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Experimental Analysis of Laser and Scanner Control Parameters During Laser Polishing of H13 Steel

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Abstract

Laser polishing is a manufacturing process in which a small amount of material is melted via laser irradiation and molten pool is then redistributed to create a smoother surface finish/superior surface quality. The focus of this study is to generate more comprehensive understanding of the effects that laser and scanner control parameters have on the formation of laser polished lines. A parameter known as "Laser On/Off delay" is varied along with the laser power to study the impact that these parameters have on the synchronization between laser power and beam scanning velocity. It was determined through experimental analysis that the "Laser On delay" parameter plays a significant role on the formation of the laser polished lines, essentially in a region that is outside to the widely characterized "steady state" zone of constant track width. A set of experiments was conducted to identify the combined effect of transient (acceleration/deceleration) phases for laser power and speed on the terminal geometry of the polished line. When the optimal transient combination of power and speed was used, surface quality improvement by 83% (areal surface roughness (S_a) reduction from 1.35 μm to 0.23 μm) was obtained.

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Keywords: laser polishing; line formation; surface quality; laser-on-delay; synchronization control

1. Introduction

The laser polishing of tool steels and metals in general have been around the manufacturing industry for more than a decade and a half. However, most of the knowledge of polishing processes is based around manual polishing

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processes which are very time consuming and often require skilled workers to complete [1-3]. This is why, in recent years, laser polishing (LP) has become more widely used due to the ability to quickly and efficiently polish surfaces. Laser polishing is the process of using laser radiation to melt a very small layer of material creating a small molten pool which uses the physics of surface tension to evenly distribute the recently melted material across the surface and thus creating a much smoother surface finish [4].

Due to the fact that LP process is fairly new in comparison to many of the conventional processes used in the manufacturing industry, many aspects of the research surrounding the topic remain focused on process optimization. Often, when experimenting with the optimization of laser polishing parameters (power, scanning speed, focal offset, etc.), a so-called “line test method” is implemented. The line test method consists of producing a series of lines independent of one another, each with varying laser polishing process parameters [5-7]. This method creates a quick and extensive amount of data which can be, and often is, used to determine the parameters which will produce the best or required surface quality.

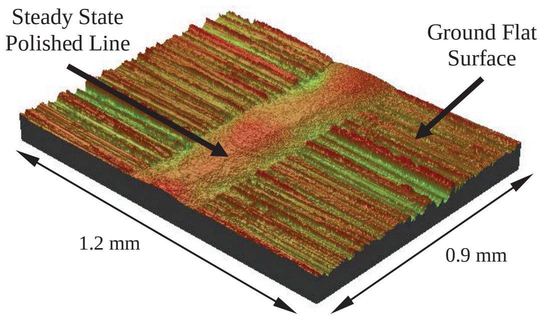

Fig 1: The topography of the steady state zone for a representative laser polished line

During the analysis portion of the line test experimentation, many researchers focus solely on the steady state zone of the laser polished line that is essentially characterized by a constant track width. As also suggested by Figure 1, the common steady state analysis generally precludes the inclusion of the transient ends of the polished line [7-9]. However, when conducting a set of line polishing experiments, it was noticed that, depending on the process parameters, the ends of the polished lines had geometric characteristics that were different from those of the steady state.

The slight alterations between the transient stage zone of the LPed line and the steady state zone may seem insignificant when considering a line test method experiment, but when placed into real world applications, the difference between the state zones may cause a decrease in the efficiency of the LP process because in most cases, the initial/final segments of the line also belong to the broader polished area. Typically, an industrial LP application will involve a requirement to polish an entire area on the surface of the product. Area laser polishing, however, simply consists of overlapping single LPed lines to cover the required area. There are many strategies for surface polishing, some of which are shown in Figure 2, many of which are similar to conventional pocket machining strategies [10, 11]. The linear method involves horizontal (or vertical) lines overlapping and can consist of all the lines being formed in the same way (ex. left to right) or altering directions. The inside-out (or outside-in) method consists of squares which get gradually larger (or smaller) and overlap until the area is filled. Finally, the diagonal method, although self-explanatory, consists of overlapping diagonal lines which, again, can all go in the same direction or altering directions each LPed line.

Although all of these methods differ from one another, they all have a common aspect which is that the beginning/ends of each line produced interacts with the beginning/end of the previous line that was made in the process. This means that if the transient stages of each line (e.g. acceleration and deceleration) in the area polishing process are not formed as expected, then the overall efficiency of the LP process will be decreased.

Thus, the focus of this study will be to generate more comprehensive understanding of the transient stages of a laser polished line formation. To achieve this, experiments will be conducted using the line test method with varying laser and scanner control parameters and the results will be analyzed for discrepancies in the transient state zones of the lines.