The characterization of AISI 1526 before and after GMAW (Gas Metal Arc Welding) weldments

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Abstract. The characterization of AISI 1526 before and after GMAW (Gas Metal Arc Welding) had been performed. Hardness test, metallography, phase composition, and residual stress data had been collected. Neutron diffraction technique had been used for getting internal residual stress data before and after weldment. Two samples with different heat treatment of tempering, 125ºC and 175ºC, are provided as main materials that will be welded with different heat input in the process of welding. With higher tempering, the hardness were decrease as well as martensite phase. The magnitude of the residual stresses was reduced by increasing the heat input. The magnitude of the residual stress in HAZ area is 425 MPa in the axial direction in the sample of Q900T125 with heat input 4,9 KJ/mm. Meanwhile, in Q900T175 with heat input 5,1 KJ/mm, the magnitude residual stress in the center of weld metal is 219 MPa in the axial direction.

1. Introduction

The high strengths of these steels can be achieved by different manufacturing processes i.e. quenched and tempered (QT) [1]. Usually the quenching operation applies high-performance lines and starts with reheating to temperatures above Ac3, which have to be rather homogeneous distributed from the surface to the center. Then the plates are quenched by using pressurised water to obtain a transformation of the microstructure into martensite or bainite, followed by a tempering process [2].

Welding is a fabrication process undertaken in melting causes by local heating. Local plastic deformation due to thermal and mechanical processing of fabricated structures is main reason of residual stresses of manufacturing processes. For welding, the non-uniform temperature distribution and cooling rates are responsible for residual stresses form in welded structures. The magnitude of the residual stresses was significantly reduced by increasing the heat input [3]. Tensile residual stress adversely affects structure operation and may lead to decrease in fatigue strength, brittle fracture or cause to stress corrosion cracking [4]-[6] while compressive residual stresses have the reverse effect [7]. There is similar trend for stress corrosion cracking as the numerical analysis coupled with experimental work confirms higher susceptibility of welded joints to stress corrosion cracking with increasing residual stresses [8]. Also confirmed the deterimental effect of tensile residual stresses on the structural integrity of welded structures through significant acceleration of the growth rate of the defects such as micro-cracks [9] while compressive residual stress will be retardation of fatigue crack propagation [10]. Therefore, accurate prediction of magnitude and distribution of residual stresses is of great importance to ensure uniformity of welded structures [11].

The magnitude and distribution of residual stresses are greatly influenced by the welding procedure and parameters and joint geometry [3]. It is expected the value of heat input to be inversely related to the magnitude of residual stresses where a higher heat input is to result in less stressed weld joint [12]. The heat input is a function between the welding speed, current, and the voltage of welding process. An increase in heat input due to increased current (constant travel speed) reduces the magnitude of longitudinal residual stresses [13]. For travel speed, an increase in heat input due to reduction in travel speed is beneficial in reducing residual stresses in weldment [3], [14]. In contradiction to the above-mentioned studies, the effect of thermal on residual stress using interpass temperature and varying heat input has been analyzed. The evaluation show a significant influence of the interpass temperature on the global reaction forces. Furthermore, increased heat input and high interpass temperatures cause higher tensile residual stresses [15]. Moreover, local residual stresses are influenced by the heat input and pre-heat temperature. Higher heat input and preheating lead to an increase of the tensile residual stresses in the weld and the HAZ. Bigger heat affected areas increase the inhomogeneous cooling and shrinking processes [1]. Numerical simulations on the effect of welding speed on residual stresses confirmed higher magnitude of residual stress at lower speed, i.e. higher heat input [16].

Therefore, the main aim of the current work was to characterize AISI 1526 steel and investigate the effect of welding heat input on the residual stresses of AISI 1526 GMAW (Gas Metal Arc Welding) weldments use neutron diffraction technique.

2. Experiment Method

As test material, two plates of AISI 1526 a dimension of 250x250mm with a thickness of 10 mm were used. The chemical composition are given in Table 1. Both samples are divided into sections using wire cut as shown Figure 1. AISI 1526 was received as a hot-rolled plate steel then given heat treatment before welding to compare a result before and after heat treaatment.

Table 1. Chemical composition.

