Fracture Toughness of Rolled H Section Steel Welds Joined by Newly Developed Flash Welding System †

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Abstract

For joining large sectional members, such as I section or H section steels, on site, a new flash welding system was developed. When H section steel (600×300(mm)) was joined by using the newly developed flash welding system, the joining time was 1/10 compared with that by conventional arc welding. There is also an advantage that when this system is used, members are employed directly from gas cutting, without groove preparations. A series of experiments have been carried out to investigate the basic mechanical characteristics of H section steel members joined by the flash welding system.

In this paper, CTOD tests and Charpy impact tests were carried out on the specimens cut from the flanges of H section steel welds joined by the newly developed flash welding system to investigate fracture toughness of the joints. Although the critical CTOD of the welds was lower than that of the base metal, it recovered to that of the base metal after PWHT. Although Charpy absorbed energy at 0℃ was about 30J, it became over 100J after PWHT. The critical CTOD of the flash welded joints could be accurately estimated from the Charpy energy of flash welded joints through the equation that was proposed for the HAZ of the arc welding.

KEY WORDS: (Flash welding), (Fracture toughness), (Critical CTOD), (Charpy absorbed energy), (PWHT)

1. Introduction

For Joining large sectional members such as I section or H section steel on site, a new flash welding system was developed to shorten the joining time of large sectional members[1]. When H section steel (600×300(mm)) is joined by using the new flash welding system, it took 5 minutes, compared with about 50 minutes by conventional arc welding. There is also an advantage that when this system is used, members are used following gas cutting without groove preparation.

A series of experiments has been carried out to investigate the basic mechanical characteristics of H section steel members joined by the flash welding system[2-3].

In this paper, CTOD tests and Charpy impact tests are carried out, as it is necessary to elucidate toughness of the joints for applying the flash welding system to steel structures. The obtained results are investigated from various points of view.

2. Experiments

2.1 Materials of specimens and welding conditions

H section steels used in the experiments are SM490A(488×300×11×18 (mm)). **Table 1** shows the mechanical properties and the chemical compositions of rolled H section steel SM490A.

The specimens for CTOD tests and Charpy impact tests, are cut from the flange of the welded H section steels. They are cut by avoiding the inside 10mm from the crossing positions of web and the inside 18mm from the edges of flanges.

Table 2 shows the flash welding conditions.

2.2 CTOD test and Charpy impact test

CTOD and Charpy impact tests are carried out for the base metal and the welded joints. Specimens are as follows:

Base metal: BM
Welded joints (as welded): WJ-A
Welded joints (after PWHT): WJ-B

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Table1 Mechanical properties and chemical compositions of SM490A.

Mechanical properties			Chemical compositions (%)					
Y.P. (MPa)	T.S. (MPa)	EL. (%)	C	Si	Mn	P	S	V
			×100			×1000		×100
366	529	29	13	28	123	14	9	2

Table 2 Flash welding conditions.

Electric power (w/mm^2)	Flash time (s)	Heat input (J/mm^2)	Upset distance (mm)
6.5	277	1800	15

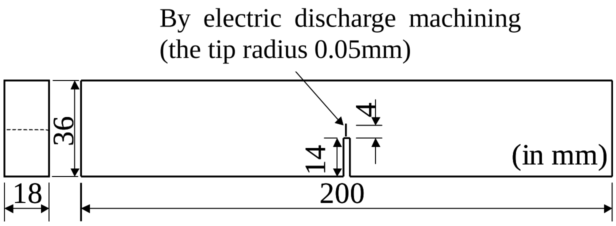


Figure 1 CTOD test specimen.

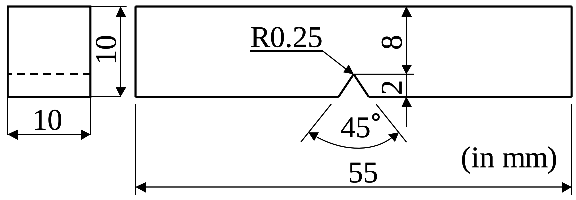
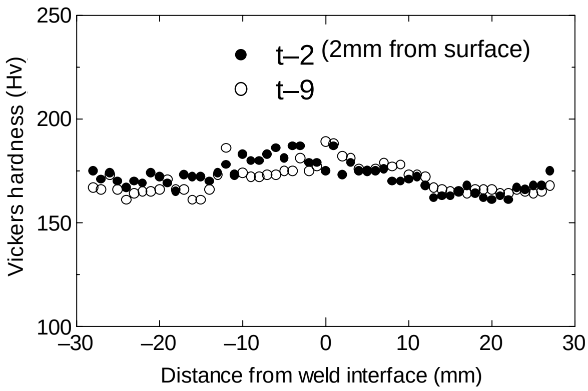
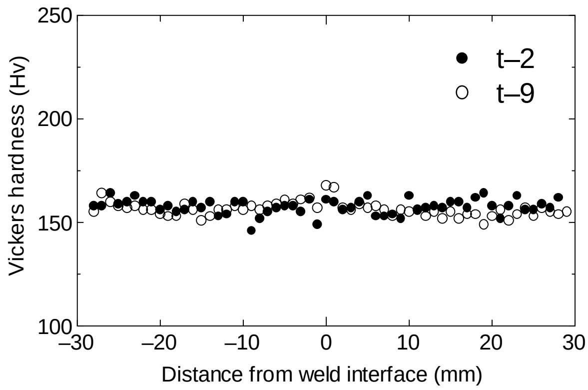


Figure 2 Charpy impact test specimen.



