INFLUENCE OF SHOT PEENING ON FATIGUE STRENGTH OF WELDED STRUCTURE.

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ABSTRACT

In the production of steel structures, welding is one of the most important processes. Welding of structure is widely used in heavy industries, transportation equipment, electrical products, construction industries, and others. Though welding is easy and cheap process, it reduces fatigue strength at the welded details due to residual tensile stress over the heat affected area, and the sharp notch formed at the weld toe can be destructive starting point. Even though numbers of researchers have tried to improve fatigue strength at welded details, the improvement of strength more than that of the base material was difficult. In this paper, the authors present the research conducted to investigate the effect of shot peening to improve the fatigue strength of welded section to the level more than that of the base materials.

KEY WORDS – Fatigue Strength, Welded Joint, Shot Peening

INTRODUCTION

Welding technology is one of the most important process technologies in the production of steel structures, and is widely applied in various industrial fields ranging from general heavy industries to transportation equipment, electric, electronic industries, steel structures in construction industries, etc. It is true that welding is easy and economical process for jointing steel structure. However, it always carries such problems as the sharp notch formed at the edge of weld reinforcement part can be the destructive starting point , and the reduction of fatigue strength of the welded part due to residual tensile stress over the heat affected area (M Isao, 1975, M Isao, 1976). To cope with these problems, the countermeasures in design such as changing the thickness of material at the welding part, increase of strength of welding part by putting pad material, avoidance of welding part from the stress center, etc. will become necessary.

One of the technologies to improve fatigue strength of metallic material is shot peening. This method blasts out fine metallic particles (steel shot or other peening media) to the surface of target work to impart residual compressive strength and higher hardness, and to increase the fatigue strength. Shot peening is quite popularly used for automotive gears and springs. This study reports the improvement of fatigue strength (M hasegawa, 2003) by shot peening method applied to welded joint.

METHODS

The base material used for the test is JIS SM490A rolled steel plate for welding structures having thickness of 6mm, the chemical composition and mechanical properties of which are shown in Table 1. The butt welding was conducted so as to make the welding line right-angled to the plate rolled direction with the welding conditions; Welding amperage: 270A. Arc voltage: 27V, Welding speed: 470mm/min.

Total 2 passes (1 pass each for top side and back side). MAG welding was conducted using welding jig. Afterwards, each pass held for 30 minutes held by welding jig. The heat input by the above welding was 9.3kJ/cm.The fatigue test specimen was prepared by machining, the shape and dimensions of which are shown in Fig. 1.

Table1 Chemical compositions of Carbon steel.

Materials	Thickness of plate or electrode diameter (mm)	Chemical composition(%)							Mechanical properties		
		C	Si	Mn	P	S	Ti	Cu	Yield strength (MPa)	Tensile strenght (MPa)	Elongation (%)
Base metal (SM490A)	6	0.16	0.36	1.45	0.017	0.003	-	-	465	576	20

Table 2 Peening Conditions.

	Diameter, μm	Material	Specific Gravity	Hardness, HV	Blasting Pressure, MPa
Abrasive A	600	Cast Steel	7.45	450	0.1～0.5
Abrasive B	300				
Abrasive C	170				
Abrasive D	150	Tungsten carbide	14	1400	
Abrasive E	100				

1) Tests for Verifying the Effects of Different Abrasives

Peening treatment was conducted with 5 types of blasting media as shown in Table 2 with the blasting pressure of 0.1 ~ 0.5MPa. The fatigue test was conducted at room temperature. Shenk type fatigue tester with the maximum capacity of 20kg-m was used for verifying the effect of peening. Loading on test specimen was stress ratio R $=\sigma_{min} / \sigma_{max}=-1$, and the repeating speed was 1800 cycles/min. Residual stress and hardness were also measured. In this research, the fatigue test was conducted to the limit of 2 x 10^6 cycles. The evaluation was conducted by using the improvement ratio I . (Fig. 2)

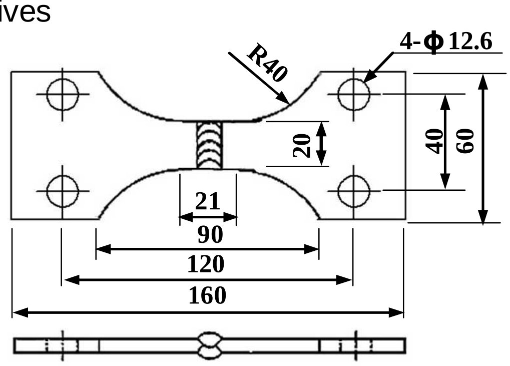

Fig.1 Shape and Size of Test Specimen.

