Improvement of the Surface Finish obtained by Laser Ablation with a Nd: YAG Laser on Pre-ablated Tool Steel.

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Abstract

Surface finish is an important requirement for tool and die makers and remains a challenge with conventional machining technologies.

Nd: YAG lasers have been utilised for many years in the area of laser marking, engraving and micro machining. In recent years, these lasers have been used in other fields, such as laser ablation of small tools for plastics injection moulding.

Laser ablation is a technology that is investigated as a method to improve the surface finish in tool steel. Different proposed strategies and techniques that are uniquely inherent to the technology will be investigated.

The focus of this study is to employ a second routine of laser ablation on samples of pre-ablated rough surfaces. These strategies are expected to add surface quality that will reduce the need for further surface finishing. Strategies that reduce surface quality will also be identified.

We report on the influence of machining parameters on the improvement of the quality of the surface finish.

Keywords
laser ablation, surface finish, tool making

1 INTRODUCTION

Laser ablation is a “laser milling” technique that uses a highly focussed laser beam to vaporise and remove a small volume of material at high feed rates. By following a scan path, it acts in a similar manner to a conventional milling system but without mechanical contact.

The technology’s applications are varied depending on the end user, but as a complementary technology with conventional milling, it is most valuable within the tooling industry for the creation of small tools and inserts.

It is a very flexible process, and is ideally suited for machining materials such as hardened steel, ceramic and other materials which are hard to machine utilising conventional machining methods. In addition, unlike electro discharge machining, it allows one to machine directly from CAD without the manufacture of electrodes.

The process of laser ablation is as follows: the laser pulse melts the material and heats it to vaporisation point. The vaporisation pressure results in the ejection of molten material from the surface [1].

One of the critical factors for the tooling industry is the quality of surface finish after machining. Better surface finishes minimise the need for post processing, which is currently done by hand and is time consuming. In some cases post machining processes can damage or reduce detail quality.

This paper reports on the initial tests to determine the best parameters for improving surface finish post-laser ablation.

2 THE LASER ABLATION SYSTEM

The laser ablation system utilised for these experiments is a DML 40S manufactured by Deckel Maho Lasertec. The laser source is a Nd: YAG laser with a maximum average output power of 100W. It has a 1064nm wavelength, and operates in a frequency range of 1 kHz to 50 kHz. Nominal spot size diameter is 40 µm – 60 µm.

The beam is steered by two galvanometer scanner mirrors, which allow scan speeds on the material of between 50mm/s and 800mm/s. A variable beam expanding telescope is utilised to compensate for different focal distances over the entire scan field. The system also has a camera for material positioning, a tactile probe for depth measurement and calibration, and an XY table for accurate movement of the material.

3 MATERIAL PREPARATION

The material used for these experiments was tool steel (Bohler K460, DIN 1:2510). This material was chosen as it is commonly used in the tooling industry. Test pockets were machined into the surface of this material to a depth of 100um to create machined surfaces with roughness in the region of 2 µm Ra. Roughness is measured using a Mahr surface scanner. These pockets were machined with maximum power, a scan speed of 400 mm/s, a track displacement of 15µm and a frequency of 20 kHz.

4 SURFACE IMPROVEMENT

Various strategies exist for machining with good surface finishes. Kaldos et al report on the importance of spot overlap, track displacement, repetition rate, power and frequency [1]. Pham et al give surface finish results for various settings of frequency, power, and scan speed [2]. The current work expands on this work and determines methods for improving surface finish after initial ablation has been completed.

A number of laser and process parameters can be adjusted for laser ablation. These include laser frequency, power, scan speed, track displacement, and laser defocus. In addition, the number of layers machined and spot size can also be adjusted.

Parameters which are not varied are shown in Table 1. These parameters have been chosen as starting values due to there frequent use for conventional machining. Parameters which are varied are shown in Table 2, together with the range of settings utilised.

Parameters	Value
Frequency (kHz)	40
Scan Speed (mm/s)	400
Track Displacement (µm)	10

Table 1: Fixed experimental parameters.

Parameters	Range
Average Power (W)	2.2 – 11.2
Defocus (mm)	0 - 3
Layers (each)	1 - 64

Table 2: Variable experimental parameters.

