Proc. of the 9th Intl. Conf. of Asian Society for Precision Engg. and Nanotechnology (ASPEN 2022)
15–18 November 2022, Singapore. Edited by Nai Mui Ling Sharon and A. Senthil Kumar
doi://10.3850/978-981-18-6021-8_OR-15-0238

Effectively and Selectively Sealant Removal Using CO2 Laser

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KEYWORDS: Precision machining, Laser for manufacturing, Laser Cleaning

A feasibility study is carried out to evaluate the effectiveness of using a laser for sealant removal. We experimentally compare the performance of two type of laser systems, Yb:YAG laser and CO_2 laser, in the task of sealant removal, which is a very common task in aerospace industry. We have proved that CO_2 laser is able to remove the sealant in a more effective and selective means compared with Yb:YAG laser. CO_2 laser can completely remove the sealant at high speed with no residual and almost no damage or defects on the smooth surface of metal (Aluminum) substrates beneath the sealant. It is also insensitive to the focusing or aiming errors and can be easily integrated with robotic arm without need of sophistic and expensive force sensing and servo control. Therefore, it provides a low cost and practical solution for fully automated large area sealant removal without an operator intervention.

1. Introduction

Over the years, laser has been employed as a tool in various machining processes due to the following advantages: high precision, zero tool wear, non-mechanical contact with low spatial constrain, high machining capability being independent of workpiece hardness. In this work, we explore the possibility of utilizing a laser to selectively remove the sealant from the metal surface without causing any damage or degradation of such surface. Previously, these sealants were removed via mechanical methods, which is slower, less precise, and requires constant tool replacement due to tool wear. More importantly, those mechanical methods need very gentle and precise control on the pressure to avoid scratch, pit, notch, crack or any other unwanted surface damages or surface defects. Especially for the surface with complicated shape or structure, such precise control on the pressure can be extremely challenging in practice. It either makes the automation or robotization of the sealant removal process very difficult and costly, or only can be implemented in extremely slow speeds in well controlled environment.

Optical laser has been widely used in various precision industrial manufacturing applications including cutting, drilling, welding, welding, surface marking and surface texturing as well as 3D additive manufacturing [1,2]. Laser was used in chip de-capping to remove the top epoxy layer on the chip. However, it was considered as invasive means and must were followed by chemical wet etching to remove the residual layer and avoid the damage of chip inside. In this paper, we explore the feasibility to use a laser alone as a non-invasive means to selectively remove the sealant or paint layer from the surface of a metal substrate. The effect of various of parameters including of wavelength, power, scanning speed on the surface sealant removal efficiency as well as potential risk of damage of the substrate surface are systemically explored and optimized in experiments. Some practical issues such as tolerance to the laser focus and aiming errors, as well as the role metal surface quality in above are also studied. It proves CO_2 laser based sealant removal can be used as an efficient, non-invasive, and practical solution for automated metal surface clean in various industrial applications.

2. Experiment

2.1 Experimental Setup

Two laser systems, a 1064 nm Yb: YAG laser and a 10.6 μm CO2 laser, are used in this study. The YAG Laser has a maximum average power of 20W; tunable pulse duration and repetition rate from 10 ns to 250 ns and from 1 kHz to 500 kHz respectively. The CO2 laser has maximum average power of 50W with fixed pulse duration of 10ns and tunable repetition rate from 1kHz to 100 kHz.

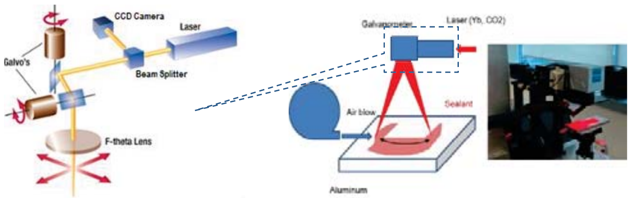
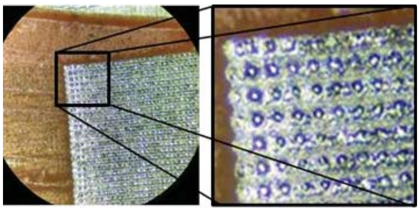


Figure 1. Schematic of experimental setup

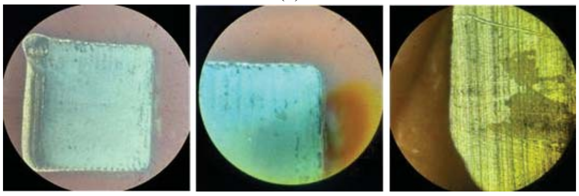
A schematic of the typical setup of a laser is shown in Figure 1. The laser is directed into a galvanometer scanner via a series of optics. The scanner has 2 movable mirrors that deflects the beam, allowing the laser beam to be scanned over an area. The laser also has a coaxial vision system to accurately aim the laser at the desired location.

2.1.1 Experimental results and Data Analysis

Aluminum plates with smooth surface, surface roughness smaller than 4 μm, are used as sample substrate throughout the experiments. On top of these aluminum plates, a sealant layer, H/temp Red Silicone Gasket Maker WB-HTR650, with thickness about 200 μm thick are applied in advance. All these samples are prepared two days in advance to make sure the sealant layers are fully dried and solid.



(a)



(b)

Figure 2 Inspection of on the surface of an aluminum plate by using (a) Yb: YAG laser and (b) CO2 laser.

