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Cleaning, cutting and welding of construction materials

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Abstract

Recent progress of fiber lasers enables us to use power intensity of 10^5 W/cm^2, which is enough to ablate materials in CW-laser processing. Considering their robustness and compactness, use of the fiber lasers in a construction site would be the next challenging field of laser applications. We are studying the possibilities of laser processing for construction materials such as concrete blocks, steel pipes, sand, stones, woods, etc., using a CW fiber laser with maximum output power of 300W. With high-speed galvo scanner, pulsed irradiation less than a millisecond is possible even with CW laser. By changing scanning speed a few orders of magnitude, one can ablate, melt or burn those materials due to flexible control of heating. Surface cleaning and rust removal of steels, cutting and welding of concretes are the useful applications in repairing, maintaining, dismantling of buildings.

Keywords: fiber laser, cleaning, welding, construction material ;

1. Introduction

Robustness and compactness are the advantages of fiber lasers, compared to the solid-state lasers, and hence can be used in a harsh environment such as construction site, which would be the next challenging field of laser applications. Although people tried to drill bedrock, cut stones and concrete 40 to 50years ago, available lasers at that time, such as CO_2 and YAG lasers, could not provide satisfactory results because of insufficient beam brightness and both peak and average power. Recently, Long et al., 2016, demonstrated to drill and core 50mm-thick concrete using a QCW fiber laser and showed promising results.

We are studying the possibilities of laser processing for construction materials such as concrete, sand, stones, etc., using a CW fiber laser with a maximum output power of 300W. With focusing or defocussing

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the laser beam, one can cut and melt or weld those materials. Since silica is the main ingredient of the construction materials, heated samples undergo vitrification or sometimes become glass beads with high-power laser irradiation. These processes might be useful for novel design of building components. Meanwhile, cutting concrete could be applied to decommissioning or repairing buildings.

2. Experiments

2.1. Experimental Setup

Fig.1 shows experimental setup. A CW single-mode fiber laser (Fujikura, FLC-300-A) with an output power of 300 W, a wavelength of 1090 nm, and $M^2 < 1.3$, was used in the experiments. The laser beam of 5-mm in diameter from the collimator was focused by a plano-convex lens with f = 1000 mm. The focal spot diameter on the work was about 1 mm. A combination of a high-speed galvo scanner and the CW fiber laser could provide a flexible laser processing. For example, 1 mm laser spot scanned at 10,000 mm/s corresponds to 100 μs pulsed irradiation and fluence of 1.3 J/cm^2 for 100 W laser power, resulting in ablation process. On the contrary, the same spot size and laser power with 1 mm/s scanning speed corresponds to 13 kJ/cm^2 resulting in melting process.

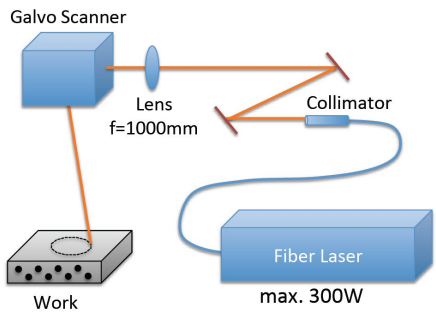

Fig. 1. Experimental setup

Fig.2 shows examples of laser-irradiated concrete surface with scanning speed of (a) 110 mm/s and (b) 1.1 mm/s. Depending on the scanning speed, (a) grooving and (b) melting was demonstrated for the same laser power and process time (the same energy dose).

