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High-speed One-side Submerged Arc Welding Process "NH-HISAW"

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Abstract

A high speed one-side submerged arc welding process of welding speed up to 1.5m/min (16mm) has been developed for shipping of double-hull VLCC. In the new process, welding wires and fluxes as same as for a ordinary process are used. Electrode numbers are increased from three to four. Leading two electrodes fuse a root of a groove and form a underside (uranami) bead. Trailing two electrodes shape a good surface appearance bead and penetration. In case of 16mm thickness plate, total 3,000A welding current of leading two electrodes and total 1,500A of trailing electrodes are necessary to obtain good one-side weld. The new system has been practically applied to block assembly lines.

1. Introduction

One-side submerged arc welding process with flux copper backing (FCuB) is employed to weld large steel panels in shipbuilding has contributed much to the streamlining of the panel assembly process. It is a highly efficient welding method which has been applied at many shipyards for more than 20 years. In the meantime, the levels of automation and efficiency of longitudinal fillet welding have dramatically improved thanks to the introduction of the line welders and simplified welding carriages. In addition, with the aim of preventing marine contamination of oil, the United States and the International Maritime Organization's Marine Environment Protection Committee (IMO MEPC) are moving to legislate for double-hulled, double-bottomed tankers. Thus, improving the efficiency of the panel welding process further has become necessary.

Under those conditions, Universal Shipbuilding Corporation (Ariake Shipyard), Nippon Steel Corporation and Nippon Steel Welding Products and Engineering Co., Ltd. carried out joint research to develop a high-speed one-side submerged arc welding process (NH-HISAW) using four electrodes in order to at least double the speed of conventional FCuB one-side submerged arc welding.

This paper describes the newly developed welding process.

2. Outline of the Welding Process

The NH-HISAW process employs four electrodes, the first and second to form the uranami bead and the third and fourth to form the surface bead. With this process, it is possible to weld, for example, a 16 mm thick plate at a rate of 1.5 m/min.

2.1 Backing method

As shown in **Fig. 1**, the FCuB one-side submerged arc welding process is one in which the backing flux is sprinkled over backing

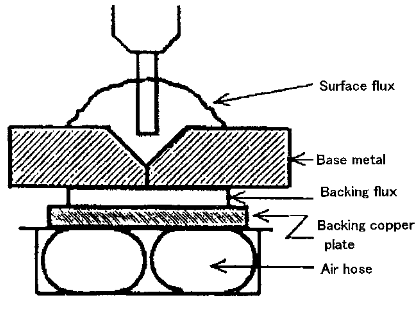

Fig. 1 FCuB test diagram

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copper plates, the copper plates are pushed up to the back of a large panel by air supplied from an air hose, and multi-electrode submerged arc welding is performed from above to form a surface bead and a uranami bead at the same time. The NH-HISAW process employs the same backing method as the conventional FCuB method (using two or three electrodes).

2.2 Formation of uranami bead

The basic concept of the NH-HISAW process is shown in **Fig. 2**. The uranami bead is formed by the two leading (i.e. first and second) electrodes as in the conventional process. During high-speed welding, however, the secondary fusion by the molten metal does not penetrate sufficiently and the keyhole is formed by the arc energy of the leading electrodes alone. Therefore, the leading electrodes require a larger welding current than in the conventional process. For example, when the plate thickness is 16 mm, the groove angle is 50° and the root face is 3 mm, the total welding current required of the first and second electrodes to obtain a satisfactory back reinforcement height at a welding speed of 1.5 m/min is about 3,000 A. The appearance of an uranami bead obtained by the NH-HISAW process is shown in **Photo 1**.

2.3 Formation of surface bead

The surface bead is formed by the two trailing (third and fourth) electrodes. The important points in forming a surface bead are as follows.

(1) Prevent the occurrence of an undercut.
(2) Secure a proper amount of reinforcement (deposited metal).
(3) Ensure the penetration of the trailing electrodes is sufficiently deep and direct the growth of dendrite of the leading electrodes upward to prevent the weld metal from cracking.

