Mechanical Characteristics of Welds Joined by Developed Welding Wire with a Phase Transformation at Low Temperature (I)

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Abstract

In the fabrication of steel structures, the correction of distortion generated by welding needs a lot of energy. The reduction of the consumption of energy for the correction of welding distortion is required from the environmental and economical point of view. So, a welding wire with a phase transformation at low temperature, which can assist in correcting welding distortion, was newly developed. Based on the mechanical properties of welds joined by using an existing welding wire, the mechanical properties of welds joined by using a newly developed welding wire were evaluated. Despite the fact that the mechanical characteristics of the newly developed welding wire were a little inferior to an existing welding wire, it did not create a problem in the practical use from the overall point of view.

KEYWORDS: (Phase transformation) (Welded joints) (Mechanical property) (Welding wire) (Consumable)

1. Introduction

In the fabrication of steel structures, the correction of distortion generated by welding needs a plenty of energy. The reduction of the consumption of energy for correction of welding distortion is required from the environmental and economical point of view. The distortion generated by welding can be decreased by using a new process as like a laser. But, the new equipment is required and the production cost is increased. Also, the distortion generated by welding may be decreased by using a phase transformation. There are several selections for the reduction of welding distortion. In this research, a phase transformation is noted among several selections. It is specially selected with regard to the economical point of view. A welding wire with a phase transformation at low temperature, which can assist the correction of welding distortion, is newly developed.

In this paper, the mechanical properties of welds joined with a newly developed welding wire are evaluated and compared with those of welds joined by an existing welding wire.

2. Experiment

2.1 Weldability

It is generally known that the transformation temperature has an effect on the welding distortion. In order to develop a welding wire producing less distortion, the transformation temperature is controlled through the regulation of Cr and Ni. **Table 1** shows the chemical ingredients of the developed welding wire. The starting temperature of phase transformation of the developed welding wire, Ms, is about 260℃. **Table 2** shows the mechanical properties of the new wire. It has high tensile strength in comparison with the existing wires.

Table 1 Chemical ingredient of newly developed welding wire.

Welding wire	Chemical composition (%)								
	C	Si	Mn	P	S	Ni	Cr	N	O
1.2mmϕ	0.057	0.49	1.71	0.008	0.005	3.00	12.10	0.006	0.090
1.4mmϕ	0.058	0.40	1.67	0.007	0.003	3.26	11.97	0.005	0.080

Table 2 Mechanical Properties of newly developed welding wire.

Welding wire	Tensile properties				Impact property
	Yield stress (MPa)	Tensile strength (MPa)	Elongation (%)	Reduction of area (%)	Absorbed energy (J)
1.2mmϕ	1180	1130	10	25	18
1.4mmϕ	1070	1126	9	18	20

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Table 3 Welding conditions.

	Current(A)	Voltage(V)	Welding speed(cpm)	Method of welding
Conditions	190-210	29-31	20-30	100% CO_2 Shielded Arc Welding

Table 4 Welding conditions.

Welding wire	Experiment	Pass	Current(A)	Voltage(V)	Welding speed (cpm)	Method of welding
Existing wire	Tensile	4	290-310	32-33	30-35	100% CO_2 GMAW
	Bending, Impact, Hardness	2				
Developed wire	Tensile	4	210-220	29-30	21-27	
	Bending, Impact, Hardness	2				

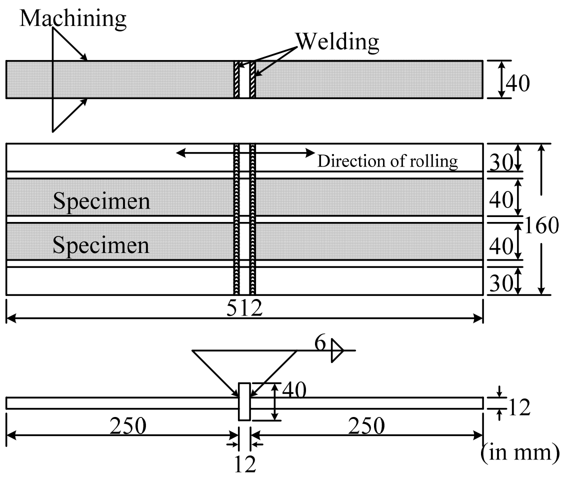


Fig.1 Shape of tensile test specimen and dimensions.

In this paper, weldability and workability of the developed wire is compared with those of an existing wire. The welding is carried out without pre- and post-heating. **Table 3** shows the welding conditions.

