Enhanced tool cutting edge detection for ultra precision diamond machining applying a conventional setting system

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Abstract

Tool setting precision is a basic requirement in ultra-precision diamond machining since it directly affects achievable machining accuracy. Different tool setting methods have evolved and brought to commercial availability. Probably the most accurate ones are based on LVDT, some apply machining of test parts and probably most wide spread are camera based systems. Systems touching the diamond tool cutting edge generally bear the risk of damaging especially fragile tools with high clearance angle. Camera based systems offer limited accuracy because of the characteristics of the optical systems applied and the need of removing the systems during machining. Applying sub-pixel interpolation methods and calibration after repositioning inside the machine system before every single measurement are two possibilities to cope with limited accuracy.[1] Thus, all of the systems in use imply specific drawbacks.

Therefore, the feasibility of a non-contact tool setting system from conventional machining for ultra-precision machining is tested. This includes integration into the machine control, repeatability tests and development of adapted measuring cycles. Modifications of the system to further improve fitting ultra-precision requirements are yet to come. A major focus applying the system was to realize automated tool setting procedure to limit machine operator influence as much as possible.

1. Introduction

The solution presented is based on a joint research project between Blum-Novotest and the Fraunhofer IPT addressing the innovative use of a laser light barrier designed for conventional and high precision milling. The addressed system can stay inside machining space during machining operation. The limited repeatability of kinematic couplings thus does not limit accuracy of cutting edge detection. The precision achieved depends especially on the machine control, the kind of signal processing and the overall machine tool accuracy. To transfer the system to detection of mcd-tools for ultra-precision machining, basically three questions have to be answered:

- Which repeatability of the trigger signal can be achieved integrating this device into an up-machine control?
- Is it possible to generate a trigger signal using MCD-tools reliably?
- How can the tool height be detected?

2. Setup of measuring device, integration and working principle

This work was performed using a Laser Control NanoNT from Blum-Novotest. The system was equipped with a touch probe pointing sideways allowing for the detection of the rake face. It was integrated into a three axes up-machine tool directly besides the main Spindle. (figure 1)

Figure 1: integration (left), focused laser beam (middle), and tool during measurement (right).

For conventional milling, laser based light barriers acting as triggers are state of the art. A focused laser beam is detected by a photo sensitive diode (PSD). Interrupting the beam with a cutting edge changes the illumination at the PSD. A trigger signal is initiated and the machine control saves the relevant axes positions instantaneously. Using the real scale signals and fast signal processing, this allows for precisely detecting tool cutting edges in 2 dimensions. To allow for best performance, the trigger signal is directly linked to the axes controllers. Reaction time can thus be reduced compared to processing the signal by the NC.

3. Application for up-machining

Cutting edge position is indirectly determined saving the actual position of the moving axes as soon as a trigger signal is detected. Precise detection of the cutting edge thus requires a repeatable and distinct trigger signal. MCD is a transparent material and the rake face and bottom surface of the mcd-tools are almost parallel. The laser passing through such object would not allow for the initiation of the trigger. To generate the required trigger signal, the laser has to be aligned parallel to the y-axis and enter into the diamond tool through the rake face. For standard applications, the rake angle is close to zero thus the rake face is aligned almost parallel to the x-z-plane. This causes only low deflection of the beam from its original pass while entering the diamond. Hitting the clearance face causes total reflection reliably because of the high optical density of diamond of 2.4.

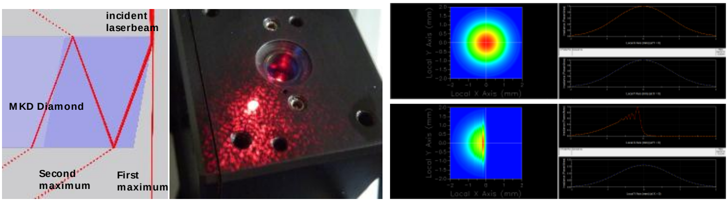

Figure 2: Reflection of the beam (left), real refraction (middle) and simulated intensity at the sensor (right).

