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Int. J. Nav. Archit. Ocean Eng. (2015) 7:315~323
http://dx.doi.org/10.1515/ijnaoe-2015-0022
pISSN: 2092-6782, eISSN: 2092-6790

Development of method to remove weld scallop and ceramic backing material of wedge type and its application

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ABSTRACT: *The weld scallop has been used for joining T-bars. There are a lot of weld scallops in shipbuilding. It is difficult to perform scallop welding due to the inconvenient welding position. This results in many problems such as porosity, slag inclusion, etc. In this study, a new method is devised to remove weld scallops by incorporating a Ceramic Backing Material (CBM). The weld scallop is removed by an elongation of the v groove. In order to insert a CBM into the groove without a weld scallop, a wedge-shaped CBM is developed. The top side of the developed CBM is similar to the shape of a general back bead. The bottom surface has a saw-toothed shape for cutting at a suitable length. This can be attached to the root side of a face plate using adhesive tape, just like a general CBM. Welding experiments in normal and abnormal conditions are carried out and the possibility of burn-through is examined. This CBM's applicability to shipbuilding is verified.*

KEY WORDS: Weld scallop; Ceramic backing material (CBM), Wedge type; Burn-through.

INTRODUCTION

Weld scallops, *i.e.* small cut-outs in ship structural members happen at many spots. Fig. 1 shows weld scallops of T-bars in the block joint stage. All T-bars have weld scallops and it can be easily guessed that there are a lot of weld scallops in shipbuilding. In 2012, the number of weld scallops in our company was approximately ten thousands.

Fig. 1 Weld scallop at block joint stage.

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Fig. 2(a) shows what a weld scallop is in detail. The weld scallop is a temporary part of the welding process. Therefore, a fan-shaped scallop has to be filled using build-up welding. In such a case, there are two welding sequences. One is the CBM fit-up of the web and face, the vertical-up welding of the web, the flat position welding of the face, the CBM fit-up of the weld scallop, and its build-up welding. The second process is the CBM fit-up of the web and face, the flat position welding of the face, the vertical-up welding of the web, the CBM fit-up of the weld scallop, and the build-up welding of the weld scallop. In both sequences, the welding of the weld scallop must finally be done, which makes a discontinuity in the weld of the web plate.

Basically, the height of a T-bar from the deck is low. This makes the welding position similar to the overhead position, which is difficult. This results in many weld defects, such as slag inclusion, porosity, lack of fusion, lack of penetration, etc. It acts as a notch and frequently causes fatigue and fracture.

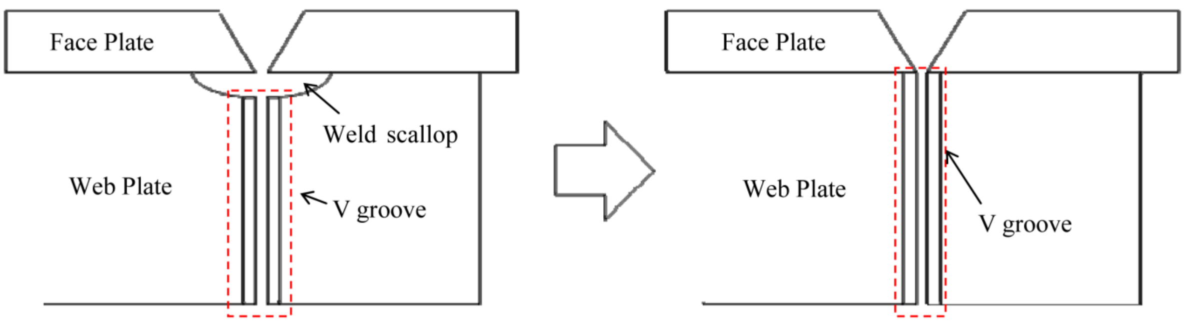
There have been some studies to analyze features of weld scallops. Some studies were conducted from the viewpoint of construction fractures. Hashida et al. (1999) studied a beam to beam connection with non-scallop in construction steelwork. Kim et al. (2008) investigated a real-scale column-to-beam connection in high-strength and high-performance steel. The steel's structural performance was analyzed by conducting seismic-resistance tests on the cross-shaped column-to-beam connections with non-scallop, ordinary-scallop, and reinforced scallop details. Wei (2007) carried out a failure experiment on four full-size specimens using steel frame beam-column welding connections under cyclic loading. He took account of the influencing factor of scallop structures. The test results show that scallop structures are the primary factors influencing the plastic deformation capacity and failure mode of beam-column connections.