2.2 Experiments with regard to the evaluation of mechanical properties of welds

Material of the specimen is SM490Y. The existing wire used is MX-Z200. It is a welding wire of 50kN class. **Table 4** shows the welding conditions to make each experimental specimen. In order to evaluate the mechanical properties, four fundamental experiments (Tensile, Hardness, Bending and Impact test) are carried out in relation to the existing and the developed wire.

2.2.1 Tensile test

Figure 1 shows the shape and dimensions (JIS Z3131) of the tensile test specimen. The yield stress and tensile strength are measured by strain gages. The elongation is measured by clip gages, with a gage length is 60mm.

2.2.2 Hardness test

In order to investigate the softening and hardening on the base metal, heat affect zone (HAZ) and weld metal, a Vickers hardness test is carried out. **Figure 2** shows the shape and dimensions (JIS Z 3128) of the hardness test

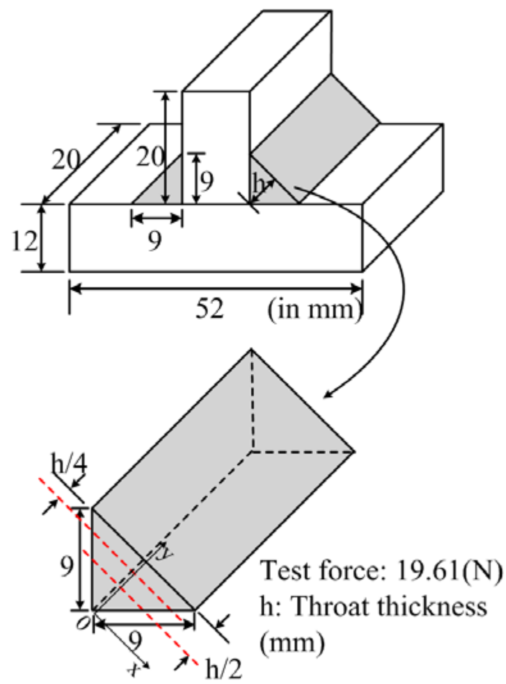


Fig.2 Hardness test specimen and measuring position.

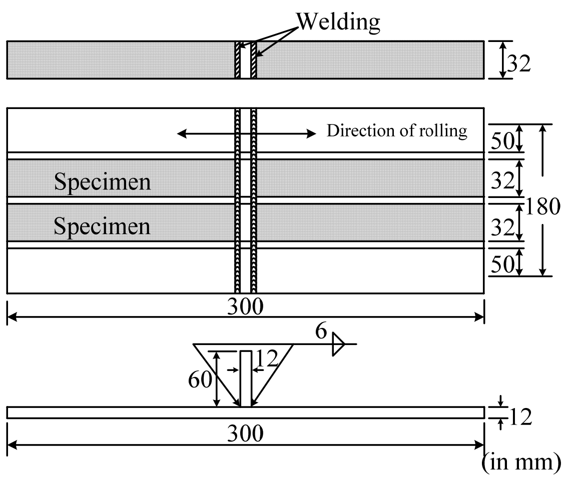


Fig.3 Shape of bending test specimen and dimensions.

specimen. Test force is 19.61N. The loading point is at the center (h/2) and quarter (h/4) of the actual throat of the fillet welds. And, with priority given to the welds, hardness tests totaling 17 points are carried out at intervals of 0.7mm.

2.2.3 Bending test

In order to investigate the deformation performance and existence of defects in the welds, bending tests are carried out. **Figure 3** shows the shape and dimensions (JIS Z 3134) of bending test specimens. For the bending test of the welds, 120° bending is performed. After that, it is checked whether defects exist on the welds. In the case of failure, the angle of the welds is measured.