2) Effects of Blasting Different Area

As shown in Fig. 3, fatigue test pieces are prepared by changing the blasting area. Shot peening area A covers the whole surface of test piece while area B covers only about 15mm with weld bead part as its

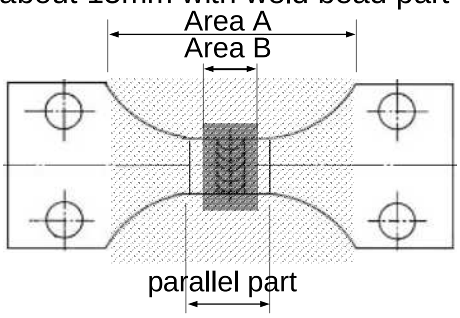

Fig.3 Peening Area.

$$I=\frac{\sigma P-\sigma A}{\sigma B-\sigma A}\times 100\ (\%)$$

σP : Fatigue limit after peening
σA : Fatigue limit of as welded joint
σB : Fatigue limit of base metal

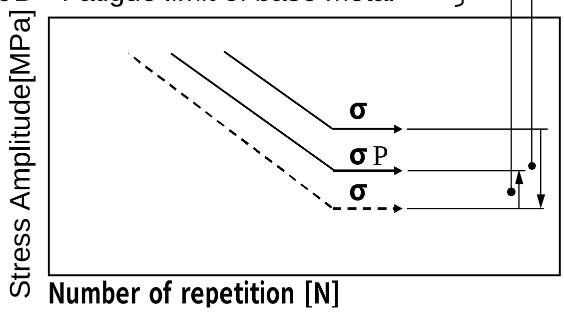

Fig.2 Improvement Ratio of Fatigue Limit I .

center among the parallel part of 21mm, and a flat plate is left as it is on the parallel part. Peening condition is set with abrasive A and Blasting Pressure is 0.4MPa. Five kinds of test pieces in total were used including the test piece of flat plate and that of as-welded for comparison purposes.

RESULTS AND DISCUSSION

1) Test for Verifying the Effect by Different Abrasive

Fig. 4 shows the relation between abrasive size and improvement ratio I. There is correlation between abrasive size and improvement ratio I regardless of the material of abrasive. The larger the abrasive size, the higher improvement ratio I is recognized.

With the abrasive size of 600 μm, the ratio I reaches as high as 180% which is impossible to achieve by ordinary weld part finishing. Furthermore, it is presumed, with the base plate material used for this test, that the peening treatment using the blasting media of about 330 μm would be sufficient to obtain the fatigue strength of welded part equal to or higher than that of flat plate.

Fig 5 shows the relation between particle size of cast steel abrasive and the added hardness measured at the position of 10 μm to depth direction from the surface. In case of abrasive size of 600 μm, the added value of hardness reached 53HV, the highest among all. Even in case of using the abrasive of 300μm in diameter, the increased hardness was 48HV. From this observation, the implication is that the diameter of abrasive gives almost no significant influence on the hardness of base material.

Fig. 6 shows the distribution of residual stress from the surface to the depth direction achieved by cast steel blasting media. Any of these blasting media obtained the residual compressive stress of about 550MPa maximum, and no obvious difference with the kind of blasting media was recognized. This result indicates that the hardness of base plate material, even the area hardened by the welding heat, is about 280HV, which is substantially lower than the hardness of the abrasive. Therefore, sufficient peening on the influential area has been done to bring up the residual compressive stress to the

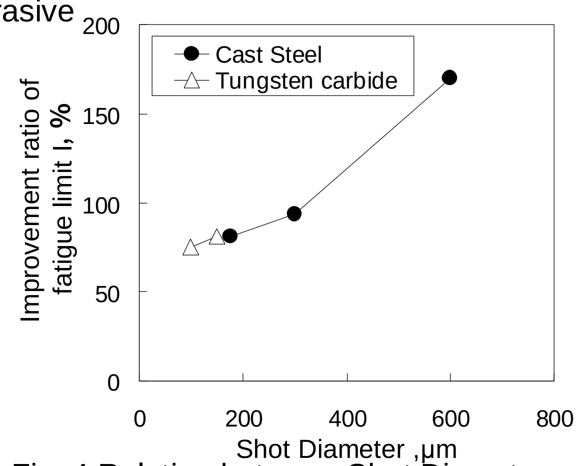

Fig. 4 Relation between Shot Diameter and Improvement Ratio of Fatigue Limit I.