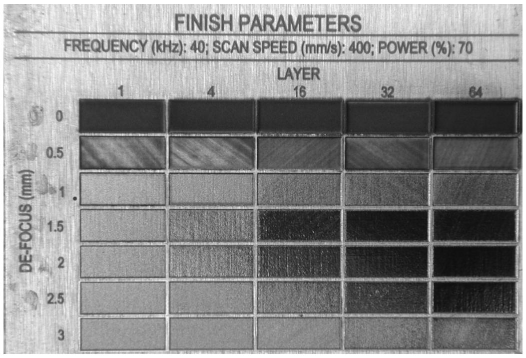

Figure 1: Photograph of a test matrix ablated with 11.2 W average power, frequency 40 kHz and scan speed 400 mm/s.

Figure 1 shows a sample of the surface of the material after ablation. Each matrix varies the number of layers ablated and the defocus of the laser beam. A separate matrix is ablated for different laser powers.

The surfaces of the pockets are measured after the finishing ablations are completed. The improvement in surface finish is calculated by taking the difference between the rough pocket Ra and the finished Ra.

Average power and pulse width measurements are made at all power levels used for machining.

5 EXPERIMENTAL RESULTS AND DISCUSSION

The results from the experiments are presented graphically in Figures 2 – 6.

Figure 2 and Figure 3 show the original surface after the roughing process plotted together with the surface after the finishing operations, for average powers of 2.2 W and 11.2 W respectively. At low powers (Figure 2) it is clear that very little surface improvement is accomplished even when multiple layers are machined. When machining in focus (or near the focus) the surface finish is worse than the starting roughness.

At higher powers (Figure 3), a clear surface improvement is obtained across the range of defocus and layers.

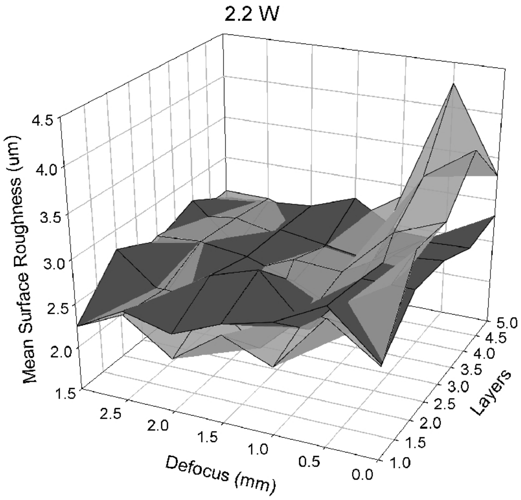

Figure 2: Rough and finished surface for a power of 2.2W.

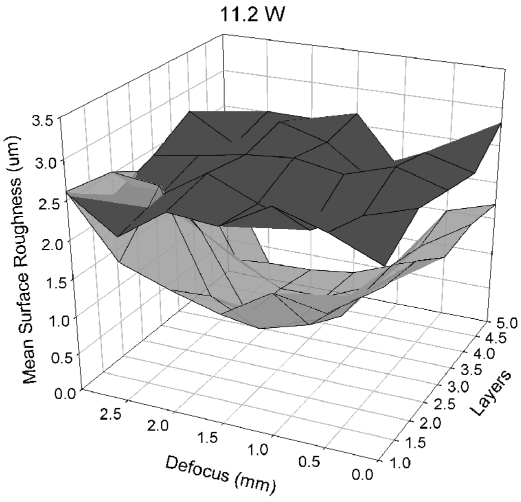

Figure 3: Rough and finished surface for a power of 11.2W.

Figure 4 shows the mean roughness improvement as a function of average power and defocus. At low powers and high defocus, very little improvement is evident. At higher powers and less defocus improvement is evident. Between these values a clear degradation in the surface is shown (valley region).