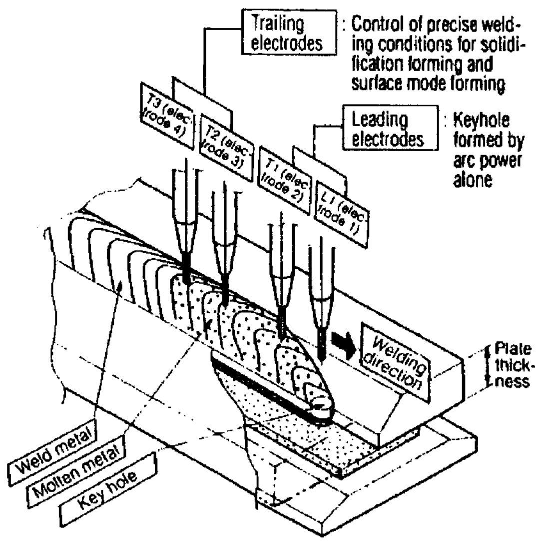


Fig. 2 High speed FCuB method welding technique model

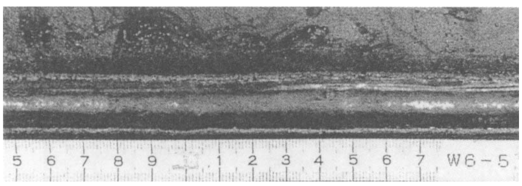


Photo 1 Photograph of uranami bead appearance

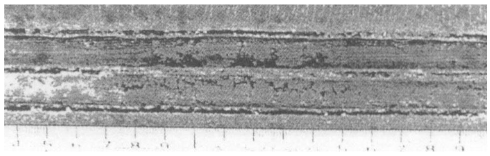


Photo 2 Photograph of surface bead appearance

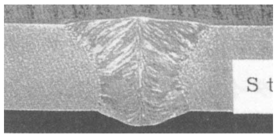


Photo 3 Photograph of macro section

In order to meet the above requirements, it is necessary to select the optimum welding conditions (particularly with regard to the welding current) and appropriate spacing between the second and third electrodes. The flux used in the FCuB one-side submerged arc welding process contains iron powder to enhance the welding efficiency. Therefore, the amount of metal deposited is determined by the amount of metal supplied from the welding wire and flux. This must be taken into consideration when deciding the welding current.

The penetration of the trailing electrodes varies according to the temperature and conditions of the leading electrode weld metal, as well as the welding current. If the space between the second and third electrodes is excessively large or small, insufficient penetration and a defective surface bead can result. Therefore, maintaining an appropriate space between those electrodes is extremely important. A surface bead appearance obtained by four-electrodes welding is shown in **Photo 2**, and the macrostructure of the bead is shown in **Photo 3**.

3. Welding Conditions

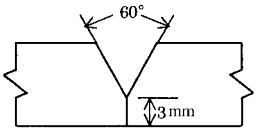
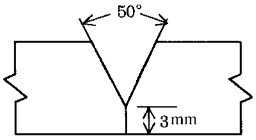
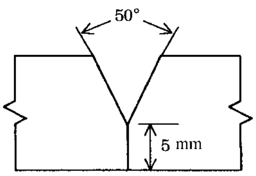
Table 1 shows examples of standard welding conditions, and **Fig. 3** compares welding speed between the NH-HISAW process and the conventional one. In the plate thickness range 9 to 16 mm, the NH-HISAW process is more than two times faster than the conventional one. Even with plate thicknesses exceeding 16 mm, the NH-HISAW process is markedly faster.

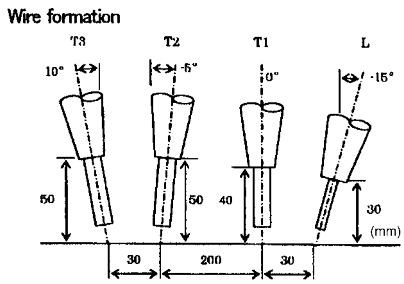
It should be noted that the welding speeds shown in Fig. 3 are those obtained when a power supply capacity of 2,000 A was used for each of the first and second electrodes. To further increase the welding speed with plate thicknesses 18 mm or more, it is necessary to use a larger power supply capacity. In applying the NH-HISAW process, the space between electrodes, electrode angle, wire formation, etc. were kept unchanged regardless of the plate thickness in order to efficiently carry out the welding work in the plant.

