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Experimental Study on Continuous Laser Polishing Die Steel S136D

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Abstract. With the traditional polishing method the mold material will cause problems such as difficulty in processing the micro-area surface and damage to the surface of the workpiece. Laser polishing technology is an advanced and new surface processing technology that has emerged in recent years. Because laser polishing has the characteristics of good polishing quality and low thermal effect, it is very suitable for high-precision polishing of mold steel, titanium alloy and other materials. By properly controlling the process parameters such as laser energy density, scanning speed, scanning pitch and defocusing amount during laser polishing, the workpiece can be polished with high precision and the surface roughness can be quickly reduced. The processing examples in the paper further illustrate the superiority of laser polishing.

1. Introduction

In industrial production, mold automatic polishing technology has a variety of more mature technology, basically meet the needs of industrial manufacturing, such as mechanical polishing, electrochemical polishing, thermal chemical polishing, fluid polishing and ultrasonic polishing, etc., and widely used in the field of mechanical equipment, electronic instrumentation, medical machinery equipment, precision optical components. However, there are some shortcomings in these polishing methods [1], and such polishing techniques are faced with the problem of post-processing [2]. For example, electropolishing, electrochemical polishing, grinding, etc., can result in rounded corners or some areas cannot be processed. For chemical polishing, electrolytic polishing, and ultrasonic polishing, the surface needs to be cleaned after processing, and the electrolyte and the grinding suspension need to be frequently replaced and processed. For manual polishing, etc., the abrasive is consumed, and the ablated particles need to be disposed of in time during processing. Therefore, it is not feasible for an irregular mold surface. If you use precision CNC machining, you will face programming difficulties. When polishing with conventional mechanical equipment, different areas of the same plane cannot be polished differently. When polishing an anisotropic workpiece, it is necessary to select a polishing path depending on the crystal orientation. These polishing methods are easy to impact the workpiece and may affect the mechanical properties and material properties of the workpiece [3]. Mold surface finishing is a difficult problem in mold processing that has become a bottleneck in mold processing.

Laser polishing is an emerging manufacturing process which improves the roughness of components through controlled melting of a microscopic surface-layer in industrial production in Figure 1. The laser polishing technique is a new surface processing technology. Therefore, with the development of precision machinery industry, laser polishing is attracting more and more attention and is widely used in industrial production, and produces products of high quality produced, reduces product costs and has multi functions.

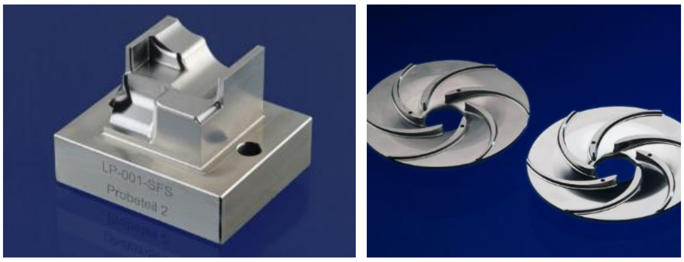


Figure.1 Laser polishing applications

In 2002, Ramos J.A et al. [4] used Nd:YAG laser and CO_2 laser to polish the selected parts of the laser sintered part, reducing the surface roughness Ra from 7.0-9.0um to 1.4-2.1um. In 2006, Lamikiz et al. [5] also polished selected laser sintered parts using CO_2 lasers. It is noteworthy that Lamikiz and other methods have not only achieved good results in surface polishing, but also achieved good results with three-dimensional polishing, and the roughness Ra was reduced from 7.5um to 1.2-1.3 um around. In addition, Lamikiz et al [6] performed a metallographic analysis on the polished parts, and found that the heat-affected zone has no defects, and is more uniform than the original sintered molded part, and the hardness of the metal surface is also improved. Ukar et al [6] found that under the optimal parameters, both lasers achieved remarkable results, the surface roughness was reduced by 80%, and Ra was less than 0.5um; but the semiconductor laser was compared with CO_2. Compared with the laser, the polishing efficiency is higher. In 2012, Temmler.A et al. [7] used a five-axis linkage manipulator combined with a three-dimensional scanning system and a fiber laser to study the laser polishing of the tool steel 1.2343 metal free-form surface. It is believed that the polishing process is mainly the remelting of the thin metal surface. After the laser irradiates the workpiece, the molten metal at the peak flows to the trough under the action of the surface tension, and there is no material removal during the polishing process, but the melt is redistributed. In 2012, Hafiza A. M. K. [8] and others studied two consecutive laser beam laser polishing AISIH13 tool steels to study the effects of surface quality. Under the conditions of argon protection, laser polishing irradiation of the same energy density was applied at the same time, and the 95% overlap ratio gave the best result, and the surface roughness was reduced from 1.35 μm to 0.18 μm. Pfefferkorn FE [14]studied the improvement of metal surface finish by thermal capillary flow during pulsed laser polishing. In the hot capillary state, the longer melt duration was used during pulsed laser polishing, resulting in a surface tension gradient and causing the Marangoni flow. The flow moved outward from the centre and caused a rise at the edge of the weld pool. The results showed that the combination of capillary and hot capillary was more effective than the single use, and polishing on Ti-6Al-4V samples, achieving a surface roughness reduction of up to 72%. Hafiz, Abdullah M. Khalid [15] studied the applicability of picosecond lasers in laser micro-polishing of Ni-based superalloy Inconel 718 (IN718). The research contents include: determining the melting state, establishing the concept of polish ability of the initial surface topography space content, and experimenting with the potential micro-polishing process capability of the ultrashort picoseconds (ps) laser. During 1D laser micro-polishing, the ps pulsed laser polishing reduced the Ra value of the material Inconel 718 from 0.50 μm to 0.24 μm, which was reduced by about 52%. It significantly improved the surface quality of the workpiece.