	Chemical composition (in wt.%)											
	C	Mn	P	S	Cu	Mo	Ni	Al	Pb	Si	Cr	V
AISI 1526	0.29	1.14	0.014	0.008	0.08	0.19	0.27	0.03	0.008	0.32	0.55	-
ER70S-6	0.09	<1.60	0.007	0.007	0.20	0.05	0.05	-	-	0.90	0.05	0.05

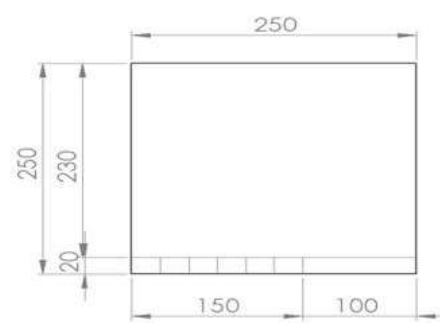


Figure 1. Specimen dimension of AISI 1526.

After heat treatment (Figure2), the prepared both specimen had identical dimensions of 230x250mm for welding. The preparatory joint squence and measurenment plane for residual stress is shown Figure 3 and 4. A total of two sample were fabricated. All weldments were accomplished with an manual GMAW multilayer welding process. The welding parameters are shown in Table 2. There was no pre or post-weld heat treatment.

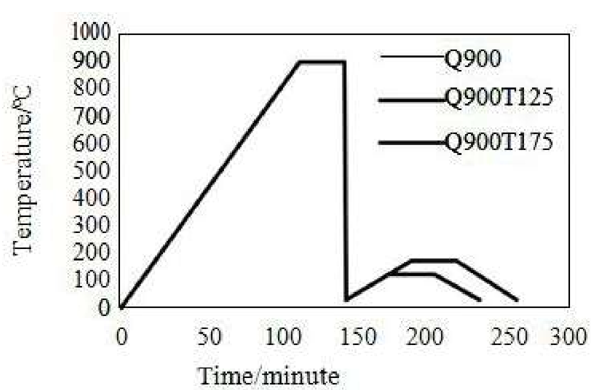


Figure 2. Shematic of heat treatment process.

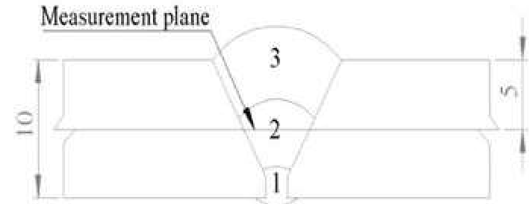


Figure 3. Pass squence in specimen Q900T125.

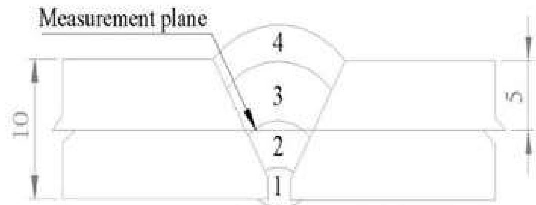


Figure 4. Pass squence in specimen Q900T175.

In order to justify the comparisson between the two different process employed in this work, it was tried to have closely possible temperature tempering (Figure 2) and welding parameters such as heat input (Table 2) and pass number (Figure 3 & 4). The chemical composition of ER70S-6 can be seen in Table 1.

Table 2. Welding parameters.

	Current	Voltage	Welding speed (mm/s)				Heat input
	(A)	(V)	Pass 1	Pass 2	Pass 3	Pass 4	(KJ/mm)
Q900T125	150	22	4,05	1,79	1,47	-	4,9
Q900T175	150	22	3,75	3,06	2,05	2,14	5,1

3. Result and discussion

3.1 Hardness and phase composition

Figure 7 shown the results of hardness and phase composition before and after heat treatment. Hardness after heat treatment is higher than raw material. Hardness increases after quenching process and it has this effect of rises martensite phase. Hardness decreases after being followed tempering process with higher tempering temperatures. During tempering process, allowing diffusion at the moment single phase BCT martensite, which is supersaturated with carbon, transforms to tempered martensite [18].

