12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

INVESTIGATION OF THE FATIGUE STRENGTH OF THE WELDED JOINTS TREATED BY TIG DRESSING

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ABSTRACT
The fatigue fracture of structural details subjected to cyclic loads mostly occurs at a critical cross section with stress concentration. The welded joint is particularly dangerous location because of sinergetic harmful effects of stress concentration, tensile residual stresses, deffects, microstructural heterogeneity. Because of these reasons many methods for improving the fatigue resistance of welded joints are developed. Significant increase in fatigue strength and fatigue life was proved and could be attributed to improving weld toe profile, the material microstructure, removing deffects at the weld toe and modifying the original residual stress field. One of the most useful methods to improve fatigue behaviour of welded joints is TIG dressing. The magnitude of the improvement in fatigue performance depends on base material strength, type of welded joint and type of loading. Improvements of the fatigue behaviour of the welded joints in low-carbon structural steel treated by TIG dressing is considered in this paper.
Keywords: welded joint, TIG dressing, fatigue strength, low carbon steel

1. INTRODUCTION
Fatigue is one of the most frequent form of the failures of the welded structures. According to ref. [1,2,3] 50 -90 percent of all mechanical failures are fatigue failures. Many experiments show that the fatigue crack mostly initiates at the weld toe. The weld toe is a primary source of fatigue cracking because of the severity of the stress concentration it produces. Apart from a relatively sharp transition from the plate surface to the weld, dependent on the weld profile, the stress concentration effect is enhanced by the presence of minute crack-like defects at the weld toe. The tensile residual stresses also reduce fatigue strength. Many methods for improving the fatigue resistance of welded joints are developed. One of these – TIG dressing is considered in this paper. The aim of TIG dressing is to remove the weld toe flaws by re-melting the material at the weld toe. It also aims to reduce the local stress concentration effect of the local weld toe profile by providing a smooth transition between the plate and the weld face. The magnitude of the improvement in fatigue performance depends on base material strength, type of welded joint and type of loading. According to reported experimental results TIG dressing increased the fatigue strength of fillet welded joints in 16Mn steel by 37% [4] and in Weldox 420 steel by 45% [5]. The corresponding increase in fatigue life in low stress regime was 2.5 times and 8.7 times respectively. Generaly, the increase in fatigue strength ranging from about 20% for butt welds in mild steel plates to about 160% for fillet welded high strength steel have been reported [6]. TIG dressing can be used for increasing the fatigue strength of new structures and repair or upgrading of existing structures. Higher manufacturing costs are compensated by avoiding repair and extending significantly the inspection intervals. In most practical applications only a few critical locations of a component have to be treated by TIG dressing.

2. MATERIAL AND SPECIMENS FABRICATION

This work was intended to determine the increase of fatigue strength of fillet welded joints in low-carbon structural steel treated by TIG dressing. Specimens were fabricated from low-carbon structural steel S355JO conformed to JUS EN 10025 2003 Standard specification. Mechanical properties of the steel are given in Table 1.

Table 1. Mechanical properties of steel

Yield strength, MPa	Tensile strength, MPa	Elongation, %
389.7	534.2	30

The chemical composition, shown in Table 2, conformed with the requirements of the S355JO Standard specification.

Table 2. Chemical composition of steel

Element	C	Mn	Si	P	S	Cu	Cr	Mo	Ti	Al	Sn
Content, %	0.15	1.46	0.24	0.015	0.012	0.03	0.03	0.02	0.013	0.04	0.002

The main plate and the transverse stiffener were welded by the MAG process. After welding, the specimens were saw cut from the assembly and then milled to finished sizes shown in Fig. 1. The rolling direction of the main plate corresponded to the longitudinal axis of the specimens and to the direction of loading.

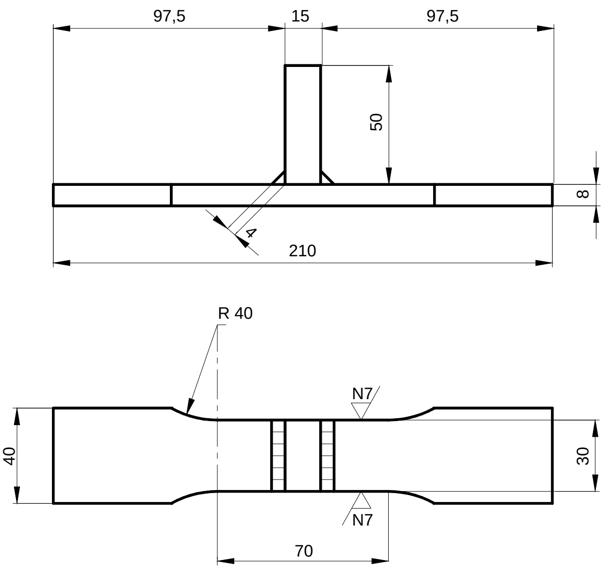


Figure 1. Test specimen

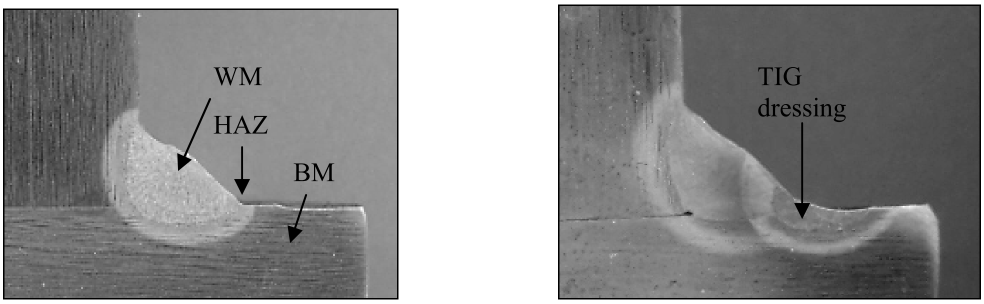
The other batch of specimens was welded on the same way as previous one and additionally treated by TIG dressing. TIG dressing was performed by using direct current, straight polarity. The shielding gas was the argon. The parameters of TIG dressing are shown in Table 3.

