SURFACE ANALYSIS STUDY OF LASER MARKING OF ALUMINUM

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Abstract

Nowadays, traceability combined with robust and permanent identification of industrial parts is becoming a crucial element of the manufacturing processes. Laser marking of metal parts is a technology showing many advantages compared to labelling, inkjet or dot peen marking. Advantages include no consumables, faster cycle time, reliability and repeatability of the process and robustness of the marks. In this paper, we aim to study the physics involved behind the process of laser marking on aluminum. The marking is generally made in black surrounded by a white background applied to increase contrast. We show the results of a surface study for both surface whitening and blackening performed with a Dektak surface profiler and a scanning electron microscope (SEM). A physical explanation of the whitening and blackening of the aluminum is provided - based on these results. Different characteristics of the surface are also discussed with regards to the laser parameters. The results explain why a blackened and a whitened surface do not scatter light the same way. The whitening is produced by the surface texture of small amplitude which creates a diffuse reflection. The blackening is produced by a surface texture of greater amplitude that increases the coupling of the light within the material.

Keywords: Laser marking; parts traceability; barcode; datamatrix; serial number.

1. Introduction

Many manufacturing industries require marking their parts with information such as product serial number, production date, bar code or corporate logo. Several methods can be used to do so, such as labeling, inkjet printing, dot peen marking and laser marking. This paper focuses on laser marking because this technology shows many advantages compared to the others, such as high speed, permanent marks, non-contact technique, consumable-free and easy maintenance. The powerful focused light energy supplied by the laser modifies the surface of the materials. With the optimization of certain parameters, it is possible to create high contrast markings on an aluminum surface.

Several parameters influence the way the laser beam interacts with the materials. First of all, the material properties such as the absorption coefficient, thermal diffusivity, melting and evaporation point are important. These parameters are intrinsic to the materials involved and often may not be changed. On the other hand, laser parameters, such as power, wavelength, pulse duration and frequency can be optimized to produce the best marking based on pre-defined criteria. For instance, marking speed is often the limiting criterion. It is therefore possible to optimize the marking parameters to ensure the code is marked as fast as possible while ensuring that it remains readable.

In this article, we study the surface modification generated by laser marking on aluminum 6061. The laser used to obtain these results is a Q-switched pulsed fiber laser. This laser operates at a wavelength of 1.06 μm and provides an average output power of 100 W. This wavelength is highly suitable for marking metal such as aluminum because it allows relatively high absorption.

2. Experimental Setup

The characteristics of the laser used are presented in Table 1. A schematic of the setup is presented in Figure 1. The laser goes into a beam expander that magnifies its size to approximately 10 mm (@ $1/e^2$). It passes through the scanning head and then into a lens that is used for focusing the beam onto the surface. The sample is placed on a heating plate to assess the effect of temperature. The fiber laser and the scanning head are controlled by a computer to mark a matrix of squares. This matrix is used to study different combinations of speed and line spacing. Two different lenses with focal lengths of 420 mm and 160 mm were tested for temperatures between 25 °C and 400 °C. The contrast, which is defined by the difference between the grey level of the white and the black, is evaluated by analyzing photographs of the sample taken under a white light at 20° from the vertical.

Table 1: Fiber laser characteristics.

Laser source type	Q-switched
Manufacturer	IPG Photonics
Model	YLP series
Max average power	100 W
Cooling	Air
Pulse duration	100 ns
Pulse repetition rate	100 kHz
Pulse energy	1 mJ
M^2	1.6

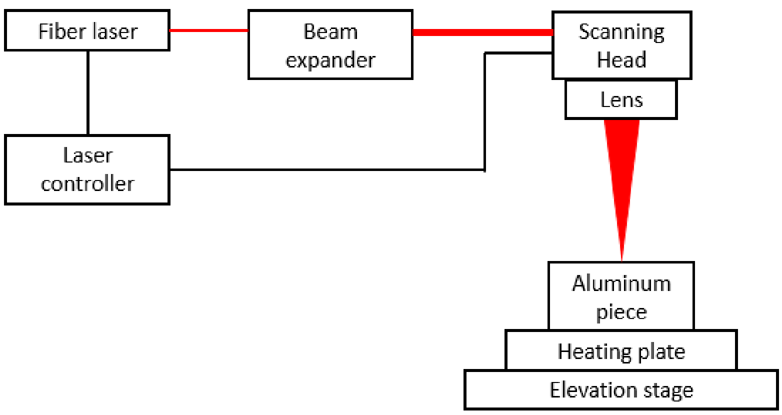

Figure 1. Schematic of the experimental setup.

In order to better understand the physics behind the marking process, the surface of selected samples from the matrix was studied. The first characterization was performed with a Dektak 150 surface profiler. This provided a 2D profile of the surface. The measurements were done perpendicular to the line inscribed by the laser. The second characterization was done with a scanning electron microscope (SEM). The images obtained show the topography of the surface of the sample and how the laser had altered it.

diffuse light. The blackening results from a more important surface modification increasing the coupling of the light within the material. The laser spot size and the sample temperature are also impacting the surface alteration and at the same time the observed contrast. Good contrast can be achieved at high temperature provided that the marking speed is high enough. In addition, large line spacing is also leading to low contrast due to white space between lines.

6. References

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