The Method of TIG dressing

1. Introduction

While most steel parent metals have fatigue strengths that nearly correspond to their static strengths, welded joints usually exhibit fatigue strengths that are drastically lower than those of the parent metals. In fact, generally the fatigue strengths of welded joints in high strength steels are the same as those of the same joint type in mild steel. This means that the higher the strength of the parent metal, the more marked will be the reduction of the fatigue strength in the welds. With the recent great advance in the technology of large structures and the accompanying rapid increase in the demand for high tensile steels, the low fatigue strength of welded joints has become a major problem ; consequently improvements are urgently required in order to exploit fully the advantages of high tensile steels. Several methods such as pre-straining, spot heating, shot peening and grinding have already been proposed, but all of them have major shortcomings as regards their ease of operation, effects or cost, and they are not generally used in practice except in special applications or small scale constructions. In contrast, TIG dressing, which is not only applicable to most welded joints where manual metal arc (MMA) welding is possible, but is also superior as regards ease of operation, effects and cost, is a very effective method of improving the fatigue strength of welded joints.

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TIG dressing consists in re-melting portions of the weld toe with a TIG torch. By this method are obtained a decrease of stress concentration caused by the flattening of the head profile at the weld toe and an increase of hardness in the dressed area as a result of re-melting. TIG dressing is applicable to all kinds of conventional bead-reinforced joints in which fatigue failure starts at the toe, and is especially effective for non-load carrying fillet welded joints.

The volume of data on the fatigue strength of TIG dressed welds is insufficient, at present, to provide statistically based data. However, the figures in the following table are given as an illustration of the improvements that can be achieved. They refer to the fatigue behaviour of transverse non-load-carrying fillet welds. Tests have also been done on TIG dressed butt welds[2].

Condition	*Yield strength of steel* N/mm^2	*Mean fatigue strength,* N/mm^2 *at* 10^5 *cycles*	*at* 2×10^6 *cycles*	*Source*
As-welded	Various	333	102	Ref (6)
TIG dressed	726	340	247	Ref (7)
TIG dressed	860	500 (estimated)	300	Ref (2)

In the present paper, recent developments in effective TIG dressing procedures for welded joints are described on the basis of studies by D. Millington[1] and the authors[2] [4];

2. TIG dressing procedures

2.1. *Objective of TIG dressing*

The principal reason for the fatigue strength improvement achieved by TIG dressing on welded joints is that the stress concentration in the toe portions is greatly reduced by the flattening of the toe profiles and the melting out of weld toe defects. Therefore, the objective of TIG dressing applied to improve fatigue strength is to obtain a smooth bead profile without any sudden change between the parent metal and the the reinforcement beads, in other words, to eliminate the so-called weld toe. To achieve this end, better results are obviously obtainable when no filler wire is used in the dressing. Fig. 1 shows the as-welded toe profile of a cruciform fillet welded rib joint of HT80 steel, and Fig. 2 shows the comparable profile after TIG dressing with a 3.2mm diameter tungsten electrode, an argon flow rate of 10 l/min, 250A welding current, 14V voltage and a welding speed of 14 cm/min without a filler wire.

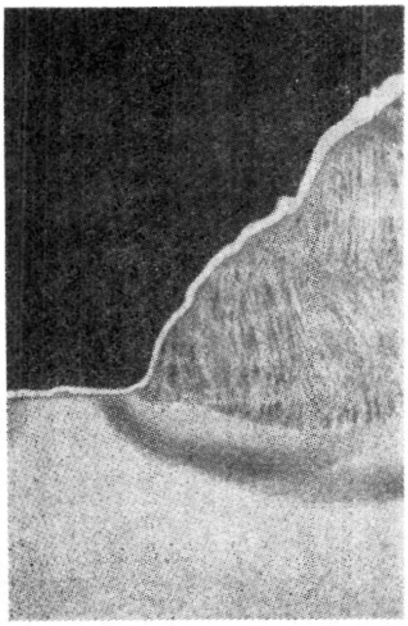


Fig. 1. Macrosection of the welded toe profile of a cruciform fillet welded joint in HT80 in as welded condition using electrode L-70 (low hydrognn type)[2] ×5.