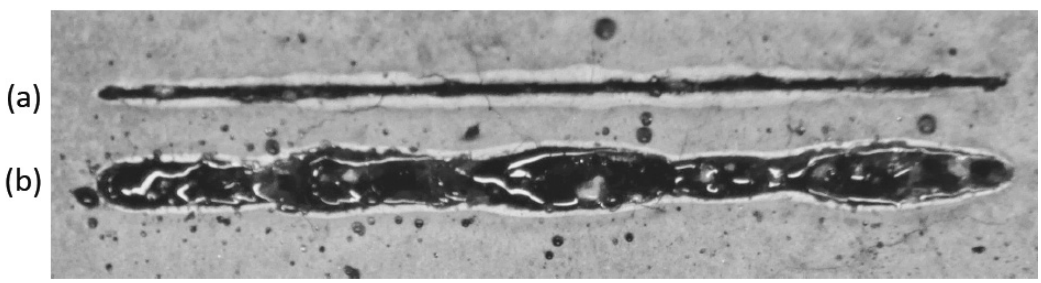

Fig. 2. (a) grooved and; (b) melted concrete surface

2.2. Surface Cleaning and Cutting

Surface cleaning, e.g. rust removal from steels, paint removal from woods, becomes one of the popular laser applications in civil and architectural engineering. The construction companies have noticed the laser cleaning is useful method for maintaining infrastructures such as bridges and towers. The laser cleaning is chemical-free and silent process and is suitable for their demands. Decommissioning the building without chemical waste and significant noise is preferred by the construction companies. Laser processing (polishing, cutting, or even engraving) of reinforced concretes, granite floor, etc. would be promising techniques for the building industries, Muto et al., 2008. Although we know capabilities of those processes, such methods and safety guideline in the construction sites are not widely approved yet. Standardization of laser-based construction methods is now going on in Japan.

Fig.3 shows an example of paint removal from wood (pine). Irradiated laser power was 154 W in 2-mm focal spot (slightly defocused). The scanning speed of 2,250 mm/s resulted in the irradiation time of 0.9ms and laser fluence of 3.4 J/cm^2. Comparing Fig.3 (a) to (d), significant burning (carbonization of the surface) was not **occurred** and the material could be reused. It was noticed that the rust removal from steels could be done with the same processing parameters.

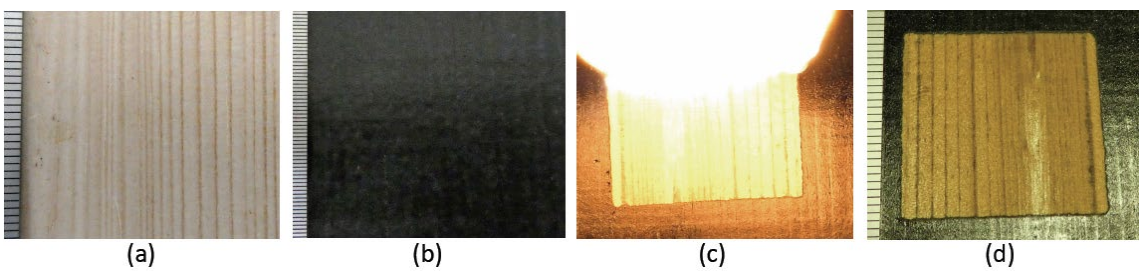

Fig. 3. Paint removal from wood; (a) the original surface; (b) painted surface; (c) during laser irradiation; (d) after laser irradiation.

Fig.4 shows cutting process of granite. Irradiated laser power was 250 W in 1-mm focal spot and the scanning speed was about 90 mm/s. With 10-minutes irradiation, cutting depth of 3 mm was achieved. We, however, could not cut through the 5-mm thick granite plate. We needed further optimization of the processing parameters.

Fig. 4. Cutting of granite

2.3. Melting and Welding

One of the popular industrial applications of CW laser is the welding of metal materials. Then can we weld concretes? Since silica is the main ingredient of the concrete, heated samples undergo vitrification (or glass formation) and could be welded. We tried to form weld beads on the concrete surface, similar to the weld beads on steels. Fig.5 shows weld beads made on concrete surface for various scanning speeds. Laser power was 100 W and the spot size was 0.6 mm in diameter, which corresponded to laser intensity of 35 kW/cm^2. Scanning speeds were (a) 22.5 mm/s, (b) 11.3 mm/s, (c) 4.5mm/s, (d) 2.3 mm/s, (e) 1.13 mm/s, (f) 0.45 mm/s. Slower scanning speed resulted in wider width of the weld beads, similar to the metal welding.

