Fabrication of Micro Fluidic Mould by Micro Milling and Laser de-burring

Wenlong Chang, Xichun Luo, James Ritchie, Jining Sun and Chris Mack
School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH14 4AS, UK
x.luo@ hw.ac.uk

Abstract

Micro injection moulding is currently widely used to fabricate micro fluidic chips. Good surface roughness and edge quality of micro fluidic channels in the micro injection mould are vital to the functionalities of the micro fluidic chips. In this paper a hybrid micromachining approach is developed to obtain high quality micro injection mould. A micro injection mould with channels of 500 μm wide and 200 μm high is machined by high speed end milling first. The micro channels are then processed by Nd:YAG nano-second laser to remove the burrs generated in the end milling process. The measurement results indicate that micro milling combined with laser de-burring is a cost effective machining process to obtain high quality micro fluidic mould.

1. Introduction

Low cost and disposable micro fluidic chips become very popular products in these days for disease diagnostic and chemical analysis [1]. These micro fluidic chips are usually made of PMMA and the width of micro channels in them is restricted within 100 to 500 μm. Both good edge quality and fine surface roughness of micro channel are crucial to carry on laminar flow in the micro fluidic devices. In the past, micro fluidic chips were usually fabricated by etching and photo-lithography. But with these two methods it is difficult to produce three dimensional shape channels requested for advanced functionalities of a micro fluidic chip. Micro injection moulding approach is then developed to overcome the shortcomings of above two fabrication approaches. Micro milling is commonly used to machine mould in the micro injection moulding approach. However, the burrs or particles generated on the edge of the channel in the mould in the micro machining process will be replicated on the fabricated micro fluidic chip. They will result in catastrophic turbulent of flow in the micro fluidic devices. Due to the micro machining mechanism the formation of micro burr is inevitable. Therefore de-burring on the injection mould after micro milling is critical to achieve the function of the micro fluidic devices. In this paper, laser de-burring is developed to obtain good edge quality in the micro fluidic mould so as to achieve laminar flowing [2] in the micro fluidic channels.

2. Experimental trials

Figure 1 shows a 3D model of a micro fluidic injection mould with channels of 500 µm wide and 200 µm high. This mould is fabricated by micro milling which is carried out on a conventional CNC machining centre Takang VMC-1202 but using a high speed spindle SF3060-ST32, and followed by laser de-burring using a Nd:YAG high power laser machine.

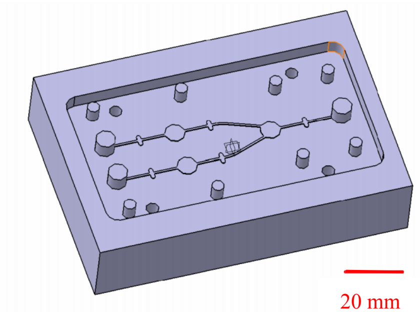


Figure 1 The 3D model of the micro fluidic mould.

2.1 Micro milling

The mould is made of NAK 80 which is a popular mould material for injection mould. 2 mm and 500 µm diameters metal carbide end mills are used for face milling and profiling respectively. Both of the milling cutters are 2-flute long neck end mills and made of 93% WC, 7% Co. The cutter surface is coated with Mugen Coating Premium to improve its tool life. In the milling process, spindle speed, federate and depth of cut per cut of 20,000 rpm, 300 mm/min and 0.05 mm are used for the 2 mm diameter milling cutter. When using 0.5 mm diameter milling cutter spindle speed of 30000 rpm, feedrate of 400mm/min and depth of cut of 0.2 mm per cut are adopted. The machined micro fluidic mould is shown in Figure 2. The burrs on the edge of the channel are shown in Figure 3(a) and the profile shows in Figure 3(b).