4. Characteristics of Welding Materials and Weld Metal

Table 2 shows the welding materials used in the NH-HISAW process. In the early stages of development of the process, we were using NITTETSU Y-A as the wire, NITTETSU NSH-1R (resin-coated type) as the backing flux, and NITTETSU NSH-50 as the surface flux. The wire and backing flux were the same as those used in the conventional processes. The surface flux was modified because it had tended to cause the central part of the surface bead to become slightly convex when a large welding current was used with a thick

Table 1 Typical welding conditions

Groove preparation	Plate thickness (mm)	Welding condition				
		Electrodes	Wire diameter (mm)	Current (A)	Voltage (V)	Welding speed (cm/min)
	12	L	4.8	1400	35	150
		T1	6.4	1100	40	
		T2	6.4	650	45	
		T3	6.4	650	42	
	16	L	4.8	1700	35	150
		T1	6.4	1300	40	
		T2	6.4	750	40	
		T3	6.4	700	45	
	20	L	4.8	1700	35	100
		T1	6.4	1300	40	
		T2	6.4	750	40	
		T3	6.4	750	45	
	25	L	4.8	1700	35	90
		T1	6.4	1400	40	
		T2	6.4	1050	40	
		T3	6.4	950	45	



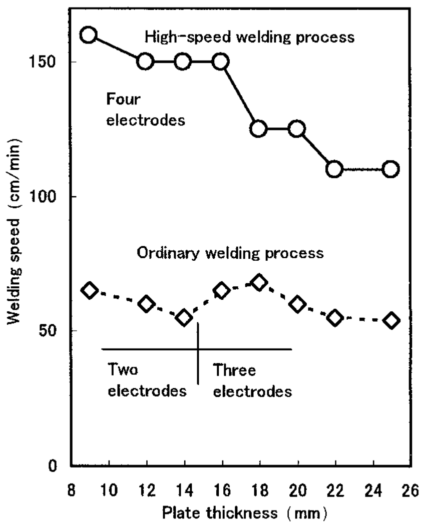


Fig. 3 Comparison of welding speed between high-speed FCuB process and ordinary process

plate. Finally, in recent years, we developed NITTETSU Y-DL wire, NITTETSU NSH-1RM backing flux (resin- coated type) and NITTETSU NSH-50M , NITTETSU NSH-55EM surface fluxes.

Table 3 shows examples of the results of a tensile test carried out in accordance with the Nippon Kaiji Kyokai Standard. The tensile performance of the weld metal obtained by the NH-HISAW process is nearly equal to that obtained by the conventional process. **Fig. 4** compares weld metal toughness between the NH-HISAW process and conventional processes. The toughness of any part of the weld metal obtained by the NH-HISAW process is higher than that obtained by the conventional process.

Photo 4 compares weld metal microstructures between the NH-HISAW process and conventional processes. In both processes, the weld metals present a mixed structure of primary ferrite (F) and bainite (Bu). In the high-speed welding process, however, the amount of primary ferrite is smaller and the bainite structure is finer because of a lower heat input and a higher cooling speed. This is thought to explain why the NH-HISAW process offers higher weld metal toughness than the conventional process.

5. Practical Characteristics—Effect on Weld Deformation

For any given plate thickness, the NH-HISAW process requires lower heat input than the conventional process, especially when the plate thickness is small. Thus, it is expected that the NH-HISAW process will reduce the stress caused by the welding heat. During discussions in the laboratory and high-speed welding after testing in the plant, it was confirmed that the amount of plate deformation (angular deformation) was noticeably smaller. This expects that the rotational deformation that is the main cause of end cracking was also reduced.

Table 2 Welding materials

Type of steel	Wire	Surface flux	Backing flux
A, B, D AH32, DH32 AH36, DH36	Y-DL	NSH-50M	NSH-1RM
E EH32, EH36 DH40, EH40	Y-DM3 + Y-DL	NSH-55EM	
Low temperature service steel	Y-3NI	NSH-55L	

Table 3 Tensile strength test results

Type of steel	Plate thickness	Weld metal tensile strength test (U1A)			Joint tensile strength test (U2A)	
	(mm)	YS (N/mm^2)	TS (N/mm^2)	E l (%)	TS (N/mm^2)	Fructure location
DH36	25	437	561	28	504 506	Base metal Base metal

