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Establishment of a laser assisted ultra-precision machining system

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Abstract
Laser assisted machining (LAM) is used in machining difficult-to-machine materials such as hard alloys and ceramics. LAM uses a laser beam with high power density to heat the material within a very limited area, and then remove the heated area using a conventional cutting tool when the temperature of this heated area reaches a desirable range. In this paper, a laser assisted ultra-precision machining (LAUPM) system was developed and assembled into the Optoform 30 ultra-precision turning machine. Basic cutting experiment has been done to demonstrate the feasibility of using this system. The experimental result shows that a high accuracy of tool laser alignment could be achieved using a novel video microscope assisted adjusting method. The laser spot diameter and the cutting zone can be controlled in less than 100µm.

Laser assisted machining, difficult-to-machine materials, ultra-precision machining

1. Introduction

High strength and heat resistant materials such as hard alloys and ceramics are being widely used in aviation, aerospace and automotive industries [1]. However due to their superior mechanical and physical properties, machining these materials with conventional method is very difficult and costly. Because the hardness and strength of difficult-to-machine materials normally decrease when the temperature is increasing, so laser assisted machining (LAM) seems to be a promising method while machining difficult-to-machine materials [2]. LAM as a machining method uses a laser beam with high power density to heat the material within a very limited area, and then remove the heated area using a conventional cutting tool when the temperature of this heated area is in a desirable range. The cutting force and tool wear could be reduced significantly while machining difficult-to-machine materials using laser assisted machining method [3-5]. Figure 1 shows the schematic diagram of a conventional laser assisted turning system [6]. In this system, the cylindrical workpiece is mounted on a rotational spindle, the laser beam is focused on the side surface of the workpiece, and the heated material then will be removed subsequently by a conventional cutting tool.

In recent years, many researchers' have carried out plenty of work in this area, but most of these work was focused on the feasibility study of LAM method on the improvement of machinability of materials, few of them had taking account of the machining accuracy since the diameters of the laser spot size being used in previous studies were in the order of several millimetres which caused a large area of heated affected zone (HAZ). It becomes difficult to adjust the laser and machining parameters with a high level of precision during the laser assisted machining process, especially when the diameter of the laser spot size is in the order of tens of micrometres. In this paper, by incorporating the laser unit into an ultra-precision diamond cutting machine, a laser assisted ultra-precision machining (LAUPM) system was established. In this system, a video microscope was adopted to assist adjusting the relative position between the laser spot and cutting tool with a high precision. Such system is used to investigate the influence of laser on the machining of difficult-to-machine materials with a high level of machining accuracy.

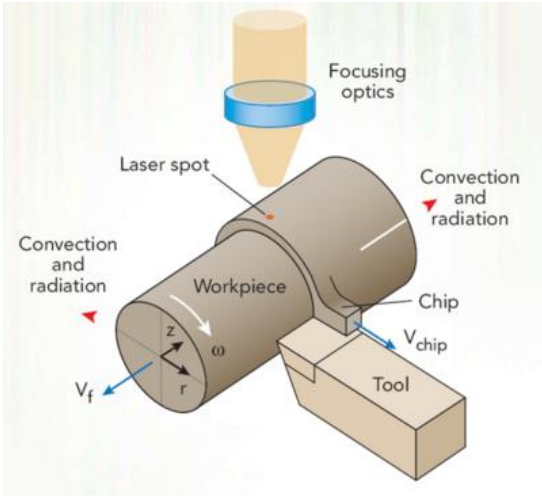

Figure 1. Schematic diagram of a conventional laser assisted turning system.

2. Establishment of the LAUPM system

2.1. Design sketch of LAUPM system

Figure 2 shows the design diagram of the LAUPM system. This system mainly includes three parts: an ultra-precision turning machine, a laser unit and a video microscope. The laser beam is focused on the workpiece surface right before the cutting tool. In this way the temperature of the cutting area could be increased to a desirable range that is high enough to soften the material. The spot size of the laser beam at the focal area is in the order of tens of micrometres. The video microscope is used to assist adjusting the relative position between the diamond tool and the laser beam focal area.

