Investigation on Steel Surface Configuration by Abrasive Water Jet Treatment

Kyushu University	Student member	○ Sanghong PARK
Kyushu University	Fellow member	Shigenobu KAINUMA
Kyushu University	Regular member	Muye YANG
IKEDA KOGYO Co., Ltd.	Regular member	Tatsuya IKEDA
West Nippon Expressway Co., Ltd.	Regular member	Takahiro ASANO
Sugino Machine Ltd.	Non-member	Yushi MORITA

1. Introduction Corrosion damage in steel bridges is an important issue in maintenance. In the restoration of a structure, the surface treatment is one of the important things before painting. If the surface treatment before painting is insufficient, corrosion may occur under the painting due to residual contaminants. Currently, blast treatment is the main method for steel surface preparation. However, during blasting, surface treatment is not done well to the inside of deep areas such as thick corrosion or groove. As a result, initial corrosion occurs under the painting. Abrasive water jet (AWJ) is a promising surface treatment method to overcome these problems. AWJ was originally developed in the 1980s as a new type of special treatment technology for cutting steel [1)]. But it can also use for polishing steel surface by controlling the size of the abrasive, the travels speed of the water jet, projection pressure, distance, etc. However, a systemic research result has not been established currently regarding AWJ polishing. This study focused on different standoff distances among the various parameters. Through this, the characteristics of the AWJ treated steel surface were evaluated based on the affected area, eroded area, erosion depth and roughness and compared with that of blast treated steel surface.

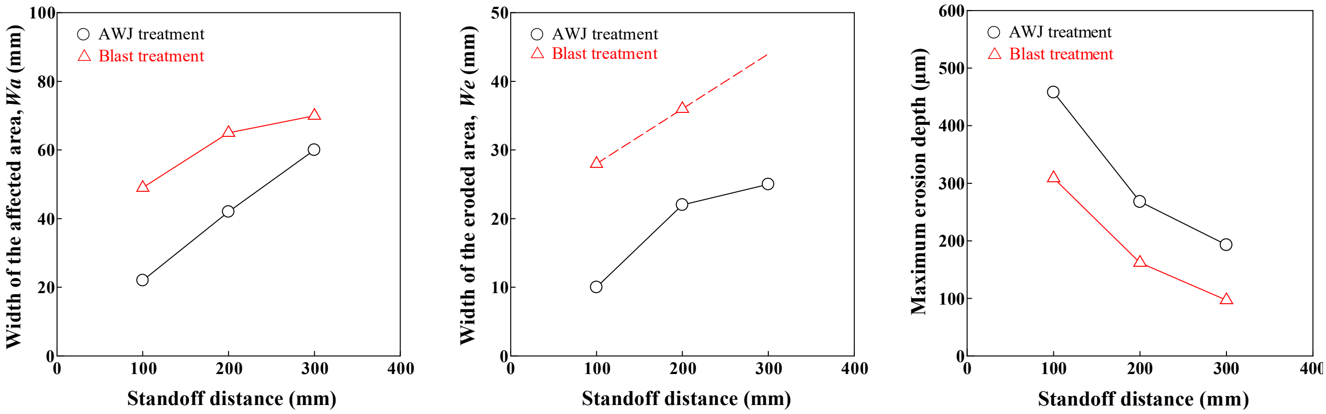
2. Specimen and test method The specimens are made from carbon steel plates (JIS G3106 SM490A) with dimensions of 70×70×6 mm. Milling (Cutting diameter: 50 mm, Cutting speed 215 m/min, Revolutions per minute:1,369 (rev./min), Blade material: cermet), it so that the surface roughness of the specimen before AWJ treatment does not affect the surface properties. To evaluate the effect of standoff distance (SOD) of AWJ on the steel surface, the surface profiles were analyzed at the abrasive supply of 600 g/min according to the distances of 100, 200 and 300 mm is carried out under the conditions as shown in Table 1. For the nozzle, Water jet (WJ) convergent nozzle used for cutting metals was selected. The diameter of the nozzle is also detailed in Table 1. Where surface profiles mean the width of the affected area (W_a), the width of the eroded area (W_e) and Maximum erosion depth. After treatment, the surface is divided into unaffected, affected, eroded areas and the erosion depth refers to the depth of the eroded area. The affected area has the surface state similar to the blasted surface, but not fully treated. The eroded area is a completely treated area, located on the track of AWJ. The depth of the erosion area is much deeper than the affected area. The width of the affected, eroded area and the erosion depth can be obtained from the inflection point of the mapping graph (Maximum curvature) [2)]. For surface profile analysis, during laser microscopy, the range of the middle part of the specimen was selected as 50 × 10 mm and measured with a resolution of 0.0213 μm in a vertical direction in the direction of AWJ processing. Select 11 surface profile lines at the same interval and the top 5 erosion depth lines for analysis. The mean of the maximum depth of five lines was defined as the maximum depth of the treated surface. Surface roughness was measured through a 3D laser microscope. the surface properties of the steel base material were measured using a three-dimensional shape measuring laser microscope (Spot diameter: 0.2 μm, Moving resolution: 0.01 μm). The measuring pitch is 2.0 μm, 50×10 mm at the center of each specimen is measured, and the baseline length is 10 mm. Line roughness was calculated based on an average of 11 lines with a base length of 10 mm. Line roughness is also evaluated for arithmetic mean roughness Ra, ten-point mean roughness Rzjis corresponding to the height direction of the surface undulation, and mean length of contour curve element RSm corresponding to the width of the surface undulation. For the blasting conditions, the pressure and distance of blast treatment were set at 0.7 MPa, 100, 200 and 300 mm to be compared to AWJ treatment. After processing, measure surface profiles (W_a, W_e and Maximum erosion depth) and roughness in the same way as AWJ treatment and compare their values.