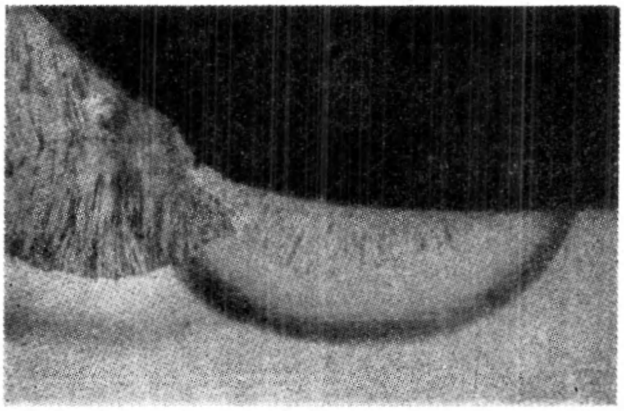


Fig. 2. Macrosection of the TIG dressed toe profile of a cruciform fillet welded joint in HT80, tungsten electrode 3.2ϕ, Ar 10 l/min, current 250A, voltage 14V, travel speed 14 cm/min. The axis of ihe TIG torch is directed, at 0.5-1.5 mm from the MMA welded toe, towards the parent metal[4] ×5.

2.2. *TIG welding machines*

For this purpose, both automatic and manual TIG welding machines are usable, but welding machines with a large capacity are desirable in order to stabilize the dressing effect by increasing heat input, and to improve efficiency by increasing dressing speed. An instance has been reported of improved uniformity of the dressing effect achieved by the use of an automatic welding machine equipped with a weaving mechanism[3].

2.3. *Pre-treatment of materials*

Mill scale, if left on the surface to be treated by TIG dressing, is apt to cause small notches or undercuts at the new toes. It has also been noted that weld toe defects are caused by slag remaining after MMA welding. For these reasons, it is very desirable that, prior to TIG dressing, mill scale be lightly ground off and slag and other contaminants removed by wire brushing[1]. However, the defects mentioned above do not necessarily always accompany mill scale and slag. Even if such defects are present, as long as a favourable bead profile is obtained, that is, one with a large radius at the toe, substantial improvements in fatigue strength may be obtained. A large radius at the weld toe arises from the use of a high heat input. Consequently, when a large heat input rate is available, or when partial manual re-dressing with a grinder is possible, pretreatments are not always necessary. Another factor worth noting is that substantial improvements of fatigue strength are observed[2] even where the TIG dressed welded joints contain undercuts caused by rust in the parent metal.

2.4. *Dressing Conditions*

2.4.1. Tungsten electrodes

When a tungsten electrode of a sharp tip angle without any contamination is used, the arc becomes widely spread, so that the weld toes can be re-melted over a broad zone and very favourable bead profiles are obtained. If the electrode tip is damaged through oxidation during use or contaminated by oxides, the arc becomes concentrated, so that the remelted zone narrows with unfavourable effects on the bead profile ; it is difficult to start the arc, and even if it is started, its stability is poor. In such unsatisfactory conditions, it is time either to re-grind the electrode tip or to replace the electrode.

Needless to say, when high heat input is applied with high currents, electrodes of large diameter must be used. If a small diameter electrode is used with high currents, the beads may be perforated or unfavourably deformed.

2.4.2. Shielding gas

In TIG arc welding, if the argon flow rate is insufficient, the arc becomes unstable and such defects as bead perforation and bead and electrode oxidation occur. Because a gas supply rate adequate to prevent such defects depends on many factors, including gas cup size, welding conditions and welding locations (indoors and outdoors), it is considered best always to determine an optimum flow rate by a trial dressing. As examples of appropriate flow rates, for a 12.7 mm gas cup, 7 l/min and for a 15.8 mm diameter cup, 10 l/min may be mentioned. Also gas lenses may be used if required (1).

2.4.3. Dressing conditions

Although dressing conditions may vary depending on the welding positions employed, the prime consideration is always to obtain a smooth bead without pores. Several examples of welding conditions (1) are shown in Figs. 3, 4. and 5. The ranges of current and speed are shown in these diagrams, of which Fig. 3 is for the horizontal vertical welding position, Fig. 4 is for the vertical downward and upward positions, and Fig. 5 is for the overhead welding positions. Because TIG bead profiles become smoother and higher fatigue strength is obtained as heat input increases, and also higher speeds are essential for higher efficiency, current should preferably be increased to the maximum feasible without causing undercuts or without deforming TIG beads.

