Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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Annals of DAAAM International

3D LASER REMOVAL - OPTIMIZATION FOR IMPROVING FORM ERRORS

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Abstract: *The current state of 3D laser removal technology has enabled the production of fine contours and cavities, three-dimensional laser engravings, and components with steep walls; all at high qualities. It is possible to process a variety of materials such as hardened steel, graphite, ceramics, various other hard metals, as well as high-strength materials such as CBN and PCD. A major advantage lies in the non-contact operation of this technology which makes it possible to machine without any tooling costs and without tool wear. There is no doubt that the technology of 3D laser removal has enormous potential. This potential can be maximized by the fine tuning and optimization of process parameters coordinated with the needs of manufacturing.*
Key words: *Laser erosion, 3D Laser cutting, Technical production*

1. INTRODUCTION

For some time one of the main applications of 3D laser removal technology has been in the model and mold making industry. This method of laser technology offers decisive advantages especially in the processing of very hard, high-melting, or non-conducting materials. These types of materials are difficult to machine with conventional removal techniques. In mold and die production this technology is excellent because of its ability to produce fine, delicate, and yet complex structures. These types of structures if performed by a milling process would be prohibitivly difficult, and if conducted through electron discharge machining (EDM), would require the production of many EDM electrodes.

In the context of injection molding applications, the production of some geometric structures frequently have problems associated with their shape or exhibit some type of form error in the production process. Often these problems can be traced to a non-optimal set of technical parameters.

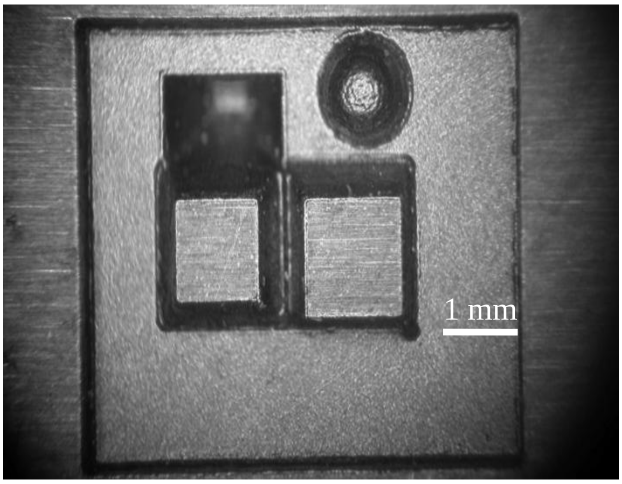

Fig. 1. Test geometry (material 1.2344)

This paper uses a LASERTEC machine; model DML 40 SI to conduct a full factorial experiment. This device has three optical and three mechanical axes. Thus the machining of vertical walls with angels up to 90° is possible by the use of a swiveling laser beam and continuously repositioning the workpiece. The machine program itself can be generated manually or created from 3D CAD data. The laser source is a continuously pumped Nd: YAG laser. The device is capable of achieving an average power of 100W and a pulse rate of 4 to 30 kHz.

The experiment is aimed at studying the influence of technology parameters in order to demonstrate how to optimize and prevent the occurrence of some types of form errors.

2. TECHNOLOGY

Laser removal is based on the localized heating of the material to be processed due to the absorption of induced laser radiation. The material's surface is melted and partially sublimated. Here, the vaporized material increases in volume compared to its solid state by a factor of 700 in a time interval of about 200ns. The resulting vapor pressure from this expansion is sufficient for most of the molten material to press out of the interaction zone. In order to support the material, a sharply focused gas beam is used with a direction tangential to the workpiece surface. The laser removal process can be divided by the process design into the form of figures, and the writing process.

The aim of this work is to identify optimal parameter settings or other appropriate measures in creating manufacturing programs to reduce production form errors that have occurred in the past. Ideally, the goal is to eliminate their occurance completely. In addition, the limits of the machine used and the available software should be observed and examined in order to understand their comparative capabilities.

Initially, an examination of the influence of obvious factors should be checked using a cavity. This is performed by conducting a full factorial experiment. It is the first approach to a production problem and is seen in further optimization as a rough guide for the setting of optimization steps. Subsequential tests are compared with these in order to confirm that the follow-up experiments with optimal settings are sufficient to avoid unwanted form errors in production.

2. EXPERIMENTAL RESULTS

In the first step, a testing sample of a particular geometry is fixed in place allowing for inspection of problematic structures. This requires a processing time-frame of about three hours. By this method a sufficient number of samples can be created within a reasonable amount of time. Figure 1 shows this geometry as recorded by the InfiniteFocus Alicona surface measurement system, which has a 5X magnification lens.