3. Test result The result of surface profiles after AWJ and blast treatment was shown in Fig.1. In the case of AWJ treatment, SOD significantly affects the treatment range (W_a and W_e). As shown in Fig.1 (a) and (b), the relationship between the SOD and the treatment range is nearly linear. For every increase of SOD, W_a expands by about 20mm, W_e expands by about 3 to 10mm. As shown in Fig.1(c), maximum erosion depth decreases significantly as the SOD increases. For every SOD increase, Maximum erosion depth decreases by about 30%.

The result of the comparison with the surface profiles (W_a , W_e and Maximum erosion depth) after AWJ and blast treatment as shown in Fig.1 (a), (b) and (c). W_a of AWJ (20 to 60 mm) is smaller than that of the blast (50 to 70 mm). Both treatments

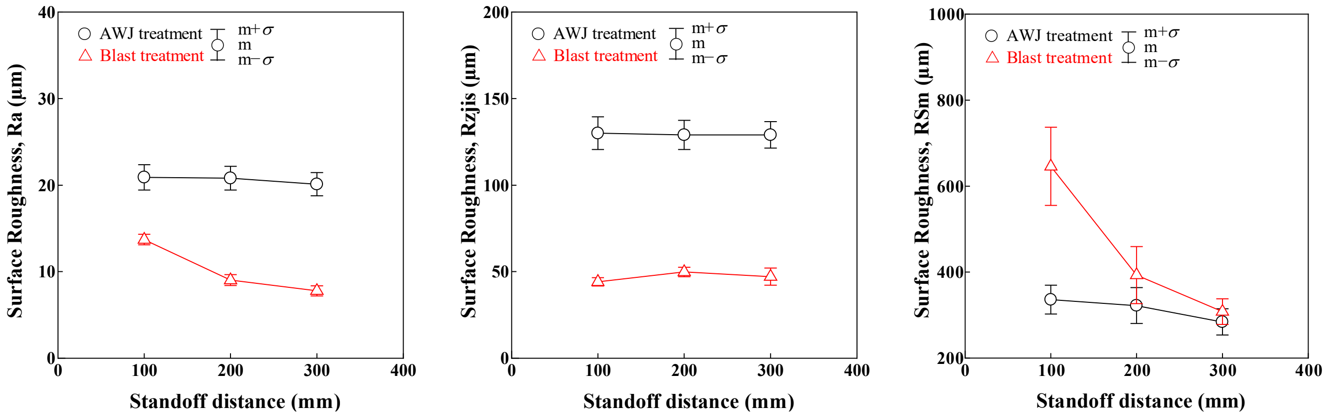
Table 1. Test parameters for AWJ treatment at milling specimens

No	Stand off distance (mm)	Abrasive supply (g/min)	Processing count (N)	Pressure (MPa)	Travel speed (mm/min)	Nozzle (Water/ Abrasive) (mm)	Water flow (L/min)
1	100	600	1	230	1.0	0.75/2.0	11.9
2	200						
3	300						



(a) W_a　　(b) W_e　　(c) Maximum erosion depth

Fig.1 Surface profiles after AWJ and Blast treatment



(a) Ra　　(b) Rzjis　　(c) RSm

Fig.2 Compared Ra, Rzjis, RSm after AWJ and Blast treatment

showed a tendency for W_a to increase as SOD increased. In the case of W_e, it was difficult to compare AWJ and blast treatment directly because there was no erosion area of 300 mm. However, except for 300mm cases, W_e of blast (30 to 35 mm) had a larger than AWJ treatment (10 to 20 mm). Maximum erosion depth of AWJ treatment (200 to 500 μm) was relatively greater than that of blast treatment (100 to 300 μm). Therefore, the erosion depth of AWJ treatment is larger than that of the blast treatment about 1.5 to 2.0 times in depth. Since erosion depth is deeper than blast treatment, so it is more effective in removing the thickest rust or deeply embedded salt. The roughness comparison of the two treatments according to SOD are shown in Fig.2. In the case of roughness, both treatments tend to decrease slightly as SOD increases. Ra, Rzjis of AWJ treatment is much larger than that of the blast. RSm of the blast treatment is larger than that of AWJ. The reason for the higher RSm for the blasted specimen is that the affected area of blast treated steel is larger than that of AWJ treatment. However, actual surface roughness is most relevant to Ra. The surface roughness of steel before painting is appropriate between 25 and 75 μm [3]. This is because if the roughness is too low, the attachment can be poor, and if the roughness is too high, the paint on the peak of the roughness cannot be properly painting, causing rust. Therefore, the above result is that AWJ treatment has more proper roughness in painting than blast treatment. Based on the above review, corrosion and embedded salts which are more difficult to remove than blast treatment can be efficiently removed during AWJ treatment. In addition, the high roughness allows for increased adhesion during painting to achieve high durability.

4. Summary　In this study, standoff distance of AWJ treatment significantly affects the surface profiles and roughness. 1) The result showed that as standoff distance increases, the treatment range increases while maximum erosion depth and roughness decrease. 2) At the same distance, the treatment range has a larger blast treatment than AWJ treatment. 3) Under the same treatment distance, AWJ treatment has a deeper erosion depth and greater surface roughness than blast treatment.

References　1) C.L. Che, C.Z. Huang, J. Wang, and H.T. Zhu, Study of Abrasive Water Jet Polishing Technology, Key Engineering Materials, Vol. 487, pp: 327-331, 2011. 2) Goldman R, Curvature formulas for implicit curves and surfaces, Computer Aided Geometric Design, 22(7): 632-658, 2005. 3) The Society for Protective Coatings (SSPC), Surface Preparation Standards, SSPC-SP10: Near-White Metal Blast Cleaning, 2007.