Development of a hybrid micro machining process and its test-bed

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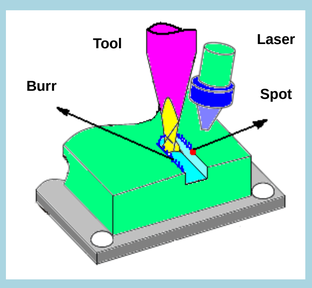
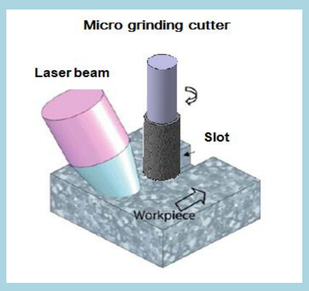
Introduction

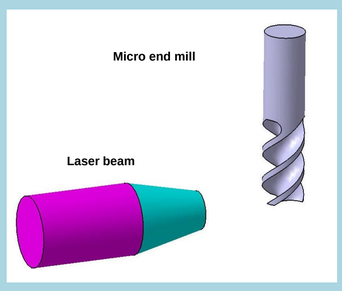
Currently microproducts that possess precision micro structured or freeform surfaces are in great demand in biomedical, dental and renewable energy industries. These surfaces will add special functionality to the microproducts such as self-clean, anti-reflection, etc. However, the complex geometric features of these products increase the difficulty in production. Development of a novel agile manufacturing capability is essential to obtain these microproducts precisely and rapidly. The project aims to develop a hybrid micro precision process (combination of micro milling/grinding/laser machining) which can greatly improve the machining accuracy and machining efficiency in manufacturing 3D micro products/ components.



Laser assisted micro milling



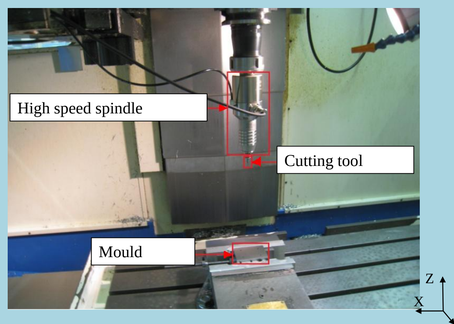
Laser assisted grinding hard steel

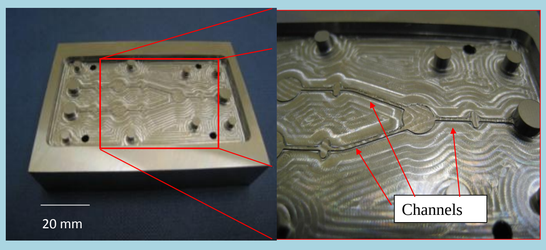


On-line structuring micro milling cutters

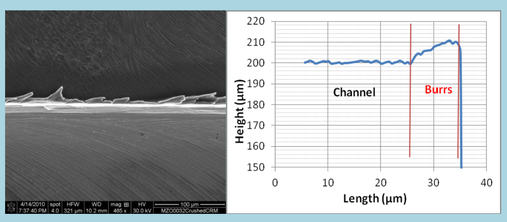
Laser assisted micro milling

Micro burrs are generated after micro milling processes because of material plastic deformation. A laser deburring process is developed to remove micro burrs generated by micro milling processes in order to obtain high quality micro fluidic injection mould.

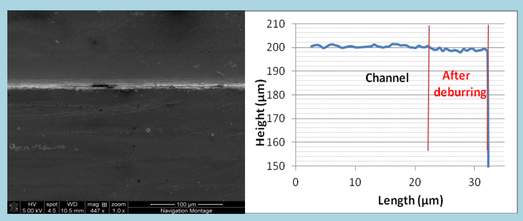




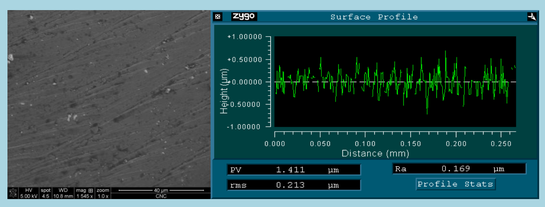
The figures show that micro burrs on the micro channels in the micro fluidic mould have been completely removed. The laser deburring method developed in this research is able to obtain high quality micro fluidic injection mould in term of good edge quality of micro channels and machined surface finish.