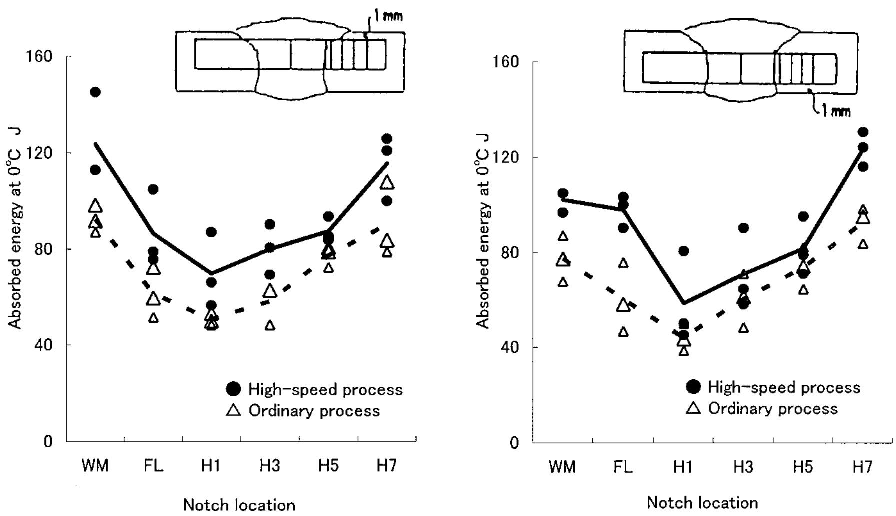


Fig. 4 Notch toughness of welds

Fig. 5 shows the relationship between plate thickness and the amount of rotational deformation of the joint end. In the conventional process, the amount of deformation is approximately 1 mm regardless of the plate thickness. In the NH-HISAW process, by contrast, the amount of deformation when the plate thickness is 16 mm or less is noticeably smaller than in the conventional process, although it is nearly the same as in the conventional process when the plate thickness is 20 mm or more. In the NH-HISAW process, the welding speed with plates 16 mm or less is 1.5 m/min. This high speed is considered effective in reducing the amount of plate deformation.

6. Conclusion

This describes the high-speed one-side submerged arc welding process (NH-HISAW) that dramatically increases the welding speed in the panel assembly process in shipbuilding–at least twice as fast as the conventional process. The authors are confident that the NH-HISAW process will contribute to improved productivity and product quality in the shipbuilding industry.

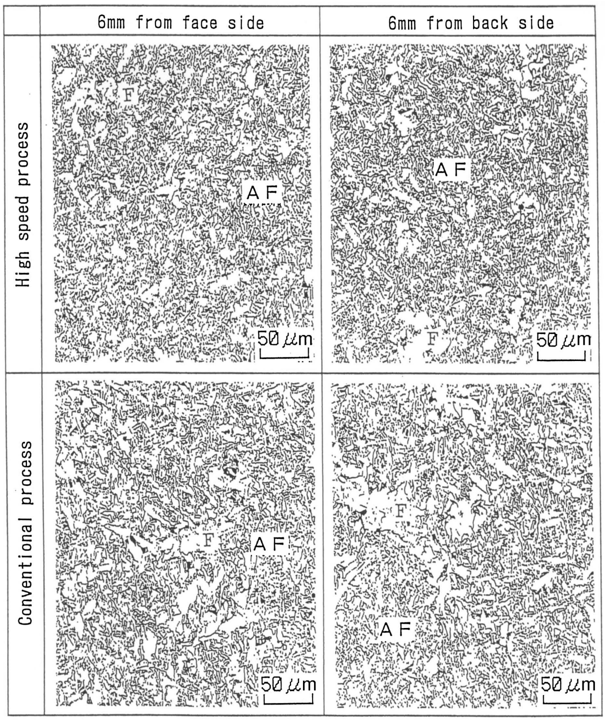


Photo 4 Micro-structures of weld metal

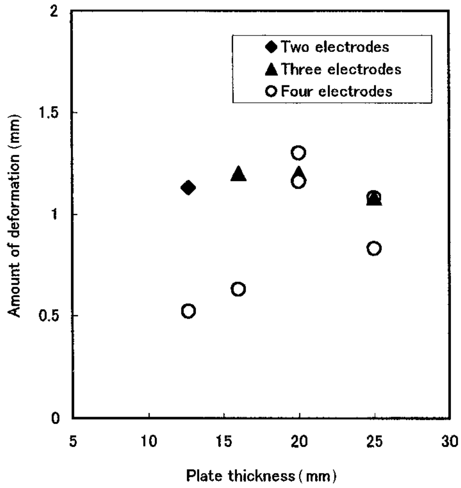


Fig. 5 Relationship between plate thickness and the amount of rotation deformation