Other studies were carried out from the viewpoint of fatigue and fracturing. Takeshi and Hideaki (2011) examined the influence of weld penetration depth and scallop on fatigue durability and stress properties. Mori et al. (2009) found that non-scallops of circular hole type were effective at preventing cracking of hot-dip galvanized steel beam-column joints. Satoru et al. (2008) investigated brittle fracturing from two or more fracture initiation points, e.g. scallops, end-tabs, weld metal, and HAZ in beam-to-column welded connections of a steel structure.

Minami et al. (2003) tried to clarify the fatigue strength of welded joints using galvanizing. Web-gusset joints and scallop details were taken up and large-scale girder specimens were made; fatigue tests were carried out on these specimens. Friche and Paetzold (1995) investigated scallops subjected to high cyclic stresses. Their results summarize several fatigue tests for various types of scallop under axial loading.

Previous studies assumed that weld scallops existed and were used. Some studies examined methods of changing scallop shape in order to reduce the notch effect. Even when the shape of a weld scallop varies, though it acts as a notch, originally. Therefore, a basic study to remove weld scallops must be carried out.

In this study, a new method to remove weld scallops is developed. For this purpose, a new CBM of wedge type is developed. The history of the development of this new CBM is explained in detail. In order to verify the material's efficacy, welding experiments in normal conditions and abnormal conditions are conducted. The material's potential application to the shipbuilding is briefly described.



(a) T-bar with weld scallop. (b) T-bar removing weld scallop.

Fig. 2 Design concept to remove the weld scallop.

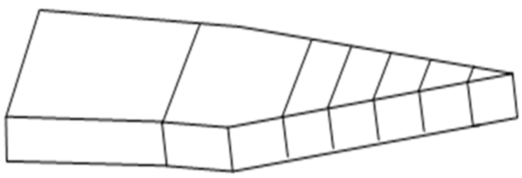
DESIGN CONCEPT TO REMOVE WELD SCALLOPS

In order to remove weld scallops, a v groove in a web plate is elongated to the area below the face plate, as shown in Fig. 2(b). The weld scallop is replaced by the base metal of the web plate, which results in weld reduction. The weld zone declines and the maximum amplitude of the residual stress lessens compared to that induced by the weld scallop. Discontinuity that acts as a notch caused by the weld scallop is removed.

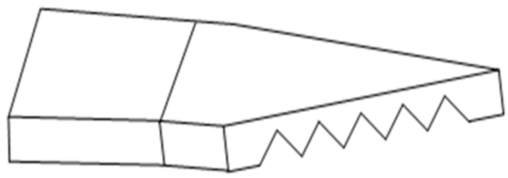
PROCEDURE TO DEVELOP NEW WEDGE TYPE CBM

In order to insert a CBM into the v groove of the web plate below the face plate, the CBM shape must be of wedge type. The root gap of the v groove in the web plate varies according to deformation, the worker's skill, etc. Therefore, when a CBM is inserted, the projecting tip of the CBM on the root side of the web plate varies. For proper fit-up, the protruding tip has to be removed. The slit shape and its interval in CBM influence the breakability and must be selected properly.