Table 3. TIG dressing parameters

Current A	Voltage V	Electrode	Electrode diameter mm	TIG dressing speed, *S* mm/min	Argon flow rate l/min
200	14	WT20	3.2	166.7	15

Heat input is $Q = \dfrac{60 \times V \times A}{1000 \times S} = \dfrac{60 \times 14 \times 200}{1000 \times 166.7} = 1.01 \dfrac{\text{kJ}}{\text{mm}}$ (IIW recommendation 1.0 – 2.5 $\dfrac{\text{kJ}}{\text{mm}}$).

Fig. 2 illustrates macrosection of welded joints in the as-welded and TIG dressed conditions. It can be noticed that weld toe radius is significantly increased by TIG dressing.



a) *b)*

Figure 2. Macrosections of welded joints: a) as-welded; b) TIG dressed

3. FATIGUE TESTING PROCEDURE AND EXPERIMENTAL RESULTS

The fatigue tests were performed on a high-frequency fatigue testing machine with a capacity of 100 kN. The specimens were subjected to tensile loads with a stress ratio R = 0.1. The fatigue cracks initiated on the plate surface at the transition between the plate and the weld toe. Only one specimen (TIG dressed) failed outside this zone i.e. in the base metal. Fatigue test results obtained from as welded and TIG dressed specimens are given in Fig. 3. The S-N curves determined by the regression analysis [7] are given in the same figure. The equations of S-N curves are:

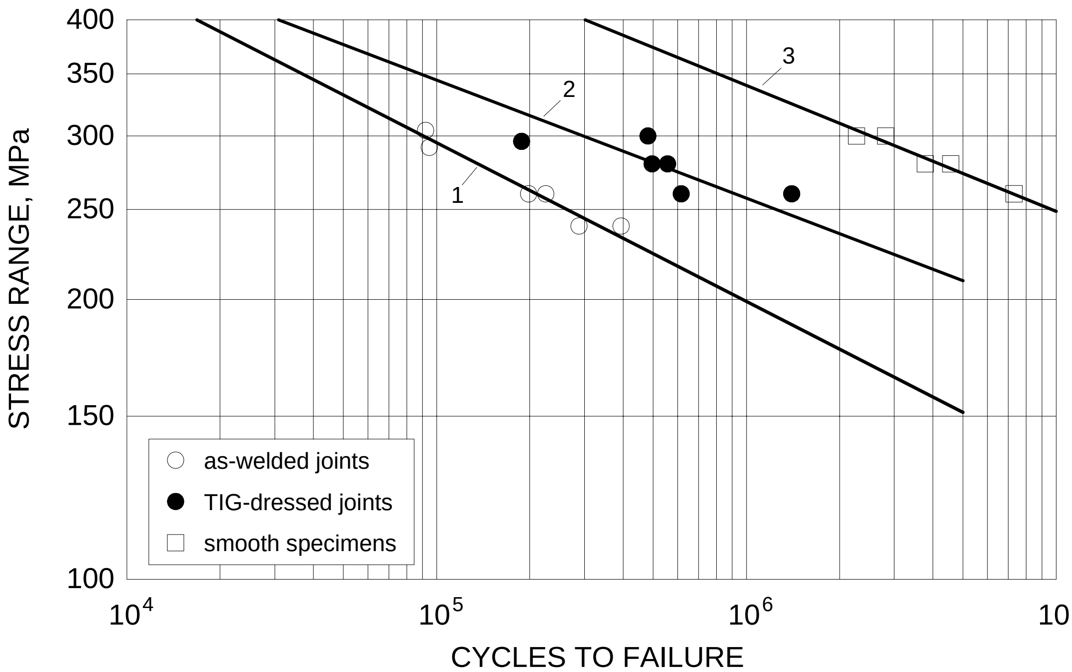


Figure 3. Experimental results and S-N curves for: 1-as welded joints; 2-TIG dressed welded joints; 3-smooth specimens

As-welded joints:

$$log\ N = 19.4643 - 5.8563\ log\ \Delta\sigma \tag{1}$$

TIG-dressed joints:

$$log\ N = 24.9603 - 7.8669\ log\ \Delta\sigma \tag{2}$$

Smooth specimens:

$$log\ N = 24.7208 - 7.3957\ log\ \Delta\sigma \tag{3}$$

4. CONCLUSIONS

One of the most useful methods to improve fatigue behaviour of welded joints is TIG dressing. The magnitude of the improvement in fatigue performance depends on base material strength, type of welded joint and type of loading. Improvement of the fatigue behaviour of the welded joints in low-carbon structural steel S355JO, conformed to JUS EN 10025 2003 Standard specification, treated by TIG dressing is considered in this paper. The comparison of the experimental data for as-welded joints and TIG dressed joints shows significant increase in the fatigue life under various stress levels and the fatigue strength at a 2×10^6 cycles. TIG dressing increased the fatigue life from 2.9 times under stress range equals 320 MPa to 6.1 times under stress range equals 220 MPa. The increase in fatigue strength at 2×10^6 cycles of the TIG dressed welded joints was 33 % compared with as-welded condition. In comparison to the smooth specimens, the fatigue strength of as-welded joints and TIG-dressed joints was decreased by 43% and 24%, respectively, at 2×10^6 cycles.

5. REFERENCES

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