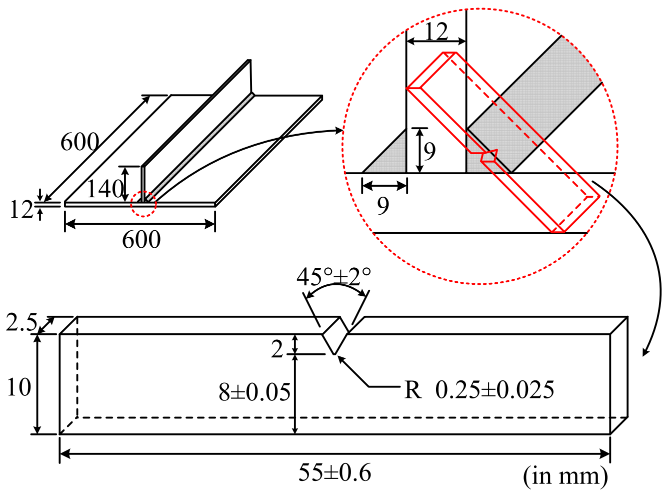
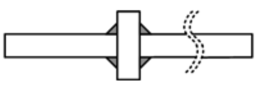
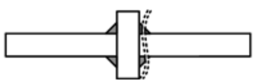
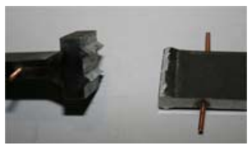
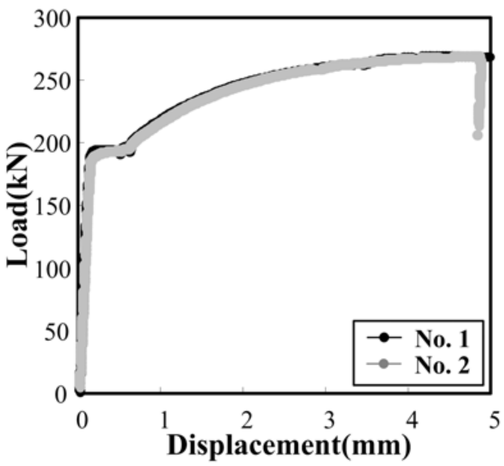


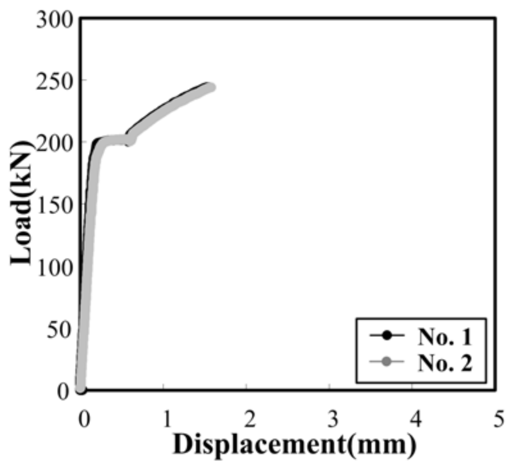
Fig.4 Dimensions of Charpy impact test specimen.

Table 5 Results of tensile test.

	Existing welding wire		Newly developed welding wire	
σ_{max} (MPa)	564	562	842	840
Position of failure	Base metal 		Weld metal 	

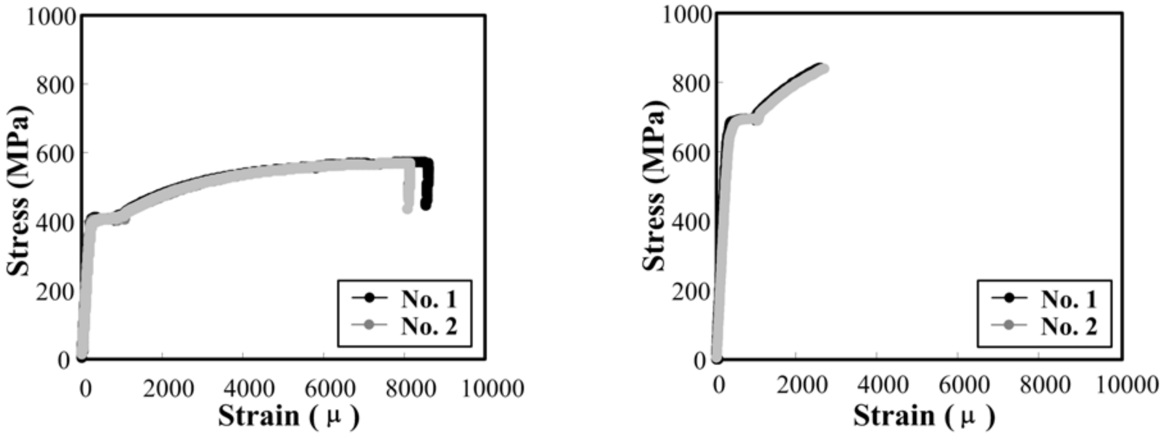


(a) Existing welding wire (MX-Z200).



(b) Newly developed welding wire.

Fig.5 Load-displacement diagram.