Laser polishing is a new material surface treatment technology that has emerged with the development of laser technology. It uses a laser beam of a certain energy density and wavelength to radiate on the workpiece to melt or evaporate a thin layer of material on the surface to obtain a smooth surface. Laser polishing solves the problems of conventional polishing methods. For surfaces with very complex topography that are difficult or impossible to polish, laser polishing enables rapid polishing of these materials. Through the numerical control system, the laser polishing liquid realizes the automatic processing of the workpiece. Therefore, it is a very promising new material processing technology [8].

2. Laser polishing mechanism

When the laser acts on the surface of the workpiece, due to the different wavelengths and absorption modes of the laser, or the chemical bond vibration of the surface material of the workpiece is intensified, the laser energy is absorbed, converted into heat, the surface melts or evaporates, or the chemical bond of the surface material lattice is broken. The surface material is removed [9]. Laser polishing is performed by the above process, through reasonable selection of processing parameters to obtain a smoother surface. Although the principle of laser polishing is not conclusive, most researchers believe that laser polishing of metallic materials is based on laser irradiation, which causes a thin layer of the surface of the workpiece to melt. Due to the influence of surface tension, the convex portion will be flattened. After the molten surface solidifies, the overall roughness of the surface decreases, and the molten pool continues to move forward as the beam moves, and the above process is repeated, as shown in Figure 2.

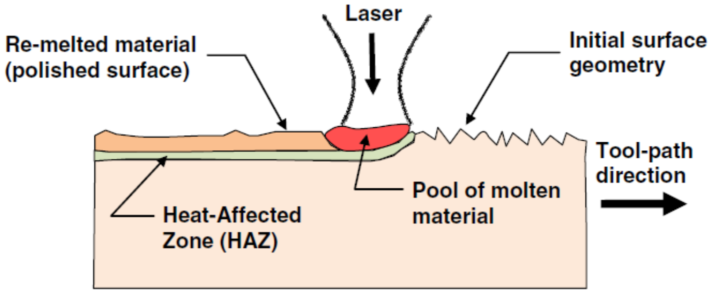


Figure.2 Laser polishing principle

The laser polishing process is essentially the interaction between the laser and the material surface, which follows the general rule of laser and material action. The interaction between laser energy and the area being processed can be divided into two main types of processes: thermal effect and photochemical decomposition. Depending on the laser and material interaction process, laser polishing can be easily divided into two types: one for thermal polishing and the other for cold polishing.

Thermal polishing generally uses a continuous long wavelength laser as a laser source. For example: a YAG laser with a wavelength of 1.06 um and a CO_2 laser with a wavelength of 10.6 um. When a continuous long-wavelength laser beam is irradiated onto the surface of the material, the surface is heated by absorbing laser photon energy. When the temperature of the active region reaches the melting point of the material to be polished, the surface active region of the material begins to melt and evaporate. Since the surface melting portion has different curvature radii, the material in the molten state flows toward a place where the curvature is small, and finally the curvature tends to be uniform everywhere. At the same time, the solid-liquid interface of the surface material solidifies at a speed of several meters per second, and the final metal material obtains a smooth and smooth polished surface [10-12].