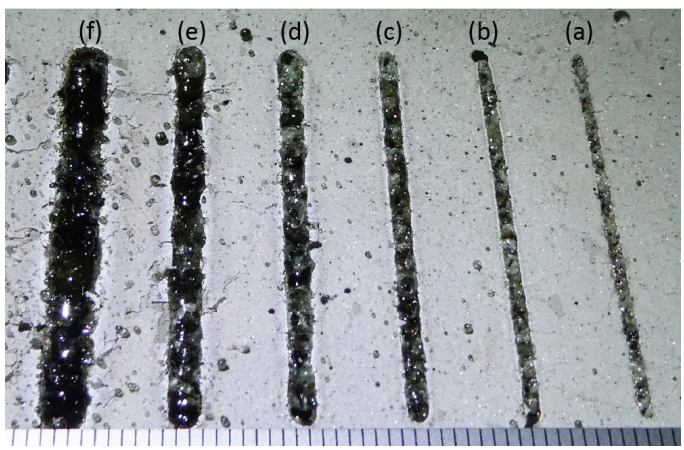

Fig. 5. Weld beads made on concrete surface for various scanning speeds. Scanning speeds were (a) 22.5 mm/s, (b) 11.3 mm/s, (c) 4.5mm/s, (d) 2.3 mm/s, (e) 1.13 mm/s, (f) 0.45 mm/s. Laser power was 100 W, spot size was 0.6 mm in diameter.

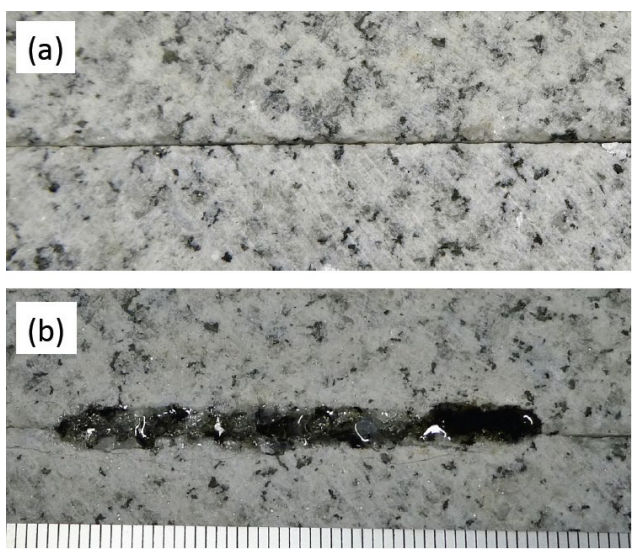

Fig. 6. Butt welding of granite: (a) before and (b) after laser irradiation.

We confirmed the formation of weld beads on concrete surface, then we tried welding of granite plates. Also silica is the main ingredient of the granite. Fig.6 shows butt welding of granite plates: (a) before and (b) after laser irradiation. Laser power was 170 W and the spot size was 0.6 mm in diameter, which corresponded to laser intensity of 60 kW/cm^2. Scanning speeds was 0.45 mm/s. We successfully demonstrated the welding of granite plates.

3. Conclusions

A high-speed galvo scanner and a SM fiber laser could provide a flexible laser processing for construction materials such as concrete, sand, stones, woods, etc. By adjusting laser power and scanning speed, we can melt or ablate the construction materials. Paint removal from wood, cutting and butt welding of granite were demonstrated in a simple experimental setup. Fiber lasers have possibilities to open the way of expanding a new laser-related market (applications in a construction site), instead of eating the existing markets.

Acknowledgements

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