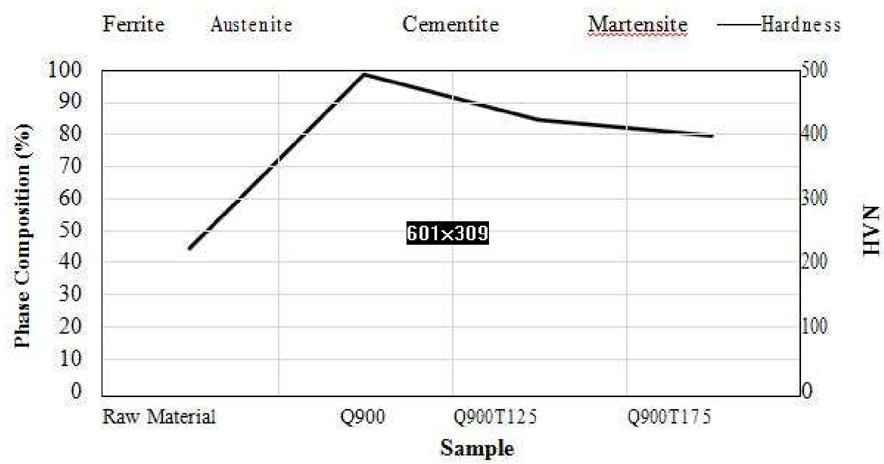


Figure 7. Hardness and phase composition before and after heat treatment.

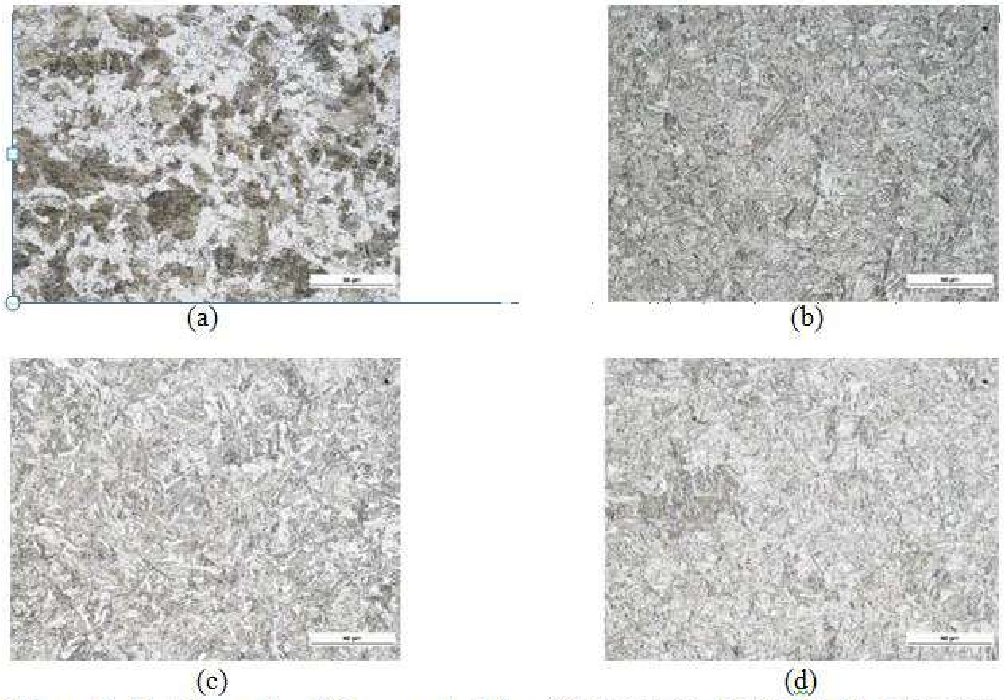
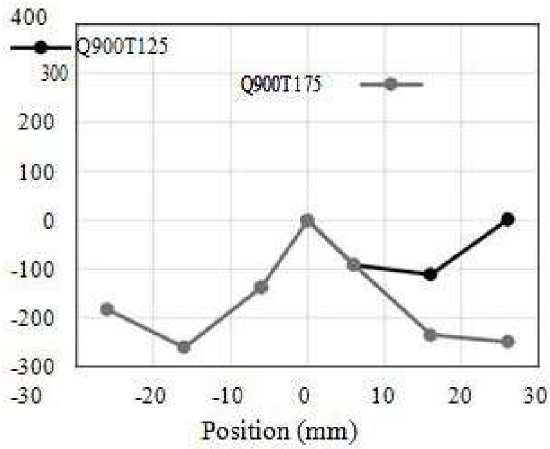


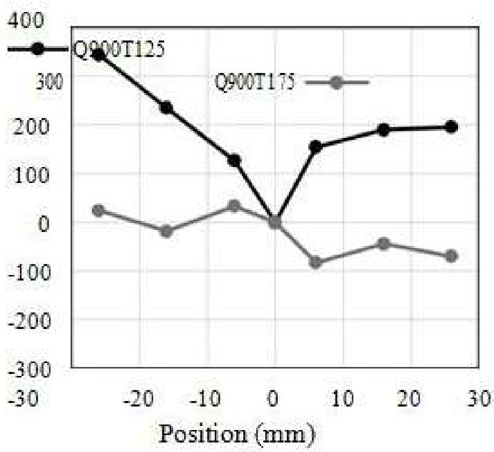
Figure 8. Metallography of (a) raw material and (b) Q900 (c) Q900T125 (d) Q900T175.