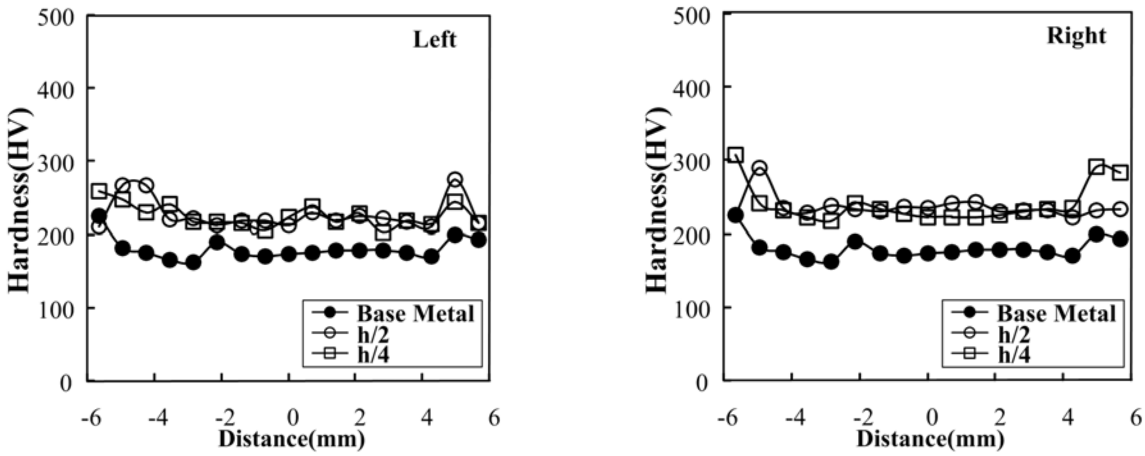


(a) Existing welding wire (MX-Z200). (b) Newly developed welding wire.

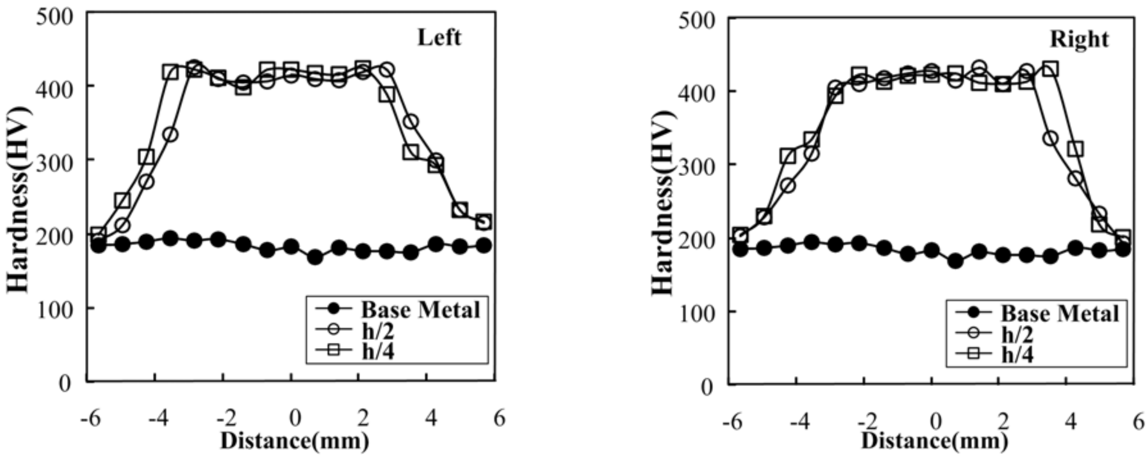
Fig.6 Nominal stress-strain diagram.

Table 6 Results of Vickers hardness test.

	Existing welding wire		Newly developed welding wire	
Hardness(HV)	225	220	409	415



(a) Existing welding wire.



(b) Newly developed welding wire.

Fig.7 Distributions of hardness.

2.2.4 Charpy impact test

In order to investigate the energy absorption of the base metal, heat affected zone (HAZ) and weld metal, Charpy impact tests are carried out. A sub-size specimen of 2.5mm width is used in this experiment. This is because the Charpy impact test specimen of 10mm width cannot be taken from the weld metal of a fillet welding (see **Fig 4**). **Figure 4** shows the shape and dimensions (JIS Z 2202) of Charpy impact test specimens. The test temperature is -40, -20, 0 and 20℃.

3. Experimental Result and Discussion

3.1 Weldability

Based on the weldability and workability of an existing wire, that of the developed wire is evaluated. The superiority and inferiority is decided by the judgment visually, by experts with 6, 15 and 31 years of experience in practical welding. According to the result, the weldability of the developed wire compared well with that of an existing wire. But, there is some concern about the generation of overlap.