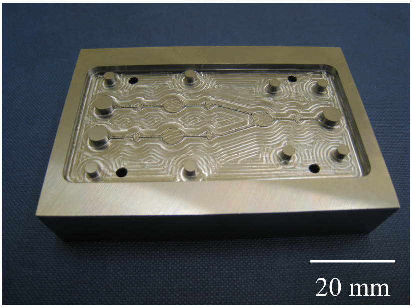
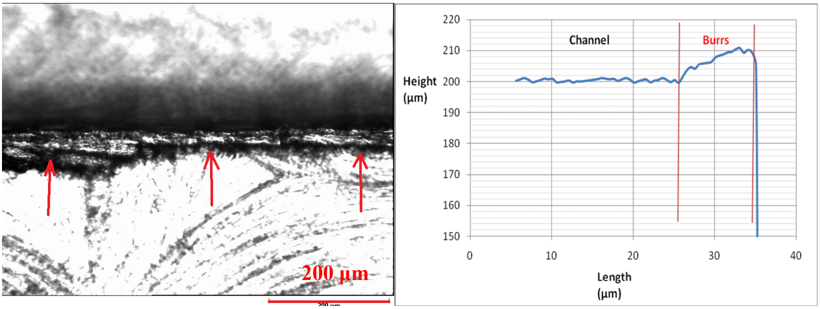


Figure 2 The micro fluidic mould machined using high speed spindle.



(a) The burrs on the edge. (b) profile of micro fluidic channel.

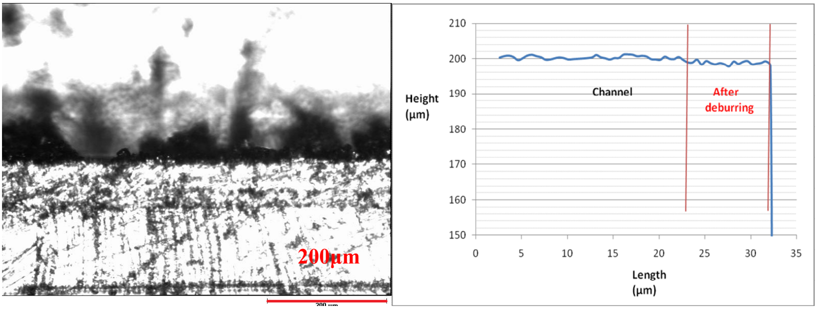
Figure 3 The burrs on the edge of the micro fluidic channels.

2.2 Laser deburring

A Nd:YAG high power laser are used in the deburring process after micro milling. The power and frequency in deburring processing are 2.5 watts and 15000 Hz. The spots size on the focus point is 20 µm diameter. The feedrate is 5 mm/min which will make sure 90% of overlap is obtained for subsequent laser pulse. The laser cutting path follows the edge of the micro fluidic channel but with an offset of 5 µm on the surface.

3. Results and discussions

The heights of the burrs on the top of micro fluidic channel measured by a CMM (WENZEL LH-65) are between 8 and 10µm. Nikon OPTIPHOD microscope is used to take a close look of the burrs. By comparing Figure 3 and Figure 4 it can be seen that the burrs generated in the micro milling process have been removed completely by laser deburring. The surface roughness on the top of the micro fluidic channel is measured by a Form Talysurf (measurement accuracy is 0.05 µm). After micromilling, the average of surface roughness Ra (in the area without appearing burrs) is 0.357 µm. After laser deburring, the average of surface roughness across the whole region of the top surface of micro fluidic channels is 0.417 µm. Although the surface roughness Ra seems to change 0.06 µm, the edge quality has been dramatically improved which is clearly shown in Figure 4.



(a) The burrs removed on the edge. (b) Profile of micro fluidic channel after deburring.

Figure 4 The edge of the micro fluidic channel after laser deburring.

4. Conclusion

In this paper a hybrid micromachining approach is developed to fabricate micro injection mould. The micro fluidic channels, 500 µm (width) × 200 µm (depth), are micro milled by using a high speed spindle with spindle speed of 30000 rpm and feedrate of 300 mm/min. The micro burrs inevitably formed at the channel edges in the micro milling process are removed by high power laser. The measurement results show that high quality micro injection mould can be obtained by applying this hybrid micromachining approach.

References:

[1] Tseng, F.G, et al, Anovel fabrication method of embedded micro channels employing simple UV dosage control and antireflection coating, IEEE 15 ICMEMS, 2002, 69-72

[2] Seoung, H.L., et al, Precision Laser Deburring, ASME 2001, Vol. 123, 601-608