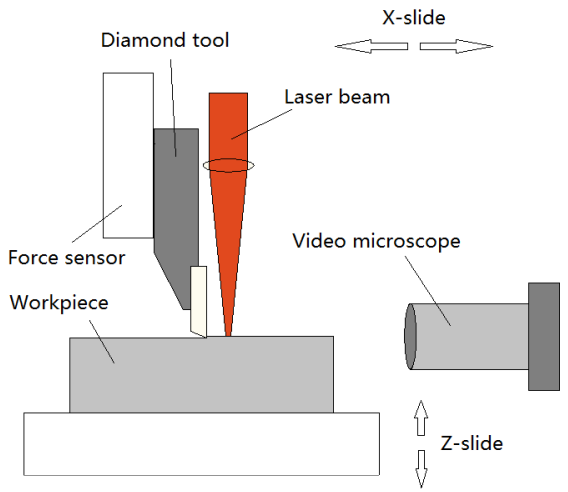

Figure 2. Design diagram of the LAUPM system.

2.1. Experimental setup of LAUPM system

Figure 3 shows the experimental setup of the LAUPM system. In this system, the laser used is a nanosecond pulsed fibre laser with a wavelength of 2µm and pulse duration of 30ns. The maximum average power is 10W and the maximum peak power is 10kW. By using a lens with a focal length of 101.6mm, the laser beam diameter could be focused to less than 50µm the smallest. The ultra-precision turning machine used is an Optoform 30 from Sterling Ultra Precision Ltd. The positioning resolution for the x and z slide is 0.04µm. The magnification for the video microscope is 400 times.

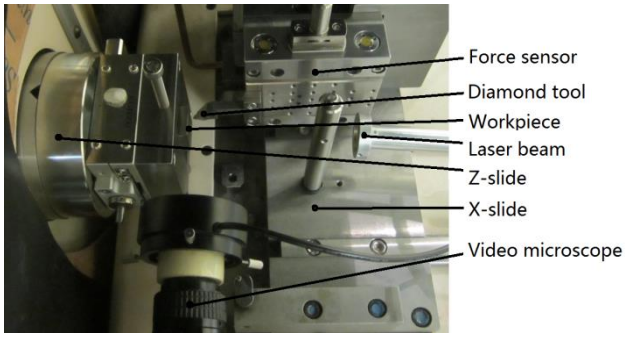

Figure 3. Experimental setup of the LAUPM system.

3. Preliminary experimental result

Figure 4 is the optical microscope image of the laser assisted diamond cutting test on a stainless steel. The image shows that the diameter of the laser spot is around 50µm, and the distance between the laser spot and the diamond tool is around 100µm. The average laser power we used in this experiment is 10W. This experimental result indicates that both the laser spot size and the tool laser position could be control precisely. The laser power adopted here is high enough to soften and even remove the workpiece material directly.

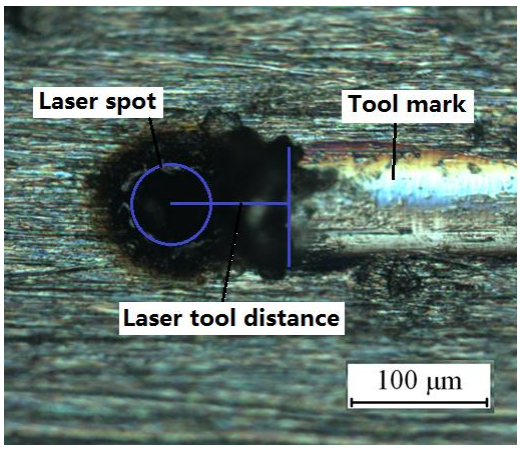

Figure 4. Laser assisted diamond cutting test on stainless steel.

4. Conclusion

In this paper, a laser assisted ultra-precision machining system was developed and assembled into the Optoform 30 ultra-precision turning machine. A preliminary experiment was carried out to test this system. The experimental result shows that the laser and machining parameters such as laser spot size and tool laser distance could be controlled with a very high precision. It is feasible to use this system to do further experiments to investigate the influence of laser on the machining of difficult-to-machine materials with a very small HAZ.

5. Acknowledgments

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