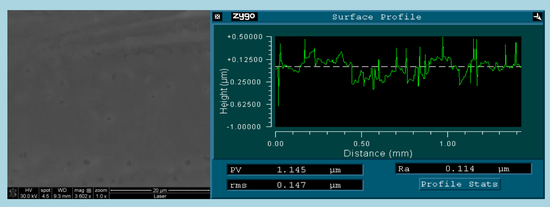
Burrs on the edge after micromilling



Burrs removed after laser deburring



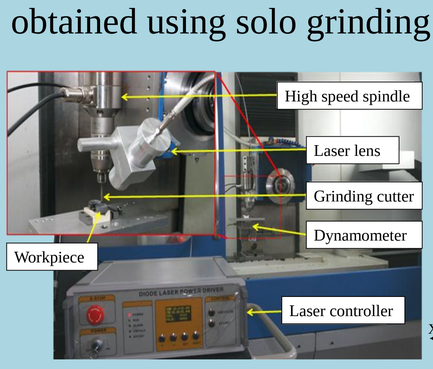
Surface roughness after micromilling



Surface roughness after laser deburring

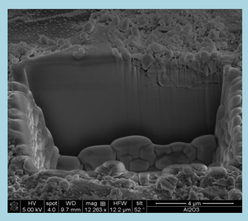
Laser assisted grinding hard steel

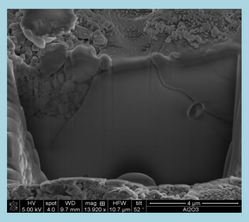
A laser assisted grinding process is developed to manufacture micro features in high strength materials. Micro grooves were fabricated on silicon nitride by using the laser assisted grinding process.
The machined surface roughness was consistently better than that obtained using solo grinding process and applying coolant.

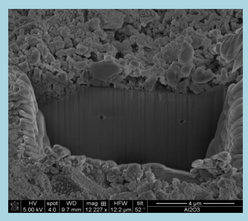


Surface roughness (Ra) μm	White light interferometer			AFM
Conventional grinding with coolant	182.543	225.197	200.041	164.43
Laser assisting grinding with air coolant	353.432	317.939	332.425	294.32
Laser assisting grinding	111.546	173.448	134.776	112.85

No subsurface damage was observed in the SEM images of cross sections of the machined workpieces when laser assisted grinding process was used.

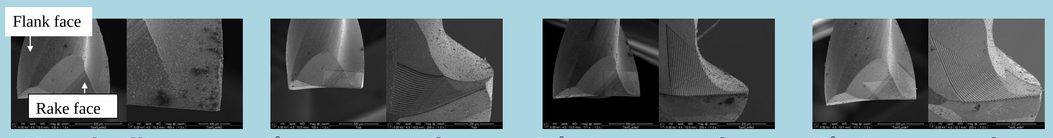

Conventional grinding with coolant


Laser assisting grinding with air coolant

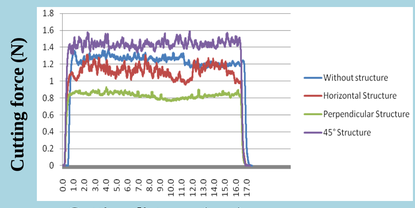

Laser assisting grinding

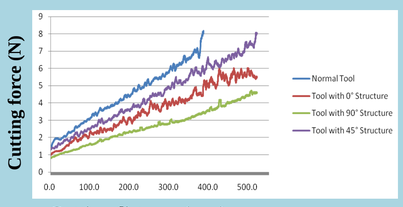
On-line structuring micro milling cutters

Laser machining milling cutter is an approach which can repair milling cutters or fabricate micro structures on the rake face of cutters in order to defer tool wear.



Normal milling cutter | 0° microstructured cutter | 90° microstructured cutter | 45° microstructured cutter

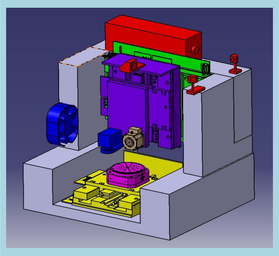


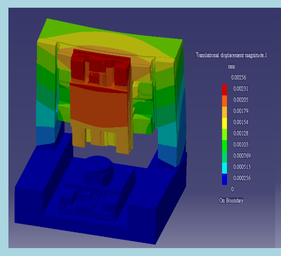


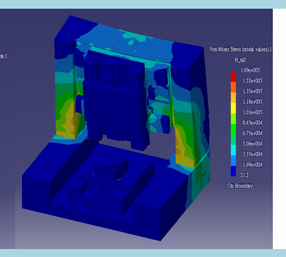
Cutting forces when using the four milling cutters

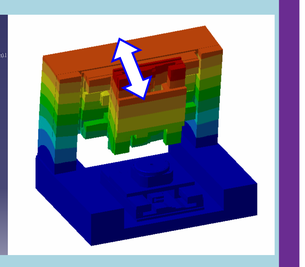
Conceptual design & analysis

In the conceptual design stage, several machine structures have been propose to accommodate the hybrid machining process. Finite element analysis is used to model the deformation and stress under gravity and calculate the natural frequency of the proposed hybrid machining centre.


Conceptual design


Analysis- Displacement


Analysis- Stress


Analysis- Frequency

Conclusion

Hybrid micro machining approaches which combine micro milling, micro grinding and micro laser machining are investigated in this study. Laser deburring can completely remove micro burrs which is generated on the edge of parts after micro milling. Better surface roughness can therefore be obtained. Laser assisted grinding process help to achieve good surface roughness and reduce subsurface damage in machining high strength materials. On-line structured micro milling cutters by laser machining can help decrease cutting force in the machining process and defer tool wear. A robust mechanical structure is needed to accommodate the above hybrid micro machining processes for agile manufacturing of high precision products.