(a) As welded (WJ-A).



(b) After PWHT (WJ-B).

Figure 3 Vickers hardness (Load : 98N).

As a post weld heat treatment (PWHT), air cooling after heating up to 920℃ (normalizing) is used. **Figure 1** shows the shape of specimens used for CTOD tests. The notch length of the CTOD test specimens is 14mm and the crack length is 4mm. The crack inserted in the CTOD tests is generally a fatigue crack. However, as the relative comparison of the test results of three series in the experiments are investigated, a crack is inserted by electric discharge machining (the tip radius is 0.05mm) which can insert a crack in the aimed position.

Figure 2 shows the shapes of JIS V notch specimen used for Charpy impact tests.

The notch is made at the interface of specimens for CTOD tests and Charpy impact tests. The test temperatures are -40℃, -20℃, 0℃ and 20℃.

Vickers hardness tests are carried out for specimens so as to investigate whether non-uniformity of strength exists near the interface or not.

3. Experimental Results and Consideration

It is reported[4)] that toughness could not be evaluated if remarkable non-uniformity of strength at the tip of a notch exists in CTOD tests and Charpy impact tests. Therefore, Vicker's hardness tests are carried out so as to confirm the existence of non-uniformity of strength.

3.1 Hardness

Figure 3 shows the results of Vicker's hardness tests. Load is 98N and the interval of measurement is 1mm.

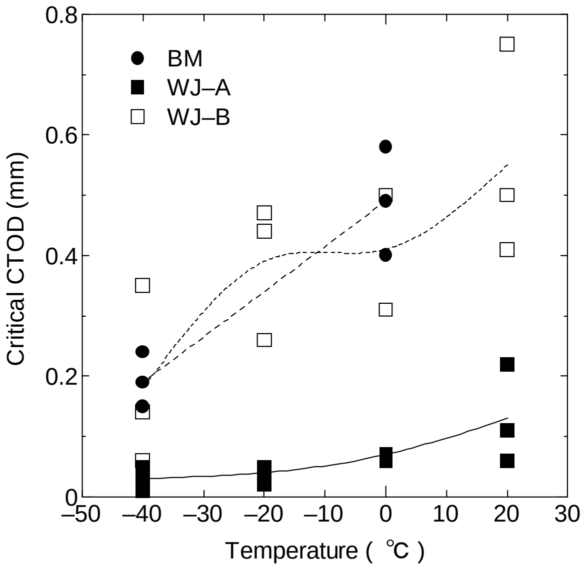


Figure 4 Experimental results from CTOD test.

In the case of WJ-A (as welded), there is a region which is hardened compared with the base metal around about 15mm from the interface. On the other hand, in the case of WJ-B (PWHT), there is no difference of hardness between welds and the base metal including near the interface.

Moreover, in both cases of WJ-A and WJ-B, there are softened positions due to decarbonization[5] at the interface. However, as the difference between the softened position and the maximum hardened position is only about 15Hv, no remarkable non-uniformity of strength exists near the interface.

Therefore, it can be considered that non-uniformity of strength hardly exists in welds of rolled H section steel jointed by the flash welding system.

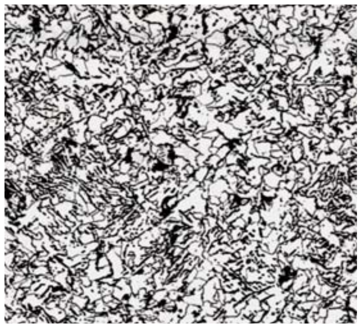
3.2 CTOD tests and Charpy impact tests

Figure 4 shows the critical CTOD values for each test temperature in the CTOD tests. In the case of WJ-A (as welded), the critical CTOD value of the interface(symbol ■) is lower than that of the base metal (BM: symbol ●).

So, PWHT is performed on the joints so as to improve the critical CTOD value. Then, the critical CTOD value of the interface (WJ-B: symbol □) is largely improved because coarse grain becomes reduced and recovers to be equal to that of the base metal (BM: symbol ●). **Figure 5** shows the microstructure of the interface in WJ-A (as welded) and WJ-B (after PWHT). From the figures, it is found that crystal grain becomes finer due to PWHT (Fig. 5(b)) compared with the as welded condition (Fig. 5(a)).

Figure 6 shows the absorbed energy values for each test temperature in the Charpy impact tests. In the case of WJ-A (as welded), the absorbed energy value of the interface(symbol ■) is lower than that of the base metal

(a) As welded.