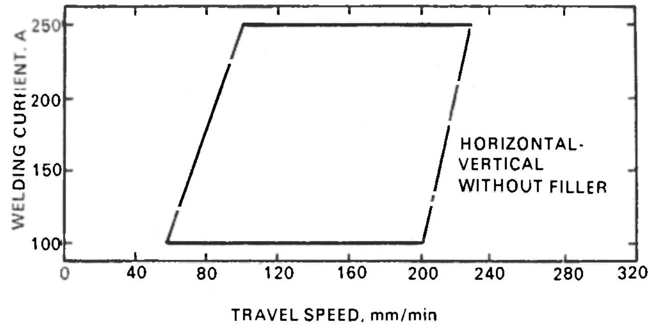


Fig. 3. TIG dressing conditions for horizontal vertical welding position(1).

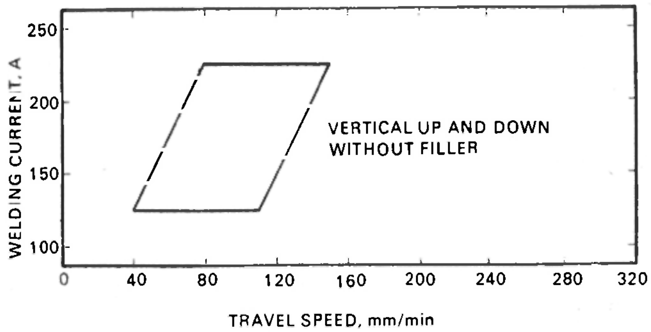


Fig. 4. TIG dressing conditions for vertical welding position(1).

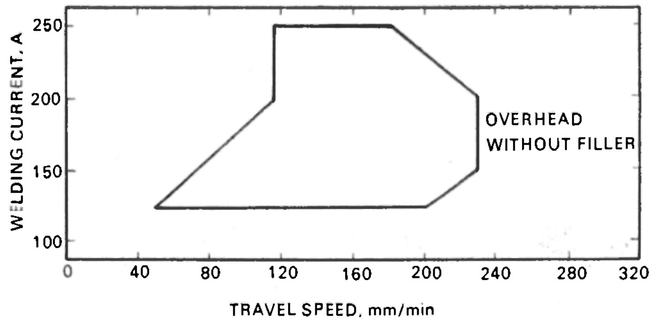


Fig. 5. TIG dressing conditions for overhead welding position(1).

As dressing effects vary greatly depending on the individual welding machines, it is advisable to determine an optimum combination of welding conditions through trial dressings.

When the hardness of the HAZ and the deposited metal increases as a result of the heat input and weld cracking is feared, appropriate pre-heating can be applied[2].

2.4.4. Position of dressing zone

In TIG dressing welded joints, the correct selection of the region of the joint to be dressed, is of prime importance. For example, even when welded joints are properly pre-treated and appropriate TIG dressing conditions are employed, if the wrong region is dressed, the bead profile will not be improved and therefore the fatigue strength will not be increased. Although the optimum position of the dressing zone varies somewhat, depending on heat input and the MMA weld bead profile, the best results are normally obtained when the arc centre is located a small distance from the MMA weld toe towards the parent metal. When the centre of the arc is aimed at the toe or slightly towards the bead, it often happens that a new toe is formed or a smaller concave bead results. For example, with TIG dressing experiments performed at a current of 250A, a voltage of 14V, and a speed of 14cm/min, the best results were obtained when the arc was aimed towards the parent metal at a position 0.5 to 1.5 mm from the MMA weld toe[4]. Fig. 2 shows a TIG bead profile obtained with this dressing position, fig. 6 shows a bead profile with the arc aimed at the toe or slightly towards the parent metal, and fig.7 shows a profile with the arc aimed slightly towards the bead. Fig. 8 shows a bead profile obtained with a narrow arc and deep penetration resulting from a damaged electrode which was aimed at a position slightly towards the bead from the toe. The resulting fatigue strength of the welded joints decreased from one sample to the next in the order given above, with the sample shown in Fig. 8 giving little improvement of the as-welded fatigue strength.

Because the optimum position of the dressing zone depends on the initial bead profile, it is preferable for

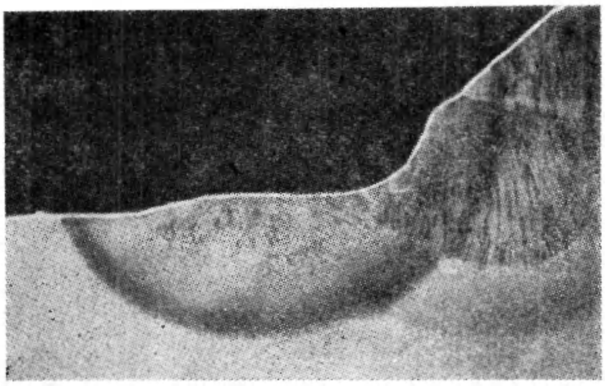


Fig. 6. Macrosection of the TIG dressed toe profile, the axis of the TIG torch directed, at 0.5 mm from the MMA welded toe, towards the present metal. Same welding conditions as in Fig. 2(4) × 5.