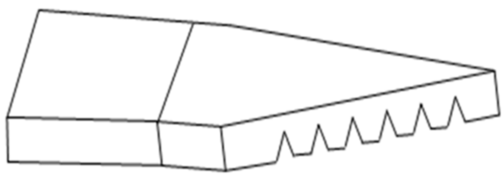
Several attempts have been made to develop a suitable CBM. Fig. 3 shows the three attempted shape types. One is a sliced type. The second is a saw tooth type. The third is a saw tooth + flat surface type. The sliced type, as shown in Fig. 4(a), is difficult to fit up because of the low strength of the sliced structure. The structure's wedge-shaped part does not keep straight at the fit-up. Several tests show that the saw tooth type has bad sinterability due to the triangular shape of each tooth. It is smashed to pieces easily after sintering. Fig. 4(b) shows a broken sample. Finally, the saw tooth + flat surface type is tested. The dense slit interval is good as a proper reply for various root gaps. However, the dense tooth type has bad formability. It is necessary to engage in a tradeoff between formability and operability. Through several tests, the slit interval of 4 *mm* is found to be appropriate. Fig. 4(c) shows the developed type of CBM with 4 *mm* interval. Its length is 75 *mm*, which cannot make up for the weld of the face plate completely. A length of at least 150 *mm* of the CBM is needed to cover the weld of the face plate fully. Fig. 5 displays the final CBM, which is of wedge shape with a 150 *mm* length. Its top side is similar to the general form of the back bead. This CBM can stick to the root side of the face plate with an adhesive tape, like a general CBM.



(a) Sliced type.

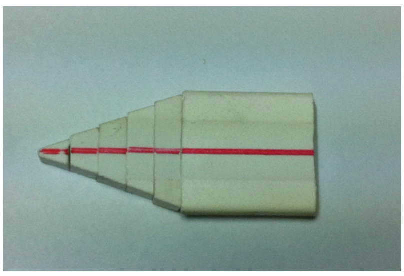


(b) Saw tooth type.



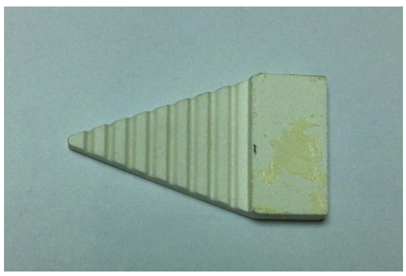
(c) Saw tooth + flat surface type.

Fig. 3 Design concept of CBM type.



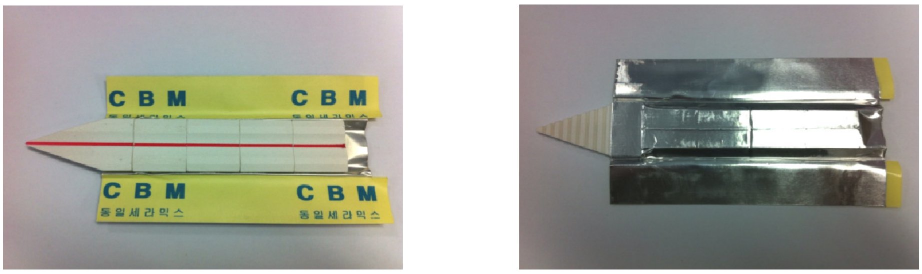
(a) Sliced type.

(b) Saw tooth type.



(c) Saw tooth + flat surface type.

Fig. 4 Tested CBM sample of wedge type.



(a) Top side. (b) Bottom side.

Fig. 5 Final wedge type CBM.

Fig. 6 shows how the wedge type CBM is fitted up schematically. The root side of the v groove in the face plate from the direction of the face side of the web plate is stuck to the new wedge type CBM. And, a general CBM is attached to the root side of the v groove in the face plate from the direction of the root side of the web plate. After the welding of the face plate is carried out, the CBM adhering to the face plate is removed. Then, a general CBM is stuck to the root side of the web plate and the web plate welding is done. The welding sequence is displayed with numbers in Fig. 6. In order to aid in the understanding of this process, various views are provided in Fig. 7

