase caused by the deburring process can be significantly attenuated by subsequent glass bead peening. A roughness reduction can be obtained by peening with non-abrasive, spherical media e.g. glass or ceramic beads. This roughness reduction also leads to a partial removal of surface textures. A complete texture removal can be obtained by abrasive peening, leading to a roughness increase. Combined two-step processes consisting of abrasive and non-abrasive peening allow a reliable texture removal without big roughness increase. They generate isotropic surface textures without sharp profile peaks and thus will facilitate demoulding of micro injection moulding parts. Hence, micro peening allows a quality improvement on micro injection moulds with low tool costs and processing times.

ACKNOWLEDGMENTS

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