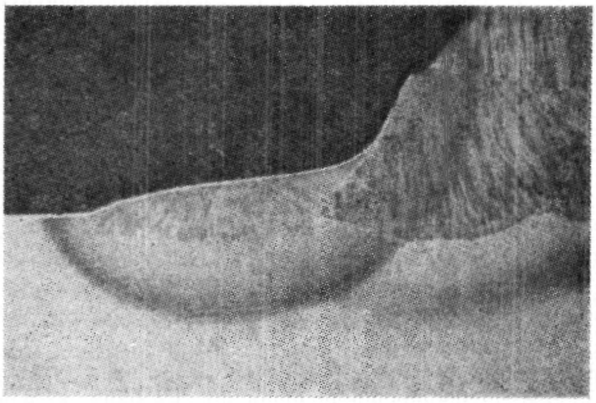


Fig. 7. Macrosection of the dressed toe profile, the axis of the TIG torch directed towards the MMA welded toe or bead. Same welding conditions as in Fig. 2(4) × 5.

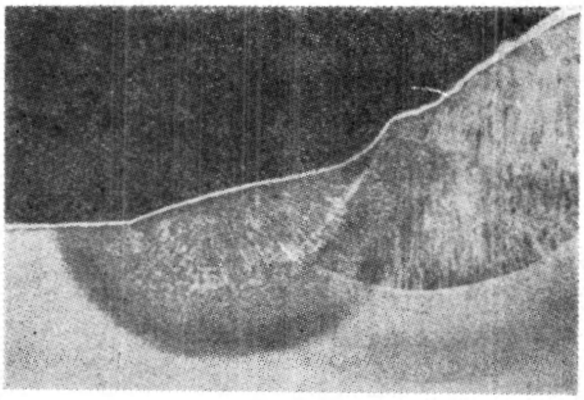


Fig. 8. Macrosection of the toe profile TIG dressed with a damaged tungsten electrade. Same welding conditions as Fig. 7 × 5.

a trial dressing to be made before determining where to aim the electrode. It may be said that, in general, for more salient beads, the electrode should be directed more towards the parent metal, and for beads with flatter profiles, the electrode should be directed nearer the toe.