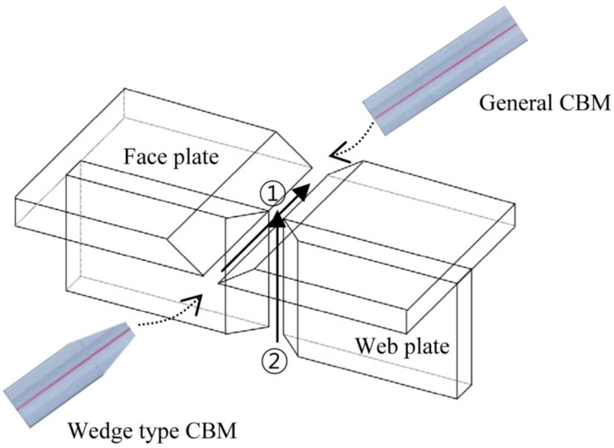
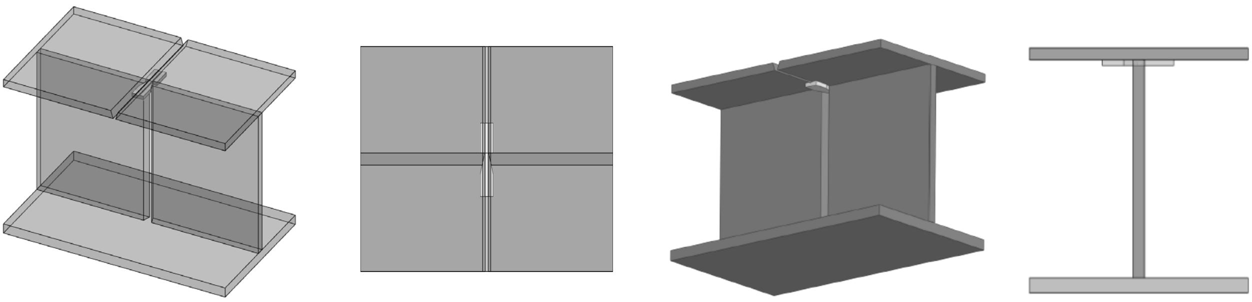


Fig. 6 Schematic diagram of CBM fit-up.



(a) 45° view. (b) Top view. (c) Bottom view. (d) Side view.

Fig. 7 CBM fit-up shape from various angles.

WELDING EXPERIMENTS

Specimen preparation in normal conditions

In order to verify the new method, welding experiments based on usual yard conditions are carried out. In usual conditions, the root gap of the web plate is larger than that of the face plate. This condition is reflected in the diagram shown in Fig. 8. Six welding tests are conducted. The detailed specimen data are provided in Table 1. Welding tests are carried out based on Welding Procedure Specification (WPS).

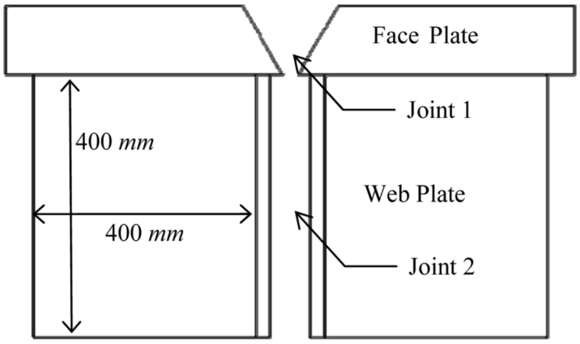


Fig. 8 Specimen size in normal conditions.

Table 1 Specimen data in normal conditions.

Case number	Face (*mm*)	Web (*mm*)	Joint1 gap (*mm*)	Joint2 gap (*mm*)	Steel grade	Groove angle (°)
1	150*19	11	5	7	AH36	35~40
2	200*35	11	5	7	AH36	35~40
3	200*35	11	10	12	AH36	35~40
4	125*14	11	5	7	AH36	35~40
5	175*20	11	5	7	AH36	35~40
6	200*35	11	15	17	AH36	35~40

Results in normal conditions

It is necessary to analyze the effect of removing a weld scallop. For this, the root side of the face plate is surveyed after the welding of the face plate is conducted. Fig. 9 shows the root side in case 1, in which there are no defects such as burn-through or slag inclusion. The other cases show the same results. After the web plate welding is carried out, the specimens are surveyed visually. Fig. 10 shows the finished welding specimens for case 1 and case 6. It shows that there are no defects, which is the same for the other cases.

For a detailed analysis, ultrasonic examination is performed. Around the area where the weld of the face plate crosses that of the web plate, ultrasonic examination is carefully carried out. It is revealed that there are no defects as shown in Fig. 11. This verifies the potential of new method to remove weld scallops and the applicability of the new wedge type CBM.