The described was simulated and tested to validate feasibility for mcd-tools. The simulation (figure 2, left) shows that most of the laser intensity does not hit the sensor (figure 2, right) and that the transparent diamond triggers a signal. Figure 3 shows the trigger positions generated by a metal blade and a mcd tool saved during independent measurements lasting for about 30 minutes. The displacement of the trigger position is a result of heating of the PSD because of the laser staying activated during the 30 minute measurement (about 0.7 µm in X-direction). The maximum deviation within 10 to 15 measurements was detected to be below 0.1 µm in Z and about 0.05 µm in X-direction. The standard deviation is about identical using HM or MCD.

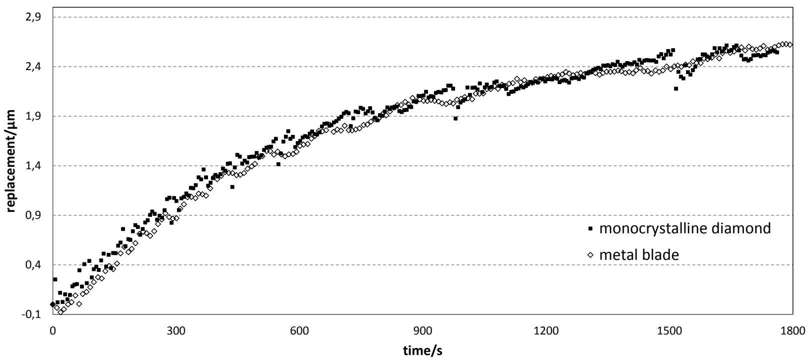

Figure 3: Repeatability of trigger position relative to first trigger position

The major influence harming performance is the duration of every single measurement since heating of the light barrier cause significant errors. A typical measuring cycle takes less than 2 minutes thus the visible and detected dislocation of the trigger position is of minor relevance.

4. Measuring process and algorithms.

Precise positioning of the cutting edge inside the focal plane of the laser is crucial to generate high reproducibility of the trigger position. Applying the light barrier for milling applications, the axis of rotation of the tools stays the same even after tool changing and positioning inside the focal plane can be guaranteed. Focusing on turning, a tool theoretically can be positioned at any position inside the machine coordinate system (MCS). The real position of the cutting tool inside the MCS thus is completely unknown after tool change. Still, locating the cutting edge inside the focal plane is crucial to allow for best measuring results. On the other hand, it has to be ensured that the cutting edge is not touched by the probe at any time. Even though repeatability outside of the focal plane is limited, it is sufficient to roughly detect tool position. The process developed thus consists of a rough determination of the tool position inside the x-z-plane, a subsequent detection of the height of the rake face and finally a precise measurement inside the focal plane (see figure 4). This procedure ensures touching the diamond only at the rake face to avoid damaging fragile tools and to reduce highly accurate measuring movements with low speed.

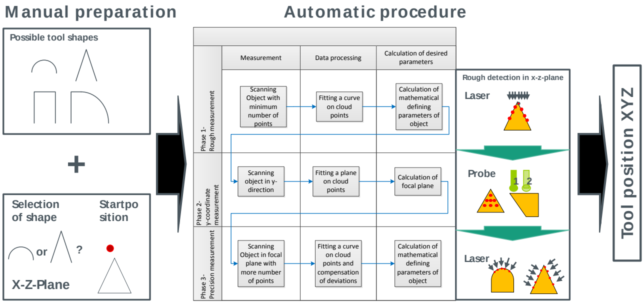

Figure 4: Measuring procedure.

5. Summary and outlook

The preliminary work shows high potential of the system. High repeatability of the trigger point and the feasibility of the measuring procedure could be verified. Future work has to take care of single characteristics of the system limiting accuracy, like shape of the trigger point, influence of tool size and thermal behaviour. After quantifying those influences, those have to be included into the measuring cycles.

Acknowledgements

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References

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