2.4.5. Arc starting and stopping[1]

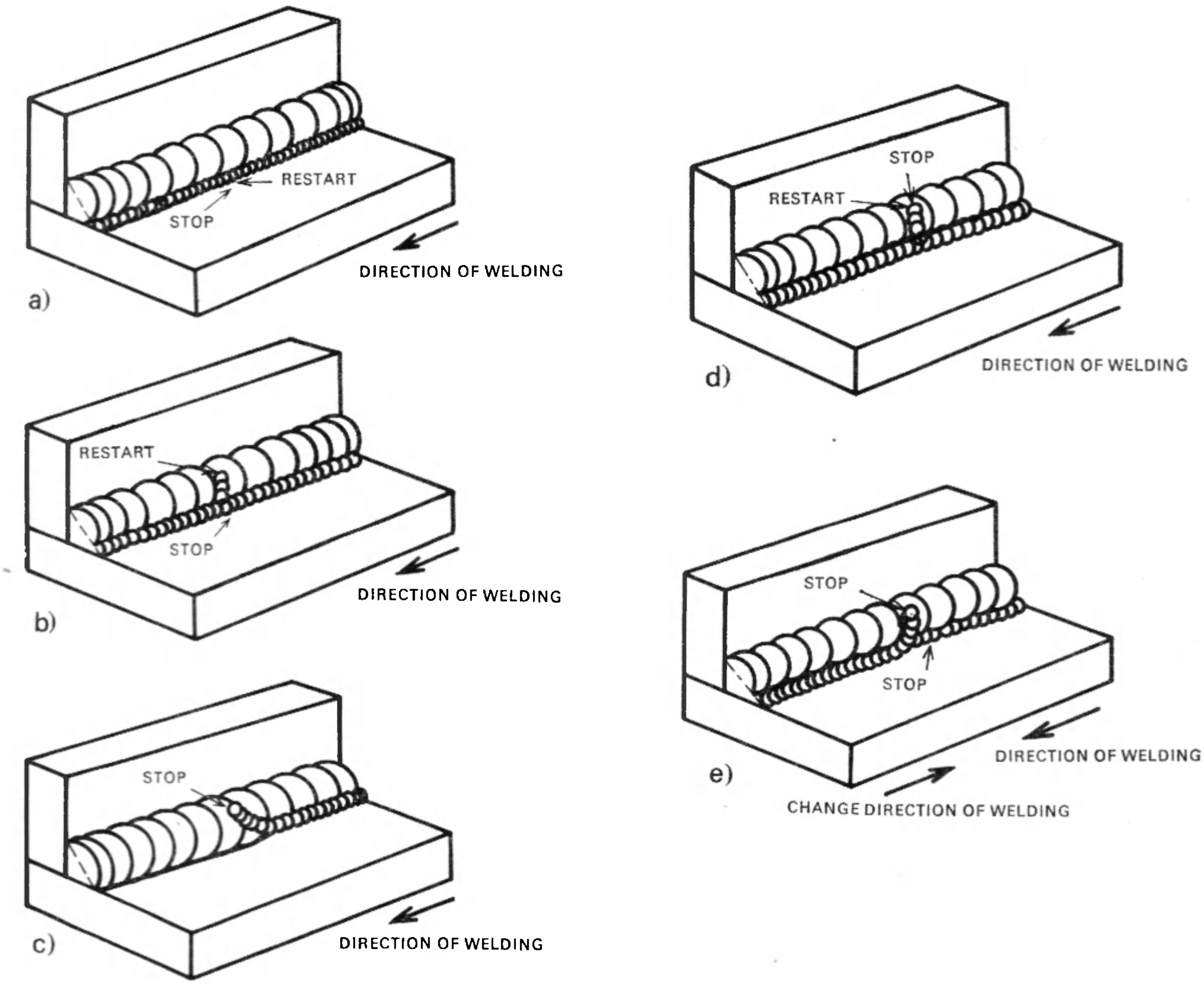
In order to prevent unfavourable TIG bead profiles and crater cracking from developing at the moment when the arc is started or stopped, it is advisable when starting the arc to do so at a point about 6mm behind where it was stopped (the step back method) or to start at a point on the bead and move downwards towards the toe. The first method is simpler and is illustrated in Fig. 9a. Figure 9b illustrates the second method.

To stop the arc, one possibility is to bring it onto the bead before extinguishing it, as shown in Fig. 9c. Alternatively, as shown in Fig. 9d, the methods of Fig. 9b and 9c may be combined, or, as shown in Fig. 9e, craters may be avoided by changing welding direction.

2.5. *Inspection and re-dressing*

As described in Section 2.1., when welded joints are TIG dressed, because toe profiles are improved in such a way that toe radii and toe angles become larger, stress concentration is reduced, and fatigue strength is improved. It follows therefore, when inspecting the result of dressings, it is sufficient to evaluate the TIG bead profiles which have been obtained. In this sense, the best TIG bead profile can be said to be such that a smooth transition line extends from the parent metal to the MMA weld bead without any socalled toe, with the TIG bead itself making a concave surface of large radii. Although not quite ideal, a TIG bead profile which was generally concave but had a small discontinuity at the toe was still found to cause a substantial improvement in the fatigue strength[4].

When a convex bead profile is obtained, ora new toe of substantial dimension is formed, one more TIG dressing run aiming at the new toe will bring the desired result. The ease of making repeated dressing runs is one of the advantages of the TIG dressing method.



Eig. 9. Examples of weld stop and restart techniques[1].

3. Conclusion

In TIG dressing, the fatigue strength of welded joints is increased through an improvement of bead profiles, and if a TIG welding machine is available, this method can be easily practised with great advantages in case of operation, effect and cost. However, as the optimum conditions to give the best results with this method are substantially influenced by such factors as welding machines, torches, bead profiles and positions, it is normally advisable to make trials before determining the dressing conditions to be adopted in particular cases.

Note :

Based on the same principle, welded joint dressing by the use of a plasma torch is also under study [5]. Although plasma dressing can be used with higher efficiency than TIG dressing, due to larger dressing width and higher dressing speed, because the plasma torch dressing method involves larger welding machines and torches than TIG dressing, the latter is simpler and easier in operation, at least for some time to come. However, if plasma welding machines are improved so as to give greater ease in operation, then plasma dressing may also have a good chance of being widely adopted for improving the fatigue strength of welded joints. Plasma dressing is the subject of a separate study by Commission XIII of the IIW.

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