3.3 Residual stress

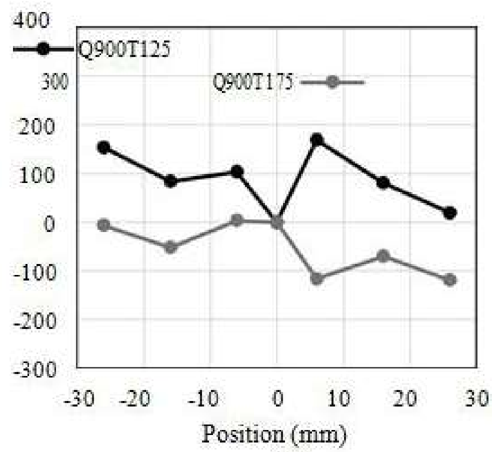
Temperature and rapid cooling rate not only generated a varied microstructure, but can also generated residual stress which can cause material to stress corrosion cracking. Measurements residual stress were performed at BATAN using DN1 and a 3x3 mm^2 slit. Figure 9 shown influence of temperature tempering on axial, normal and transverse residual stress before welding. Axial, normal and transverse residual stress is random and formed by quenching and tempering process. There are differences in magnitude of residual stresses in both specimens. In Q900T125 specimen residual stress is greater than that of Q900T175 specimen. Normal and transverse residual stress are tensile in Q900T125, because of temper process at 175°C residual stress has changed compressive. The difference in magnitude residual stresses in both specimens is about 200 - 300 MPa. This is due to tempering temperature which can result in reduced residual stress. The higher tempering temperature of residual stress will decreases significantly.



(a)



(b)

