Precision Grinding with In-Process ECM-Dressing

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Abstract

In this paper fundamental investigations on the capabilities of electrochemical in-process dressing of bronze bonded diamond grinding wheels are presented. Distinct types of bronze bonds with different chemical compositions are investigated regarding their dressing performance during precision grinding of cemented carbide or ceramic mould inserts. Therefore, the resulting surface finishes and form accuracies of the grinding process will be analysed. In addition the G-ratios (ratio of the removed material volume of the workpiece and the removed material of the grinding wheel by wear) are measured and investigated for the different grinding wheel specifications and in-process dressing conditions.

1 Introduction

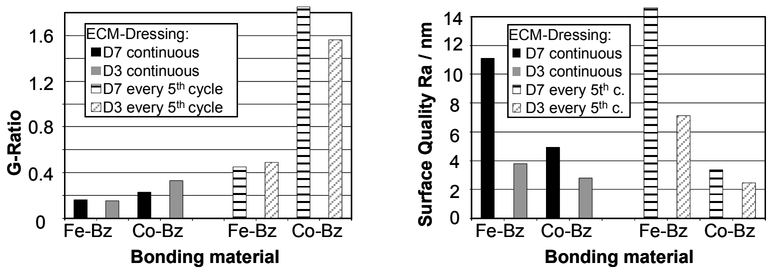
Precision grinding is a key technology within the process chain for manufacturing of moulds with high shape accuracies and optical surface finishes. This is the main emphasis for the production of spheres, aspheres and structured shapes of lenses in the optical industry by glass moulding and plastic injection moulding operations. The workpiece quality and form accuracy significantly depend on the grinding process and especially the appropriate trueing and dressing operations. The effort of following steps of the process chain depend on the quality of the grinding result. Therefore, the surfaces should possess such a good surface quality that a subsequent polishing process is unnecessary. This will reduce the needed steps of the manufacturing process, the needed manufacturing time and eventually lower the manufacturing costs.

By using metal bonded grinding wheels high wear resistances and profile constancies can be achieved. Bronze-bonded grinding wheels in particular can be used efficiently for the grinding tasks, as it is easier to modify their chemical composition - and therefore their bond hardness - to suit a specific grinding task. Hence, these grinding wheels can be used for the precision machining of hard and brittle mould materials like cemented carbides or ceramics which are used in the glass moulding operations for the optical components. But the combination of very small grained diamonds down to the smallest sized grains of only micrometers and the metal bond causes great difficulties for conventional dressing. Due to the metal bond composition of the grinding wheel the unconventional process of electrochemical dressing is a powerful alternative dressing technology, [1, 2].

2 G-Ratios of Grinding Wheels with different Bond Materials during In-Process ECM-Dressing

The G-ratio of grinding wheels with distinct bronze bonds were investigated regarding their dressing performance during precision grinding of a silicon nitride cylinder. The G-ratio is defined as the ratio of the removed material volume of the workpiece and the removed material on the grinding wheel. As bonding material an iron bronze was compared to a cobalt bronze with grit sizes D7 (grit size 5-10 µm) and D3 (grit size 2-5 µm) during two different electrochemical in-process dressing strategies based on Electrolytic In- Process Dressing (ELID), [3]. Firstly the ECM-Dressing was performed continuously during the process and in the second measurement the ECM-Dressing was activated during every fifth grinding cycle. During the continuous dressing the removed material on the grinding wheel is naturally bigger than during the cyclic process. On the other hand the grinding wheel may become less sharp in this variation and the volume of removed material on the workpiece will decrease as well as the surface quality. On the other hand using the continuous dressing process the shape accuracy will decrease due to the reduced grinding wheel diameter.

As seen in **Figure 1** the G-ratios of the cobalt bronze is higher than the ratio of the iron bronze in both dressing strategies and grit sizes. The measurements give prove that the cyclic electrochemical trueing process result in higher G-ratios, as expected. Thus the cyclic process reduces the wear of the grinding wheel significantly. Using the cyclic process, the G-ratio of the bronze bond is with 1,6 about four times larger compared to the iron bond. The different grit sizes only have a minor influence on the G-ratio contrary to its influence on the surface quality. Naturally the surface quality is better using smaller grit sizes. As seen in the surface quality graph in **Figure 1** the surface roughness of the continuous ECM-Dressing of the cobalt bronze bond is significantly smaller compared to the iron bond. The surface quality of the cobalt bond is roughly the same for the continuous and the cyclic ECM-Dressing. Further analysis of the D7 iron bond grinding wheel revealed a poor grit distribution as reason for the high deviation in surface roughness.



Process Parameters:
- Grinding wheel: d_S = 75 mm, b_S = 2 mm
- Workpiece: Si_3N_4-cylinder D = 25 mm
- Coolant: CIMIRON CG-7; κ = 2 mS/cm
- ECM-parameter: U = 60 V; τ = 0,1; f = 100 kHz
- Kinematics: Rotational periphal plunge grinding
  v_c = 27 m/s; v_f = 5 mm/min
  n_w = 100 min^{-1}
  a_e = 2 µm (D7); 1 µm (D3)

Figure 1: Achieved G-ratios with in process ECM-Dressing

Since the cobalt bronze achieves the best roughness, noticeably under 10 nm which results in a mirror like surface quality, as well as the highest G-ratio using the cyclic electrochemical in-process dressing operation the bonding material is suited best for high precision grinding of the given cylinder.

3 Grinding of a Mould Insert as a Field of Application of ECM-Dressing

Due to the results above a spherical cemented carbide mould insert for the precision glass moulding operation was manufactured using a cobalt bronze bonded grinding wheel with a D7 grit size and a cyclic electrochemical in-process dressing strategy, as seen in **Figure 2** together with the according measurement plot. Using the above mentioned process parameters an optical surface quality could be achieved with an Ra-value of about 6 nm. The peak to valley vertical deviation was about 0.53 µm.

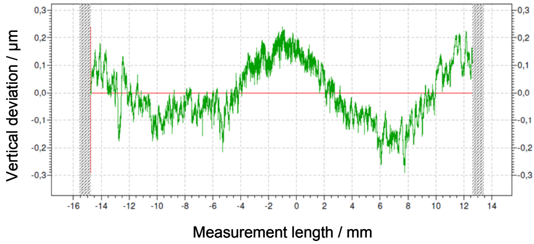


Figure 2: Picture of a mould insert for high precision glass moulding and according measurement plot

4 Conclusion

Electrochemical in-process dressing of bronze bonded diamond grinding wheels can be used to reduce the needed steps to manufacture mould inserts for the precision glass moulding operation. A subsequent polishing process is unnecessary due to the optical surface quality achieved by grinding.

5 Acknolowledgements

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