Effect of Blasting and Laser on Substrate Roughness and Coating Adhesion

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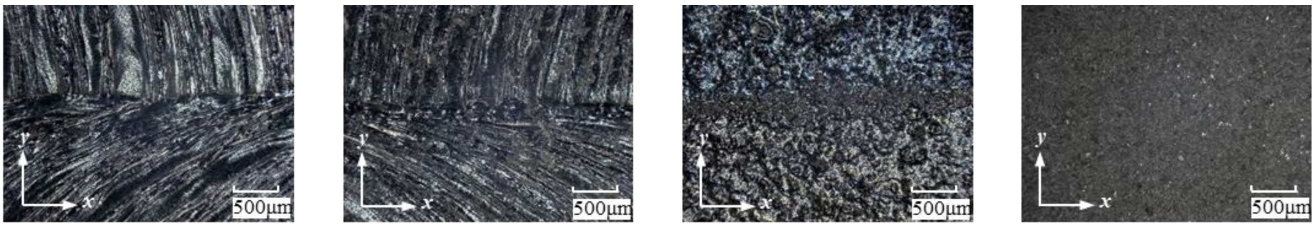
1. Introduction Surface treatment is a necessary step before steel structure repainting and reinforcement. To ensure the quality of repaint and reinforce, the rust needs to be properly removed and the steel surface should have a special 3D configuration to improve the adhesion of the metal substrate to the coating or reinforcement material. Grit-blasting is the most generally used surface treatment method. In addition, laser is also used in surface treatment, including pulse laser and continuous wave scanning laser (CW laser). The working environment of pulse laser is lower power and relatively limited, and the rust removal effect cannot be obtained[1)]. Therefore, we proposed a CW laser which can achieve excellent rust removal effects, and different laser parameters can construct different processed surface configurations. In this study, to provide a reference for repainting and reinforcement of steel structures, the roughness of the substrate with grit-blasted and laser-treated treatment was measured by a laser microscope. And also, the adhesion test was carried out using their treated substrates.

2. Test Methods The specimens were made from carbon steel plates (JIS G3106 SM490A) with dimensions of 150×70×6 mm. Blasting surface treatment used Fe-Ni mixed grit with an average diameter of 425 μm. The pressure and distance of blasting treatment were set as 0.7 MPa and 100 mm, with a spray angle of 60°. Besides, laser surface treatment used a constant diameter laser beam to scan the metal surface at a constant speed. The adjacent laser ring was overlapped in ring width (equals to laser spot diameter), and each parallel laser path was overlapped in ring diameter to achieve the effect of complete rust removal. The laser parameters are listed in Tab.1 and the surface conditions of the blast-treated and laser-treated steel plates as shown in Fig.1.

Tab. 1 Condition of Laser Surface Treatment

Laser Condition	Overlap Rate O_r(%)	Power P(kW)	Scanning Speed v (rpm)	Area Processing Power P_a (kW/cm^2)	Processing Efficiency E_p (cm^2/s)
A	50	2	4000	1377	9.0
B	50	2	7000	1377	15.7
C	25	3	7000	516	63.0

* $P_a = P/S_{scan}$; $E_p = v/S_{scan}$; S_{scan}: Processing area per scanning time.



(a) Laser-A (b) Laser-B (c) Laser-C (d) Abrasive Blast

Fig.1 Surface Conditions of Blast Treated and Laser Treated Steel Plates

The substrate roughness of the treated specimens was measured by coating thickness tester. The basic parameters for detection were set to λ_c=2.5 mm, λ_s=8 μm, and v=0.5 mm/s reference to *JIS B0651* and *ISO 3274:1996*. Since the CW laser has directivity, defined the direction of the laser path as x and the perpendicular as y show as Fig.1, the substrate roughness in both x and y directions was measured 5 times to take the average value.

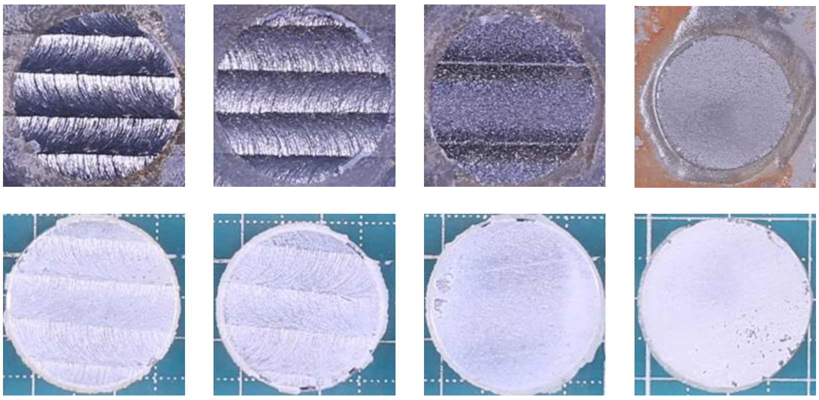
The surface adhesion force was measured by dolly made of Al with a diameter of 20 mm during the axial tension test. In general, the main components of coating and reinforcing adhesive are epoxy resin, so that the epoxy adhesive was chosen for testing, which owns a tensile strength can reach to 28 MPa under high-temperature hardening. After curing the specimens in an environment of 80°C for 1 hr, the tensile test of the bond specimen was performed with a tensile speed of 0.5 mm/min [3)].