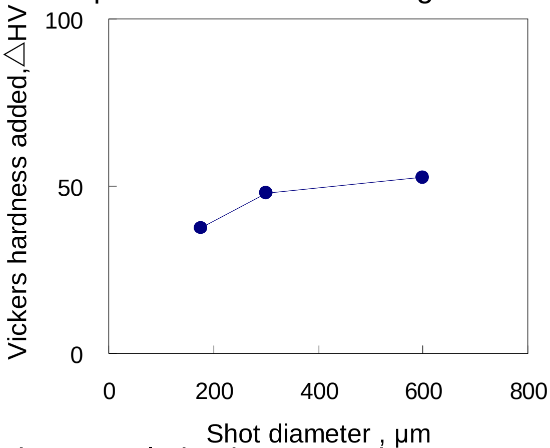

Fig. 5 Relation between Shot Diameter and Vickers Hardness added.

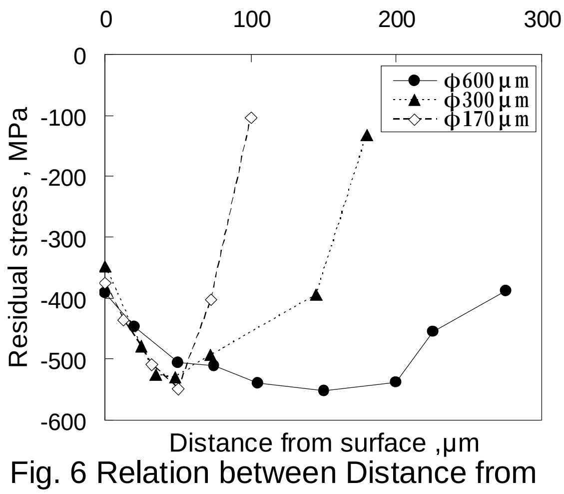

Fig. 6 Relation between Distance from Surface and Residual Stress.

level of limit value of this base material. However, it was observed that deeper residual stress is imparted by the abrasive of larger particle size. It is considered that this phenomenon is caused by the difference of kinetic energy inherent to each particle of abrasive, and abrasive of small diameter can not achieve great impact to the deeper section.

The shape before and after shot peening is overlaid with modeling compound, magnified by profile projector, photographed, and the figurations are measured, compared and studied. Before measurement, height of reinforcement of weld h, toe end radius r, reinforcement width L and toe edge angle θ are defined as shown in Fig.7 below. The stress concentration coefficient α is calculated from the formula used in the study of S. Kawai and his team (S Kawai, 1979). The welding length of welding test material (540mm) was divided into three equal lengths, and 3 pieces of patterns having width of about 50mm were prepared at each position. Figure 7 is average shape of processing before and after. As MAG Auto welding system was used, the variation of the shape of weld reinforcement is comparatively small. The variation of toe end angle and toe end radius was about 5% max.in case of as-welded, and about 3% max. In case of peening treated. The results of measurement are shown in the same figure. Before treatment, r was about 0.20mm, which was increased to about 2.23mm after treatment, an increase of more or less 11 times. Toe edge angle, θ, was reduced from 41 ° to 37 ° . This result indicates, as shown in the figure, the reduction of about 25% in stress concentration coefficient from about 1.57 of before treatment to about 1.19 of after treatment.

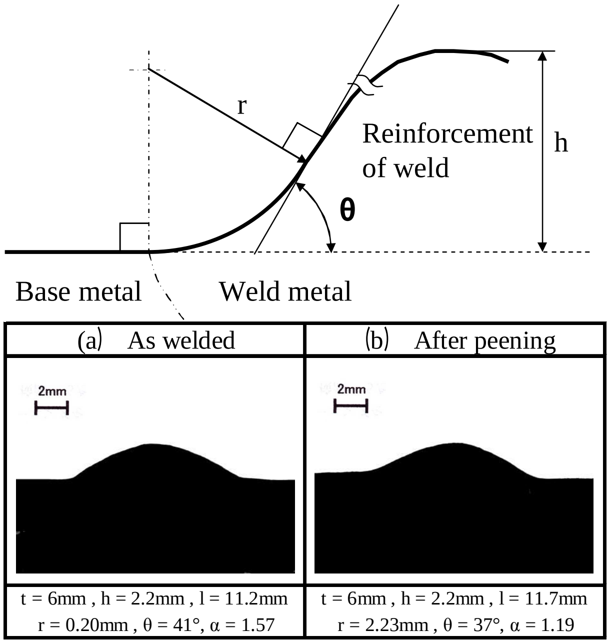

Fig.7 Bead Configuration After Peening.