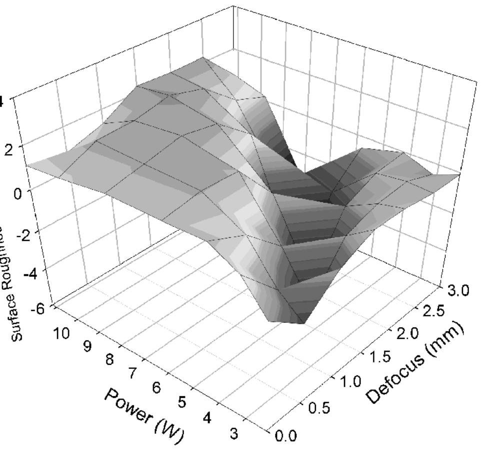

Figure 4: Mean surface roughness improvement averaged across all layers.

Figure 5 shows finished Ra as a function of the power density of the laser. Figure 6 shows the improvement in Ra as a function of power density. There are 3 distinct regions which can be identified. Region 1 shows very little surface improvement. This is a region where there is not sufficient power density on the surface of the material to have any effect. Region 2 shows degradation in the surface roughness. Region 3 shows improvement in the surface.

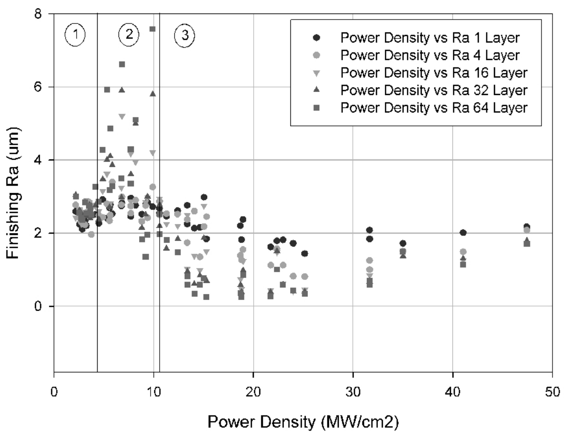

Figure 5: Finished Ra as a function of power density, showing 3 distinct machining regions.

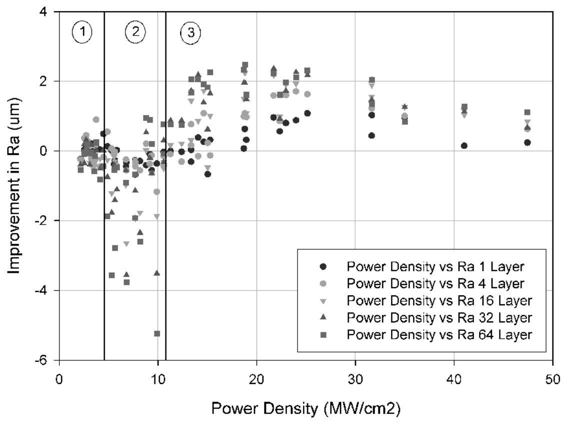

Figure 6: Improvement in the surface finish as a function of power density.

Two distinct ablation regimes have been documented [3]. These regimes correspond with the melting and evaporation of the metallic surface. The melting regime is difficult to control leading to problems with repeatability. Region 2 of the above figures corresponds to this regime. Region 3 corresponds to the evaporation regime, where repeatability is less of a problem and clear improvements in surface finish are obtained.

These figures give a good indication of laser parameters which should be chosen in order to improve the surface finish.

It is also clear from these results that increasing the number of layers machined increases the surface quality.

The best Ra value obtained was 0.25 µm. In the power range of 9-11 W, and defocus values of 1.5-2 mm, the Ra was consistently better than 0.4 µm. This is better than the standard laser ablation values of 1 µm Ra obtained from the DML40S as given by the manufacturer [4].

6 CONCLUSIONS AND FUTURE WORK

This work has focussed on the improvement of surface finish on pre-ablated tool steel. The results clearly show that improvement is possible over the conventionally machined surface. A best finish of 0.25 µm Ra was obtained.

The results also show clearly the melt and evaporisation laser ablation regimes.

Future work will focus on determining the effect of other laser parameters on the surface finish. These parameters will include scan speed and frequency, which were kept constant for these experiments.

In addition, the current tests will be repeated, focussing more closely on those areas where good surface finishes were obtained.

7 REFERENCES

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9 BIOGRAPHY

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