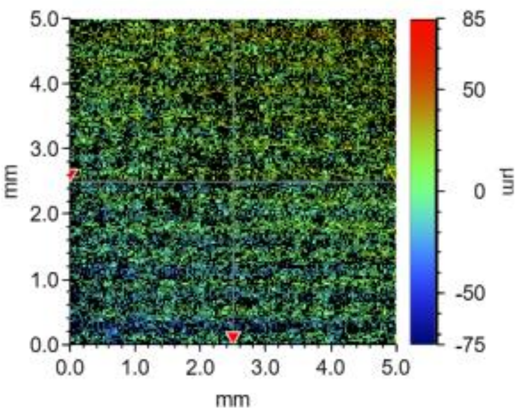
The cold action of the laser and the material is photochemical decomposition, also known as photochemical action. It refers to the action of the surface of the material after laser illumination, because the surface of the “single photon absorption” or “multiphoton absorption” laser photon energy, the chemical bond of the surface layer of the material is destroyed, or its lattice structure is damaged. After photochemical decomposition, the resulting product expands at an active rate, eventually exploding itself and detaching from the area, while taking away excess energy. The process of action is also known as photolysis stripping [13]. The polishing process is performed by removing the material of the surface layer of the workpiece by the above-mentioned photo-disbonding action, which is called laser cold-polishing.

3. Experimental study

This experiment was carried out on a self-developed five-axis laser polishing machine. As shown in Figure 3, the selected material for polishing was S136D mold steel, as shown in Figure 4. In this experiment, a continuous laser is used to process the surface of the mold steel, and the continuous laser is polished according to a given numerical control program. Under the control of the CNC motion control system, the continuous laser can achieve high-precision polishing of the surface of the die steel S136D. Continuous laser polishing of the surface of the mold steel, the processing parameters set: 1000w continuous laser, power: 210W, polishing speed is V = 160mm / s, scanning spacing: 0.15mm. The initial surface roughness of the mold steel before polishing was 7.245 um, as shown in Figure 5. After continuous laser polishing, the surface roughness Ra of the material was 0.782 um, and the surface roughness of the workpiece was reduced by 89.2%, as shown in Figure 6. There is a lot of undulation on the surface of the original mold steel S136D. The principle of continuous laser polishing is that the laser beam irradiates the surface of the workpiece, so that the thin surface of the metal surface is remelted and then solidified rapidly. During this process, the surface of the remelted surface is convex, and the surface tension is Redistribution under the influence, so that the surface of the mold steel is flat, which further demonstrates that continuous laser polishing has the effect of reducing the surface roughness of the mold.

Figure.3 Laser polishing machine

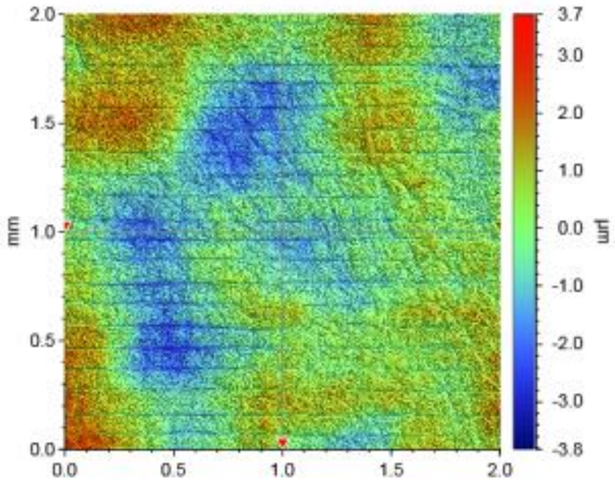
Figure.4 Die steel before and after laser polishing



Analytical Results

Labe	Value	Units
Sa	7.245	μm
Sku	3.319	
Sp	76.813	μm
Sq	9.085	μm
Ssk	-0.071	
Sv	-68.645	μm
Sz	145.458	μm

Figure.5 Surface roughness before laser polishing



Analytical Results

Label	Value	Units
Average	0	nm
Data Points	4187291.904	
Percent Data Points	99.94	%
Ra	0.782	µm
Rp	3.714	µm
Rq	0.958	µm
Rt	7.549	µm
Rv	-3.835	µm

Fig.6 Surface roughness after laser polishing

4. Conclusion

Traditional polishing methods have certain limitations, and laser polishing technology is a new type of surface processing technology. Because laser polishing has great advantages, it is widely used in high-precision polishing of materials such as die steel and titanium alloy. In the paper, the continuous laser is used to process the die steel S136D, and the polishing effect is obtained. The surface roughness is reduced by 89.2%. The example further demonstrates that laser polishing can significantly reduce the surface roughness of the material.

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