Then, all these samples are exposed under Yb: YAG laser and CO2 laser for sealant removing. In all experiments, the laser powers and explosion time are optimized in advance to make sure there is no sealant residual and the laser influence on underneath metal substrate are minimized. As shown in Fig. 1 (a), when Yb: YAG laser is used, the damage of the substrate surface cannot be avoided. In contrary, CO2 laser is able to remove the sealant without any modification of the surface quality of the sample as shown in Fig.1(a). This phenomenon can be explained by the huge difference between the laser absorption coefficient of metal and resin materials [3]. Around 1μm, the laser absorption coefficients of typical metal materials are 2~5 times smaller than that of resin. While at 10 μm, laser absorption

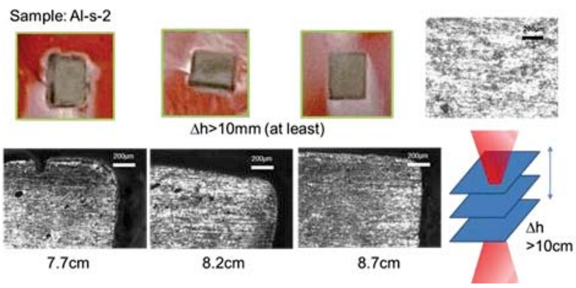


Figure 3 The laser sealant removal at different focal plane. f=750mm.

coefficient of metal materials is 1500~5000 times smaller than that of resin. Hence, almost all CO2 lasers are absorbed by the resin and cause no damage of the metal substrate.

Most traditional laser manufacturing approaches usually need high precision control on the focal plane with μm resolution to guarantee the performance laser processing. Such precision control mechanism is extremely complicated and expensive and only can be afforded by high value-add applications such as semiconductor industry. Considering the difficulty to maintain high accuracy of the laser focus and distance control in practical surface clean application, we also explore the tolerance of CO2 laser based sealant remove method to laser focusing and aiming error. The experimental results are shown in Fig. 3. There is no significant effect on metal surface are founded after the sealant removing when it is located within a zone not more than 1cm away from the laser focal plane. The scan lens used in the experiments has a focal length of 7.5cm. At least 15% variation of the focus error can be ignored in the practice, especially in the large area sealant removal with long focal length lens are used.

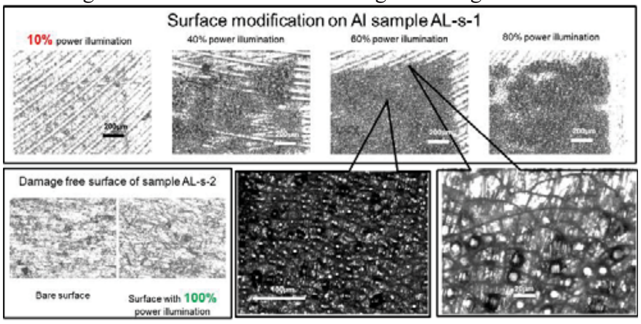


Figure 4: Top: Surface of Aluminum plate 1 (Ra< 4 μm)after CO2 laser expose with power of 10%, 40% , 60% and 80% of full power. Bottom Left: Surface of Aluminum plate 2 (Ra < 10 μm) after 100% CO_2 laser expose.

However, we notice that CO2 based sealant removal method is sensitive to surface roughness of the metal. An experiment to explore the sensitivity of the method to surface quality are executed and the results are shown in Fig. 4. There are randomly distributed melted sites appeared on the metal plate with surface roughness about 10 μm. It is induced by the tip enhancement effect of light filed, which leads to localized hot spots and surface damage especially when sample surface fluctuation period is close to the CO2 laser wavelength.

3. Conclusions (Times New Roman 10pt)

In summary, we have proved the CO2 laser is a potential means to remove the sealant effectively and selectively from the metal substrates without damage or defects generation on smooth metal surfaces, which is very common in aerospace industry. We also proved the proposed laser sealant remove method is insensitive to focus or aim error, with acceptable speed and scalability for large area applications. Compared with traditional sealant remove method, laser-based method has following advantages:

- Almost no damage to substrate material or vicinity of the treatment areas
- Large tolerance to laser focusing error removes the needs high resolution distance sensing module, pressure sensor and force control and leads to significant cost reduction.
- Omni & non-contact solution with tunable treatment width, depth, speed, and no need frequently tools exchange to match target's morphology or mechanical property variation.
- No corrosion & poison chemical use and less health issue.

Therefore, it is a good candidate as end-effector for robotic arm-based sealant remove applications. The relatively loose and non-critical control requirement will greatly simply the system complexity and lead to high cost-efficient, high speed and high throughput of the system.

ACKNOWLEDGEMENT

This work was supported by RIE2020 Advanced Manufacturing and Engineering (AME) Industry Alignment Fund, Singapore Aerospace Programme Cycle 14 (A2015a0126).

REFERENCES

1. R. Bogue (2015), "Lasers in manufacturing: a review of technologies and applications", Assembly Automation, Vol. 35 No. 2, pp. 161-165.
2. G. Guanghao et al. (2021), “Research status of laser additive manufacturing for metal: a review”, Journal of Materials Research and Technology, Vol. 15, pp. 855-884.
3. J.D.B. Featherstone et al. (2001). Fundamental interactions of lasers with dental hard tissues. Medical Laser Application, Vol. 16, Issue 3, pp. 181-194.