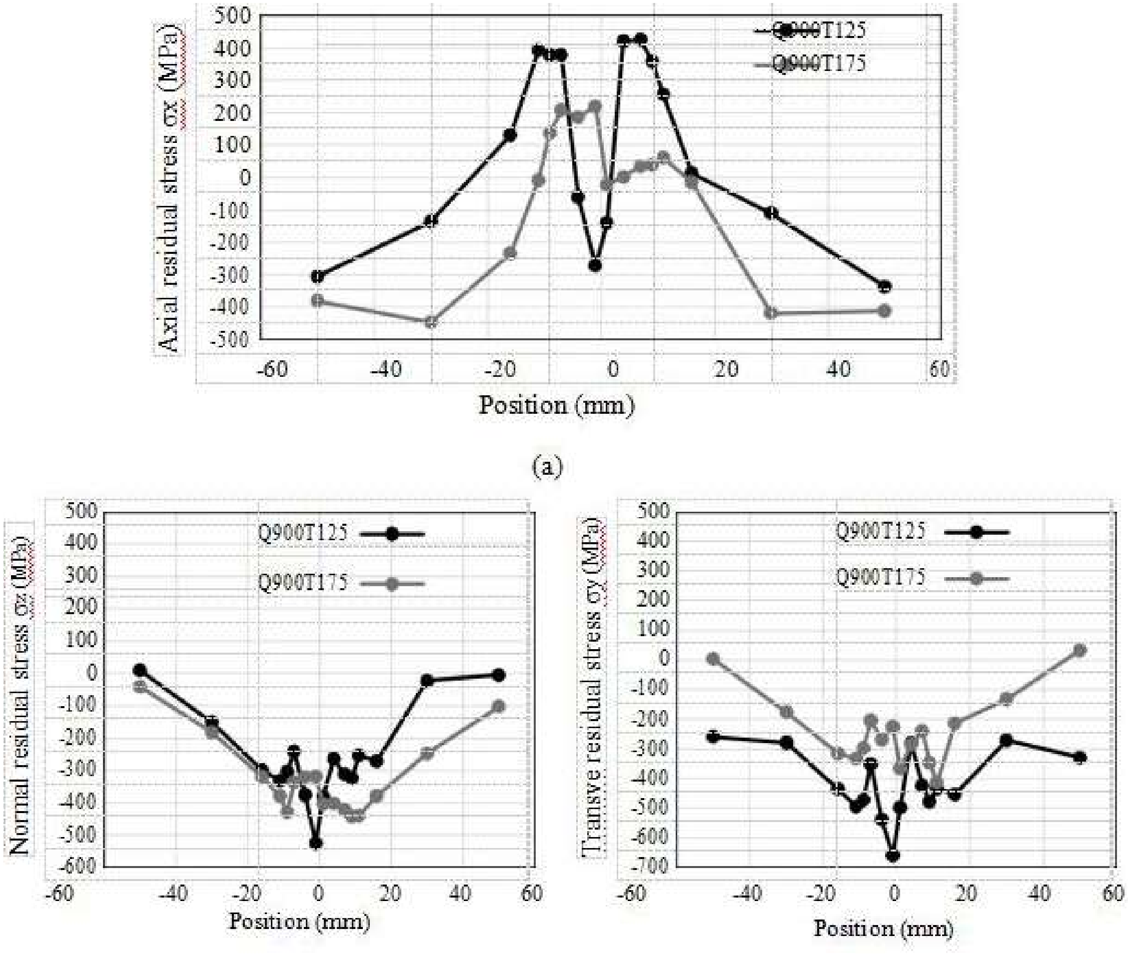


(c)

Figure 9. Influence of temperature tempering on residual stress (a) axial (b) normal (c) transverse direction.

Effect of heat input on residual stress can be seen from the ratio of residual stress distributions Q900T125 and Q900T175 specimens. Heat input is influenced by different welding speeds since the welding voltage and current were kept constant. A total of three (3) welds were deposited for Q900T125 specimens obtained 4,9 KJ/mm and four (4) for Q900T175 specimens 5,1 KJ/mm. Figure 10 shown influence of heat input on axial, normal and transverse residual stress after welding is complete.

Compressive residual stress concentrated in the weld center. Axial residual stress is higher than normal and transverse for both specimen. These results seem to suggest that expansion and shrinkage during welding along a weld centreline are much higher than perpendicular to the weld giving buckling is the dominant distortion in all welded [10]. It is clear that increasses heat input can reduced residual stresses in axial direction. The maximum residual stress on the specimen Q900T125 (low heat input) is HAZ 425 MPa, but on specimen Q900T175 (high heat input) in the centre of weld metal is 219 MPa. The higher shrinkage during cooling causes increase of the residual stress in the HAZ area in both specimen [1,3,17].

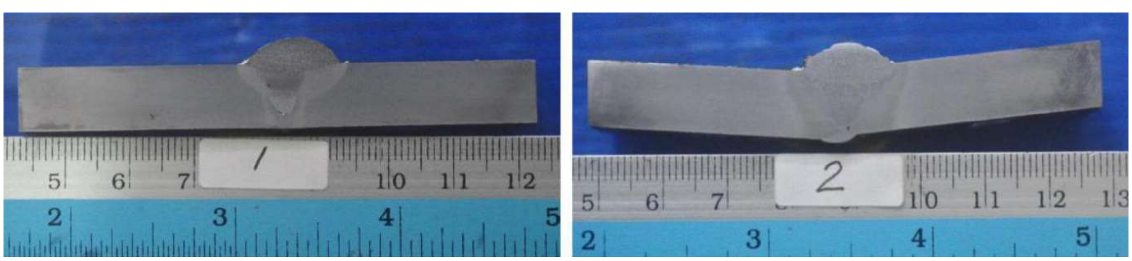


(a)

(b) (c)

Figure 10. Influence of heat input on residual stress (a) axial (b) normal (c) transverse direction.

A significant difference the residual stress distribution resulted from the difference in heat input. However, this difference does not occur in transverse residual stress. Where the magnitude residual stress in the weld area on Q900T125 (low heat input) is identical slightly larger than Q900T175 (high heat input).



(a) Q900T125. (b) Q900T175.

Figure 11. Gas metal arc welded joint.

Figure 11 shown welded jonit both specimen. Figure 11 (a) show the surface of joint is flat. In figure 11 (b) show a curved joint. HAZ area in specimen Q900T125 smaller than Q900T175. Both of these differences are due to multipass and heat input during welding process (voltage and current were kept constant).

4. Conclusions

The characterization of AISI 1526 before and after GMAW (Gas Metal Arc Welding) were discussed. The influence of temperature tempering and heat input were considered. The following conclusions can be made :

The characterization are influenced by tempering temperature. In this work, the higher tempering temperature indicates the lower hardness and the decrease of martensite phase followed by the increase of the ferrite and cementite pahse.

With the increase heat input affected the residual stress. The higher heat input can reduce the residual stress in the axial direction.

The maximum tensile residual stress in the HAZ area, increase the shrinking processes during cooling.

5. Acknowledgements

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6. References

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