(a) From the direction of face side of web. (b) From the direction of root side of web.

Fig. 9 Root side after welding of face plate.

(a) Case 1.

(b) Case 2.

Fig. 10 Welding specimen.

초음파탐상검사보고서
ULTRASONIC TESTING REPORT(A)

보고서번호 Report No.			
일자 Date.	2011.08.11		
Page	1	of	2

공사명 Project name	N/A	주문주 Owner			
제품명 Item Name	WELDING TEST BLOCK	관련근거 Required by	N/A		
블록번호 Block No.	N/A	도면번호 Dwg. No.	N/A		
재질 Material	AH36	두께 Thickness	14~35	표면조건 Surface Cond.	WELDED
용접방법 W/D Process	N/A	이음부/개선형태 Joint/Groove	TEE-S.B BUTT-S.V	탐상방법 Scanning	TSB2S-4XYZ BSV1B-4XYZ
절차서번호 Procedure No.		합격기준 Acceptance Standard	ASTM A-609 LEVEL II		
시험장비 Equipment	제작처 Maker: Krautkramer; 모델 Model: USM35 DAC	관리번호 Control No.	NDT-U02	접촉매질 Couplant	C.M.C

탐촉자 Transducer	형태 TYPE	각도 Angle	주파수 Frequency	크기 Size	기준감도 Ref. dB	교정시편 Cal. Block
	B4S	0°	4 ㎒	ϕ10	54 Db	STB-A1
	MWB45	45°	4 ㎒	8*9	48 dB	IIW R/B
	MWB60	60°	4 ㎒	8*9	51 Db	IIW R/B
	MWB70	70°	4 ㎒	8*9	56 dB	IIW R/B

확인번호 Identification No.	Result Acc.	Result Rej.	각도 Angle	불연속 Discontinuity Location (mm)	Length (mm)	Depth (mm)	Echo Height (%)	Test Length (mm)	REMARK
UT-01	V							100	
UT-02	V							100	
UT-03	V							100	
UT-04	V							100	
UT-05	V							100	
UT-06	V							100	
		~	B	L	A	N	K	~	

	Name/Sign	Level	Date		
Examined by	E. B. KIM	II	2011.08.11	Class	Review ☐ Witness ☐
Approved by	Y. H. SON	III	2011.08.11	Owner	Review ☐ Witness ☐

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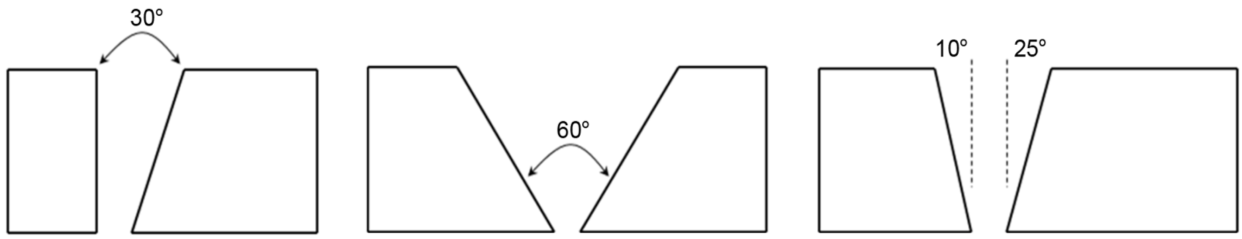
Fig. 11 UT report.

Specimen preparation for abnormal conditions

The working conditions in the yard are not as good as those in the testing shop. There are many possibilities of abnormal conditions such as misalignment, wide gap, etc. Therefore, it is necessary to carry out a study on the applicability of the new method in unusual conditions.

In order to determine the representative abnormal conditions, the yard production team, ship owners, and Classes are interviewed. They all have great interest in the possibility of burn-through, particularly after the first pass of the face weld in abnormal conditions.