(b) After PWHT.

Figure 5 Micro structure of weld interface (Power: 100).

(BM: symbol ●), similar to the critical the CTOD value (Fig. 4) in the CTOD tests . The absorbed energy value of the interface (WJ-B: symbol □) is largely improved due to PWHT. At 0℃, the absorbed energy value of WJ-A is about 30J and that of WJ-B is over 100J.

It is elucidated that although toughness of the joints of rolled H section steel (SM490A) is lower than that of the base metal, because crystal grain is coarse, toughness is recovered to become equal to that of the base metal after refining by PWHT.

3.3 Correlation of critical CTOD and absorbed energy

The committee of Japan Welding Engineering Society proposed the correlation formula[6] for the critical CTOD value, δ_c, and the Charpy absorbed energy value, vE, objecting to HAZ of thick plates. That is,

$$\delta_c(T)=[\alpha \cdot \{vE(T+\Delta T)/9.8\}^{\beta}]/\{\sigma_Y(T)/9.8\} \qquad (2)$$

where,

$\alpha=1.0$, $\beta=1.1$ ($\sigma_Y(T=20℃)>353(MPa)$)

$\Delta T=134-30\sqrt{t}$ ($t \leqq 30(mm)$)

T: temperature (℃) t: thickness (mm)

$\sigma_Y(T)$: yielding point at T℃ (MPa)

Figure 7 shows the relation between the critical CTOD value estimated from the above-mentioned Charpy impact tests by using Eq. (2) and the measured critical

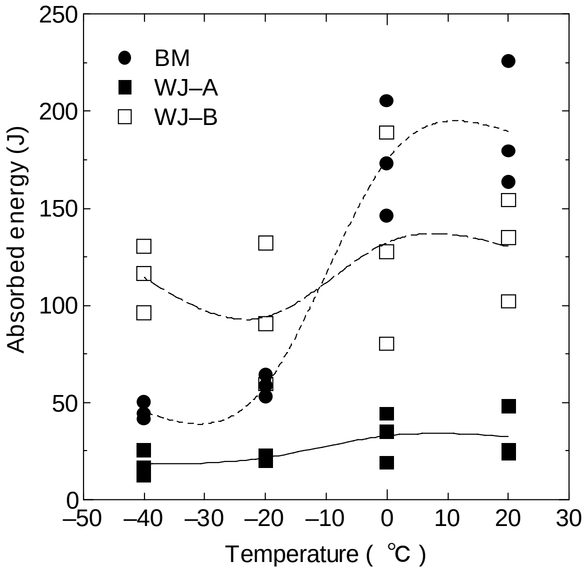


Figure 6 Experimental results from Charpy test.

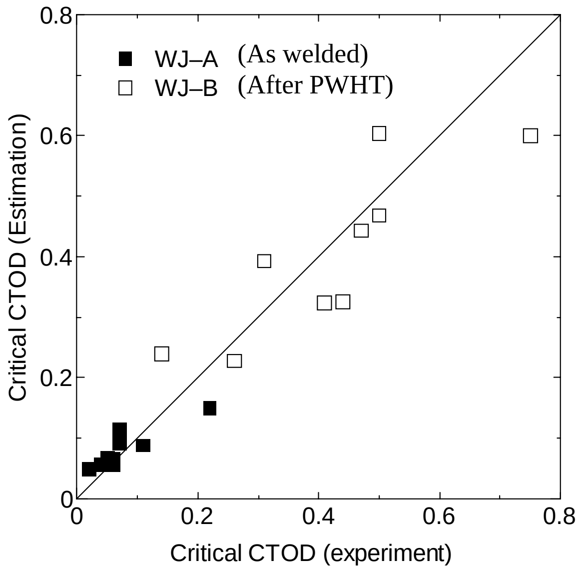


Figure 7 Relation between critical CTOD and CTOD obtained by using Charpy absorbed energy.

CTOD value. The critical CTOD value of the interface of the flash welded joints and the critical CTOD value obtained from Eq. (2) have a good correlation whether PWHT is done or not. It is confirmed that the critical CTOD value can be accurately estimated even when using the equation proposed for the HAZ of arc welding in which the critical CTOD value is estimated from the Charpy absorbed energy value.
Japanese)

4. Conclusions

Hardness and toughness for the flash welded joints of rolled H section steel (SM490A) were investigated.

The obtained results are as follows.

(1) Non-uniformity of hardness hardly existed whether PWHT was done or not in the Vicker’s hardness test.
(2) The critical CTOD value of the interface was lower than that of the base metal. Although the main cause is coarse crystal grain following the heat input of welding, the critical CTOD value recovered to be equal to that of the base metal due to refining by PWHT.
(3) The absorbed energy value of the joints as welded was about 30J at 0℃ and that of the joints after PWHT was over100J.
(4) The critical CTOD value could be accurately estimated by using the equation proposed for the HAZ of arc welding in which the critical CTOD value was estimated from the Charpy absorbed energy value.

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