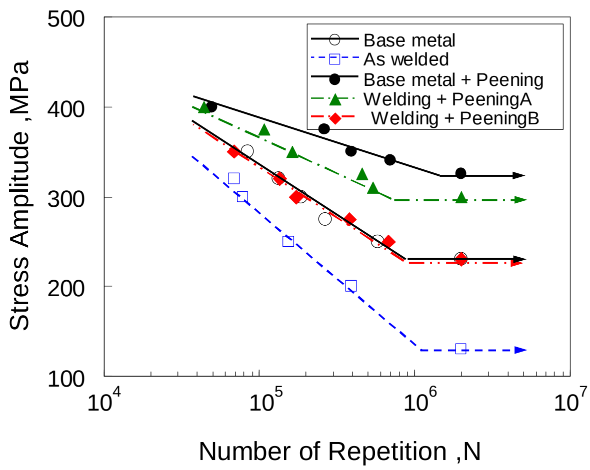

Fig. 8 Effect of Shot Peening on Fatigue Strength of Welded Joint.

2) Peening Area Test

With regard to the improvement of fatigue strength at the welded part, various methods of improvement have been introduced and presented at Japan Welding Society. There is a general consensus that any improvement treatment on welded part can never achieve improvement ratio over 100%. However, the result achieved by abrasive A was the improvement ratio of 180% which is far beyond the fatigue limit of base plate. This test was conducted to verify the above achievement. The result is shown in Fig. 8. Abrasive A, which achieved the highest improvement effect was used, and the fatigue test was conducted by changing the area of peening treatment. The photographs of typical fractured test pieces are shown in Fig.9.

The fatigue limit of plate material is about 230MPa whereas that of as-welded test piece was about 130MPa, a decrease by about 100MPa was recognized. The fatigue limit of test piece A, the whole surface of which was peening treated, was about 300MPa, higher by about 70MPa to that of base plate. However, it was observed that it is still lower by about 20MPa compared to 320MPa obtained by the peening treatment on the base plate. It is true that the fatigue strength of both welded and base plate parts is improved as well by shot peening. It is also true that the fatigue strength of welded part achieved by shot peening is lower than that of base plate part due to the stress concentration on welded toe part. In case of specimen B, the fatigue limit was the same as the base plate without treatment, and the break point was not at the welded toe but at the base plate part.

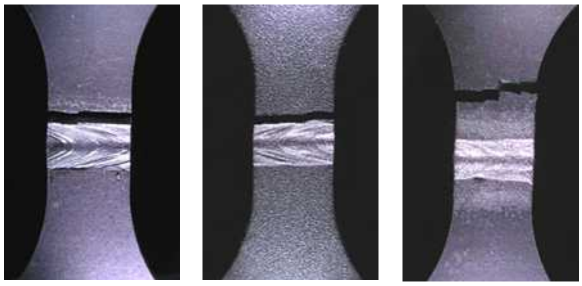

Fig. 9 Macroscopic View of Fractured Specimen.

By these facts, it is clarified that the shot peening on the welded details can make the strength of the welded part higher than the base plate part.

Summary

The effect of fatigue strength improvement on welded joints by shot peening treatment using various blasting media was investigated. The results obtained by the tests are as follows.

1. Shot peening is the effective technology for fatigue strength improvement of welded joints. In case the abrasive having diameter of more than 330μm is used, it is possible to obtain the fatigue strength equal to or more than the base plate material.
2. The experiments proved that there is correlation between abrasive diameter and improvement ratio. The larger the abrasive diameter, the higher the improvement ratio attained.

Conclusion

It is not possible to expect the achievement of fatigue strength higher than that of the base plate by the method of treatment for reinforcing the welded toe part alone. However, shot peening treatment, capable to cope with complicated shape, wide area in a short treatment time, can improve the fatigue strength of the whole welded structures, not only the improvement of welded details alone.

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