Evaluation of pulsed QCW laser irradiation on concrete in upward direction

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Pulsed laser processing of material which includes laser drilling, welding, cutting, etc. is an important part of the laser technical application. Laser irradiation techniques for removing concrete structure defect in the tunnel of railways is an urgent task for operation and maintenance in the JR West tunnels, Japan. Mechanisms of melt ejection and effect of pulsed laser parameter helping to control and enhance performance for pulsed laser irradiation on concrete were investigated in our previous work [1].

In this work, the experiment has been performed for upward laser drilling and cutting on a tip of concrete, as show in **Fig. 1**. For requirement of small apparatus with high accuracy, as working in the tunnel transportation, the QCW (Quasi continuous wave) fiber laser system having compact dimensions was connected with optical head, which is controlled by workstation. The laser beam is focused with a lens of 200 mm focal length, giving a beam diameter of 1.0 mm on a surface of the concrete in the upward direction, so that the incident beam will make angle (α) upwards to bottom surface of concrete. In order to analyze the performance of pulsed laser irradiation in upward concrete with incident beam angle of 15 degrees, the process parameter of pulse QCW laser such as peak power of 1.3 kW, pulse duration of 10 ms, and repetition rate of 10 Hz are set in the experiment.

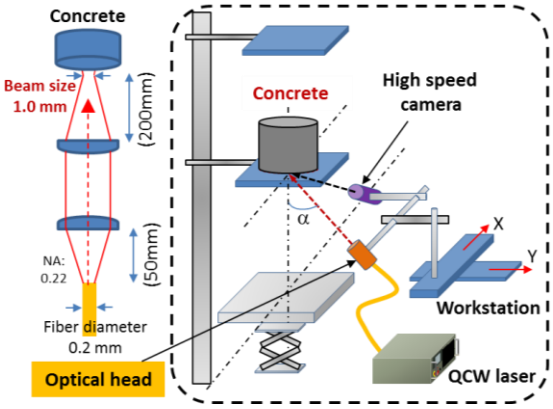

Fig. 1 Experimental setup of QCW laser drilling and cutting on concrete in upward direction

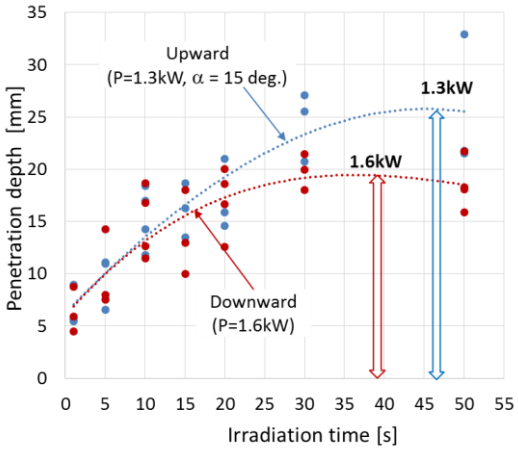

Fig. 2 Performance of pulsed laser in comparison of upward and downward drilling

Fig. 2 shows that the penetration depth was increased in upward drilling compared with that of downward drilling. Especially at higher peak power, this increase was enhanced due to the assistance of gravity. Also, the performance of pulsed laser drilling increases with irradiation time. However, if the irradiation time is much longer, the penetration depth reaches the saturation values. The saturation of penetration depth in upward drilling even at lower peak power is higher than that of downward drilling.

In addition, the effect of overlapping factor on performance of pulsed laser upward cutting concrete is investigated. The high cutting depth is achieved with increasing overlap percentage. However, at very low cutting speed corresponding to very high overlap percentage, the cut kerf is blocked by the larger glassy dross, which could not ejected from cut kerf. Therefore, there exists an optimal percentage of overlapping region, which satisfies the requirement of the effective cut depth and cutting speed. For this experiment, the optimal percentage of overlapping region is achieved about 40-50%. Also, cut depth is a function of scan number in pulsed laser upward cutting concrete. An increasing scan number with optimal overlapping percentage region will increase cut depth.

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References: [1] Nguyen Phi Long et al., the 76th JSAP Autumn meeting 2015 [14a-2F-4], p. 03-175.