3. Test results The measured roughness of laser and blast substrate are listed in Tab.2. Due to the lower scanning speed, R_a, R_q, and R_{sm} of Laser-A in the x-direction are approximately twice that in the y-direction, showing orthotropic anisotropy. The surface profile R_z and R_p are directly affected by P_a. Compared with Laser-C, Laser-B has a higher area processing power which leads to more obvious laser processing traces. Moreover, the substrate roughness along the laser movement direction x has a negative correlation with the E_p, which means the higher the laser processing efficiency, the lower R_a, R_q, and R_{sm} obtained. It should be noted that the roughness of the blasting surface is between laser parameters B and C.

Tab.2 Substrate Roughness of Laser and Blasting Treated Plate

Roughness Parameter	Laser-A		Laser-B		Laser-C		Abrasive Blast	
	x	*y*	*x*	*y*	*x*	*y*	*x*	*y*
R_a	9.61	5.29	7.59	7.09	3.58	3.34	6.52	5.88
R_q	11.41	6.46	9.44	8.71	4.48	4.36	8.44	7.42
R_z	45.2	31.88	45.8	38.47	24.57	25.94	44.52	41.33
R_p	21.23	18.21	22.13	18.67	9.5	11.61	21.24	20.74
R_{sm}	1283.56	552.3	585.12	642.66	544.8	556.16	308.66	320.28

*R_a: Arithmetical mean deviation of the assessed profile; R_q: Root mean squared; R_z: Maximum height of the profile; R_p: Maximum peak height; R_{sm}: Mean width of the profile elements.



(a) Laser-A (b) Laser-B (c) Laser-C (d) Abrasive Blast

Fig.2 Fracture Surface Conditions (Upside: Steel; Downside: Dolly)

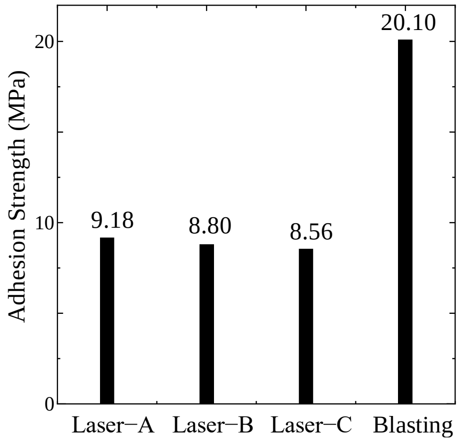


Fig.3 Adhesion Test Results

The fracture surface conditions of four specimens as shown in Fig.2, and corresponding adhesion test results as shown in Fig.3. The adhesive itself did not break when broken and almost all the adhesive left on the surface of dolly, meaning that the tensile force is the adhesion strength. The adhesion strength of laser parameters A, B, and C was 9.18 MPa, 8.80 MPa, and 8.56 MPa, which has a certain positive correlation with the maximum substrate roughness. However, the adhesion strength of the blasted surface can reach to 20.10 MPa, is about twice greater than that of laser-treated specimens. The significant differences may be caused by oxides and acid compounds generated on the metal surface during laser processing, which needs further research.

4. Conclusions 1） The surface roughness of abrasive blast is between Laser-B and Laser-C condition, but the adhesion strength of the blasted surface is twice that of the laser-treated surface; 2) Lower scanning speed can cause orthotropic properties of laser-treated surfaces like Laser-A condition; 3) The adhesive strength between the laser-treated surface and the epoxy resin is affected by the substrate roughness.

References 1) Matějíček, Jiří, et al. "The Role of Laser Texturing in Improving the Adhesion of Plasma Sprayed Tungsten Coatings." Journal of Thermal Spray Technology.28.7 (2019): 1346-1362., 2) Park, Cho-Hee, et al. "Preparation and characterization of dual curable adhesives containing epoxy and acrylate functionalities." Reactive and Functional Polymers 73.4 (2013): 641-646., 3) Al-Zubaidy, Haider A., Xiao-Ling Zhao, and Riadh Al-Mahaidi. "Experimental evaluation of the dynamic bond strength between CFRP sheets and steel under direct tensile loads." *International Journal of Adhesion and Adhesives* 40 (2013): 89-102.