3.2 Experiments in regard to the evaluation of mechanical properties of welds

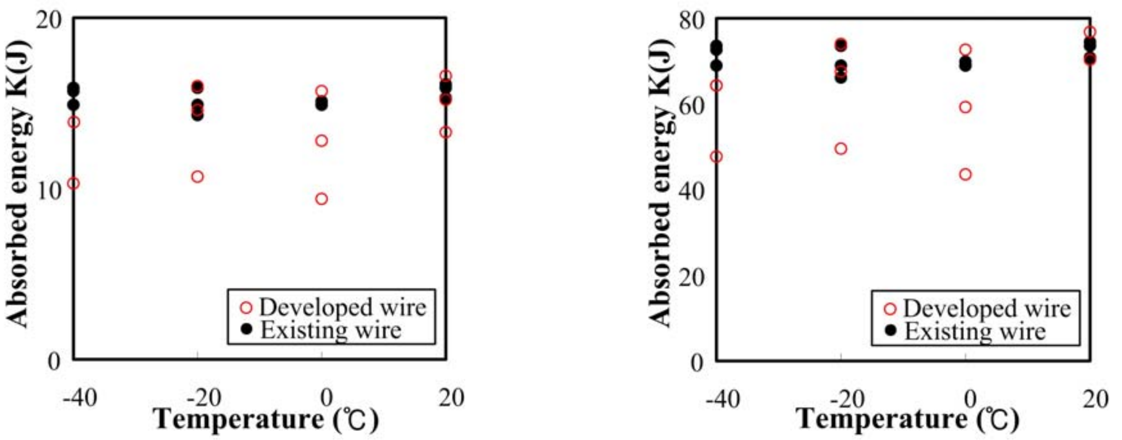
3.2.1 Tensile test

Table 5 shows the results of the tensile tests. **Figure 5** shows load-displacement and **Figure 6** shows stress-strain diagrams.

All specimens using an existing wire are broken at the base metal. But, the specimens using the developed wire are broken at the weld metal. The stress of a specimen, which is broken at the weld metal, is generally

Table 7 Results of 3-point bending test.

	Existing welding wire		Newly developed welding wire	
Failure load(kN)	37.7	37.7	50.7	50.7
Angle of failure(°)	90	90	65	66



(a) Energy absorption. (b) Converted energy absorption.

Fig.8 Results of Charpy impact test.

Table 8 Results of Charpy impact test with respect to size of test specimen.

Capacity	Specimen	Temperature (℃)	K_{v2} (J)
50Kg-m	Full #1	20	131.5
	Full #2		124.4
	Full #3		132.4
Average			129.5
5Kg-m	Half #1	20	20.7
	Half #2		21.0
	Half #3		22.8
Average			21.5

calculated using the area of the weld metal. The strength of a specimen is estimated by the 70% value of calculated stress. Stress of the developed wire and of the existing wire exceeds the yield stress of the base metal. The strength of the developed wire is sufficient, but the elongation of the developed wire does not match that of the existing wire. However, this does not present a problem from the point of view of allowable stress design (and fatigue strength mentioned in the next paper (II)).

3.2.2 Hardness test

Table 6 shows the results of Vickers hardness test and **Figure 7** shows the distribution of hardness.

The hardness of the developed wire is higher about 1.9 times than that of the existing wire. Despite the fact that the hardness is high, it does not present much of a problem.

3.2.3 Bending test

Table 7 shows the results of 3-point bending test. The breaking load and position of failure in the bending test specimen using the developed wire has the same value as compared with that of bending test specimen using the existing wire. The angle of failure of the bending test specimen using the developed wire is 25% smaller in comparison to that of the bending test specimen using the existing wire. But, this does not create a problem because the angle of failure is over 60°.

3.2.4 Charpy impact test

Figure 8(a) shows the results of Charpy impact tests at each test temperature. **Figure 8(b)** shows the energy absorption converted to the value for the full size test specimen. For converting the energy absorption into a value for a full size test specimen, test specimens of 10mm and 2.5mm thickness are taken from base metal (SM490Y). The Charpy impact test is carried out for those specimens. **Table 8** shows the results of Charpy impact tests with respect to size of test specimen and capacity of the Charpy impact test machine [1). With the ratio of these results, the conversion factor for the value of full size test specimens, $\eta = 4.625$, is obtained. The energy absorption for full size test specimens is obtained by multiplying the energy absorption for the Chary impact test specimen of 2.5mm thickness by this conversion factor.

In this experiment, the converted energy absorption is over 40J. According to the JIS G3106, the general energy absorption of SM490Y is 27J. Therefore, despite the fact that the energy absorption of the developed wire has a lower value as compared with that of the existing wire, it does not present a problem for practical use.

4. Conclusion

In order to decrease the consumption of energy accompanying the correction of welding distortion, the welding wire with a phase transformation at low temperature was newly developed. Based on the characteristics of welds joined by using the existing wire, the characteristic of welds joined by using the developed welding wire were evaluated.

Despite the fact that the mechanical characteristics of the developed wire were a little inferior to the existing wire, this did not present a problem for practical use from the overall point of view.

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