



Improving fatigue strength of welded 1300 MPa yield strength steel using HFMI treatment or LTT fillers



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ABSTRACT

Fatigue improvement techniques are widely used to increase fatigue strength of welded high strength steels. In this paper high frequency mechanical impact (HFMI) and a Low Transformation Temperature (LTT) filler material were employed to investigate the effect on fatigue strength of welded 1300 MPa yield strength steel. Fatigue testing was done under fully reversed, constant amplitude bending load on T-joint samples. Fatigue strength of LTT welds was the same as for welds produced using a conventional filler material. However, HFMI treatment increased the mean fatigue strength of conventional welds about 26% and of LTT welds about 13%. Similar distributions of residual stresses and almost the same weld toe radii were observed for welds produced using LTT and conventional consumables. HFMI increased the weld toe radius slightly and produced a more uniform geometry along the treated weld toes. Relatively large compressive residual stresses, adjacent to the weld toe were produced and the surface hardness was increased in the treated region for conventional welds after HFMI. For this specific combination of weld geometry, steel strength and loading conditions HFMI treatment gave higher fatigue strength than LTT consumables.

1. Introduction

Nowadays there is a strong demand for lighter structures, especially among vehicle industries. One possibility to minimize the weight is to make the components from high strength steels and join them by welding. Many components experience fatigue loading during all or part of their life time and welded connections are often the prime location of fatigue failure. This becomes more critical in welded high strength steels as fatigue strength of welds does not increase by increasing the steel strength. A possible solution to overcome this issue is to use fatigue improvement methods. The two main approaches are (a) modification of the weld toe geometry (by, for example, grinding or re-melting methods) and (b) modification of the residual stress induced by welding (for example by shot peening). The former improves the fatigue strength through reduction of the local stress concentration factor by ensuring a smooth transition between the weld profile and base metal. The latter contributes to fatigue strength increase by reducing tensile residual stresses or even by inducing compressive residual stresses in the weld toe region [1,2].

Over the last few years, many studies have been conducted to investigate different fatigue improvement methods. One recent method is application of high frequency mechanical impact (HFMI) treatment. A number of publications have shown the usefulness of this method to increase the fatigue strength of welds. The increase in fatigue strength is believed to be mainly due to residual stress modification and partly by weld toe geometry modification and increased local hardness in the treated region [3–7]. However, almost all the reported studies are for welds in steels with up to 960 MPa yield strength level. Another recent approach to increase the fatigue

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Table 1
Chemical compositions of base and filler materials (wt%).

		C	Si	Mn	Cr	Ni	Mo
Base material	Weldox 1300	0.25	0.5	1.4	0.8	1.3	0.7
Welding consumable	Coreweld 89 ^a	0.08	0.6	1.3	0.5	2.6	0.7
	LTT ^a	0.01	0.7	1.50	13.0	6.0	0.01
	OK Tubrod 14.11 ^a	0.03	0.8	1.5	0.04	0.01	–

^a Nominal all-weld metal composition.

strength is to weld with special consumables of so-called Low Transformation Temperature (LTT) type. This method is a more economical technique since it does not need any additional treatment after the welding. The increase in fatigue strength when using LTT consumables is a result of the volume expansion due to transformation of austenite to martensite at low temperatures, typically around 200 °C. This reduces the tensile residual stresses or even creates compressive residual stresses in the weld region particularly in the weld toe [8–13]. The applicability of LTT fillers to increase the fatigue strength of welds has been investigated for steel welds with yield strengths up to 1021 MPa and mostly for cruciform shaped welds. Fatigue testing have shown much higher fatigue strengths for LTT welds compared to welds produced using conventional filler materials [14,15].

There has not been any study on the application of LTT filler materials to increase the fatigue strength of welds in steels with yield strengths higher than 1021 MPa. Also no study has been done to compare the effect of LTT filler to that of HFMI treatment on fatigue strength of welded high strength steels. Thus, the aim of the present paper is to investigate the effect of using an LTT consumable or HFMI treatment (see also [16]) on fatigue strength of welds in 1300 MPa yield strength steel. The effect of HFMI treatment on LTT welds is also studied for the first time.

2. Materials and methods

2.1. Base and filler materials

Weldox 1300 plates with a thickness of 15 mm was used as the base metal. The yield strength of the base metal was 1295 MPa and its tensile strength was 1562 MPa. Three filler materials, one experimental and two commercial were chosen. The experimentally designed metal cored wire with higher amount of Cr and Ni to produce a low martensite start (M_s) temperature was coded as LTT. The two commercial wires were: Coreweld 89 (a high strength wire) and OK Tubrod 14.11 (a medium strength wire). The chemical compositions of the base material and filler materials are given in Table 1 and mechanical properties of all-weld metals are summarized in Table 2.

2.2. Welding setup

Welded assemblies were produced by joining two plates with dimensions of 500 × 200 × 15 mm. Robotic Gas Metal Arc Welding (GMAW) with Ar + 18% CO₂ as shielding gas, was used to produce full penetration fillet welds from both sides. LTT and conventional welds were produced in five beads. In conventional welds OK Tubrod 14.11 was used as filler material in the root bead (bead 1) and a high strength (Coreweld 89) filler material for the other beads while in LTT welds all beads were welded using a LTT consumable. Welding parameters are summarized in Table 3. The welding sequence is shown in Fig. 1(a). The different weld toes were named L1, L2, U1 and U2 (see Fig. 1(a)). The welded assemblies were sliced and machined to produce specimens, with dimensions as shown in Fig. 1(b).

2.3. High frequency mechanical impact treatment

High frequency mechanical impact treatment was performed on LTT and conventional welds with the frequency of 20,000 ± 400 Hz. Indenters with radii of 1.5 mm for the lower weld toes (L1 and L2) and 3 mm for the upper ones (U1 and U2) were used for the peening. The amplitude of vibration of the sonotrode was 40 μm. Detailed information on the treatment can be found in [16]. HFMI treatment was performed based on the IIW recommendation [17].

Table 2
Typical mechanical properties of all-weld metal.

Welding consumable	f_y (MPa)	f_u (MPa)	Impact toughness at – 40 °C (J)
Coreweld 89	910	965	72
LTT	736	1127	49
OK Tubrod 14.11	420	555	47

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