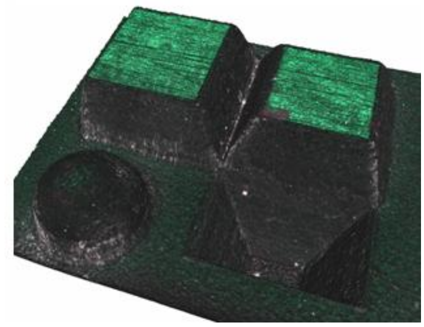

Fig. 2. Test geometry measured with Alicona InfiniteFocus G4

Of particular interest to this research was the wedge-shaped gap between the two surveys; this will be discussed in further detail. In the past similar gap-shaped structures created under certain settings produced unwanted penetration observeable at the bottom of the groove.

In particular, three parameters were examined which may have an influence on these form errors. The first is the number of edge cuts, next, the track offset (equal to the lateral delivery or distance of the processing path) between the edge sections, and lastly the value of the magnification. The magnification value causes a shift in the hatch area towards the edge of cropped area, and ultimately an overlap of the two areas.

In the course of the current full factorial experiment these three factors were varied in two developmental stages. With these settings eight production samples were machined. The images of these samples were obtained by using the surface measurement system Alicona InfiniteFocus G4. Figure 3 shows an example of an image from a sample which was made with eighteen edge cuts in a track offset of 7µm, and with a magnification value of 12µm.

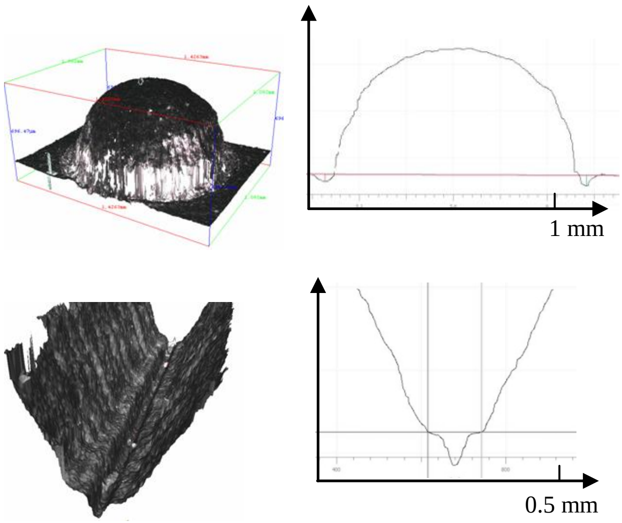

Fig. 3. Hemisphere and slatted floor

The undesirable penetration at the bottom of the column is significant and is clearly visible. Similar penetrations are also visible at the bottom of the well as an excess valley. They mainly occur on the sloping walls of the recess.

Based on these recordings, the gap opening angle, depth of the penetrations encountered, the radius of the hemisphere, and other geometric characteristics of the examined structures were measured. The collected measurements were compiled and analyzed statistically. The sensitivity of the relevant factors as well as the influence of the shape error was investigated.

From this analysis, it was shown that an underlying error probability of 5% was present based on the number of edge cuts. Both the number of edge cuts, and the opening angle have a significant influence on the formation of the valley at the bottom of the cut as well as on the expression of the gap. The cutting edge must be set to a minimum number in order to avoid possible excess cutting depth. However, in order to increase the opening angle of the column, it is essential to conduct the cutting edge number as high as possible. Such an enlargement of the opening angle is urgently needed because its value had an arithmetic mean of only 49.3°, much lower than the preset target value of 60°. This adverse variance was also evident when comparing the median of the angle instead of the arithmetic mean. The median of the angle is measured with values as location parameters and is strongly influenced by even two outliers. In this case the median was calculated to be only 45.5°. There are now two conflicting claims on achieving optimal column geometry.

By modifying the production's programming it was ultimately possible to increase the opening angle of the gap while generating the sample's form without the unwanted excess penetration. The samples made with this modification show no emergence of slatted floor, due to the change in the number of edge cuts performed.

Figure 4 shows a scanning electron micrograph of two slatted floors at 400x magnification. The left image displayed is from a modified production program created sample. The picture on the right shows the slatted floor from the first sample.

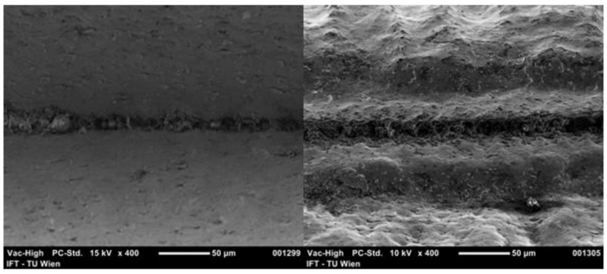

Fig. 4. Comparison oft two slatted floors

5. CONCLUSION

With this experimental study a significant improvement in the accuracy of the sample's shape was shown to be possible by using the technology of laser removal combined with an adjustment in the process parameters and changes to the processing strategy. Further continuation of this work will open up the opportunity to consider this treatment strategy in fixed deposit cycles of CNC programming.

6. ACKNOWLEDGEMENT

We would like to thank Ernst Wittner GmbH for enabling us to carry out this work.

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