Based on this, three unusual types are selected, as shown in Fig. 12. Type 1 shows a web groove that is beveled. The one side of the web groove has a vertical angle and the other has a 30° angle. Type 2 shows the case of a groove angle larger than the normal angle. A 60° groove angle, larger than normal angle of 30°, is selected. Type 3 is one in which each bevel angle is different. One side has an angle of 10° and the other has an angle of 25°.



(a) Type 1. (b) Type 2. (c) Type 3.

Fig. 12 Abnormal conditions of groove shape in web plate.

Burn-through may happen easily when the root gap of the face plate is larger than that of the web plate. This condition is reflected in the welding specimen shown in Fig. 13. The two cases of root gap are considered and the root gap of the face groove is made 5 *mm* wider than that of the web groove. Considering the three cases with grooves and the two cases with root gaps, a total of six welding tests are conducted. The detailed specimen data are provided in Table 2.

Table 2 Specimen Data in abnormal conditions.

Case	Face (*mm*)	Web (*mm*)	Joint1 gap (*mm*)	Joint2 gap (*mm*)	Steel grade	Groove shape in web plate
1	150*19	11	10	5	AH36	Type 1
2	150*19	11	10	5	AH36	Type 2
3	150*19	11	10	5	AH36	Type 3
4	150*19	11	15	10	AH36	Type 1
5	150*19	11	15	10	AH36	Type 2
6	150*19	11	15	10	AH36	Type 3

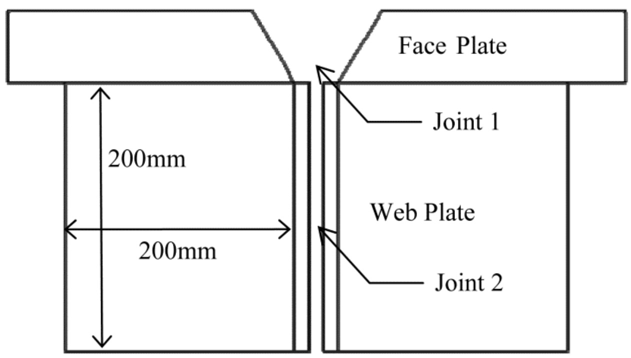


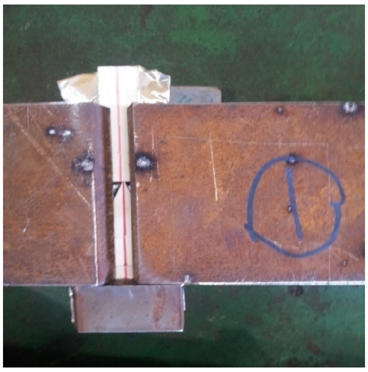
Fig. 13 Specimen size in abnormal conditions.

Results of abnormal conditions

Fig. 14 shows the fit-up shape in case 1 and case 4. Because the root gap of the face plate is larger than that of the web plate, a large gap is seen in the area where the wedge CBM contacts the general CBM. This shows the possibility that burn-through may happen after the first pass welding of the face plate.

After the first weld of the face plate for cases 1 and 4, the root side of the face plate is surveyed visually. This survey reveals that burn-through does not happen, as can be seen in Fig. 15. The other cases do not have burn-through, either.

In order to cause burn-through, high heat input is necessary. SAW usually has high heat input, but this process uses FCAW, which has low heat input. The specimen temperature is usually as low as the air temperature. Also, the T-bar has three directions in which to dissipate the weld heat. This heat dissipation results in rapid bead cooling and prevents burn-through from occurring. The results of visual inspection are provided in Table 3.



(a) Case 1.

(b) Case 4.

Fig. 14 CBM fit-up shape in abnormal conditions.

(a) Case 1.

(b) Case 4.

Fig. 15 Root side of face plate after the first pass welding of face plate.

Table 3 Results of visual inspection.

Case	Burn-through
1	No occurrence
2	No occurrence
3	No occurrence
4	No occurrence
5	No occurrence
6	No occurrence

Yard application

The new method of removing weld scallops and the new wedge type CBM have been applied to many ships since the abnormal test was finished. The first ship is an LNG, which requires delicate care. Ultrasonic tests are carried out for several spots. There are no welding defects at the investigated spots. This validates the applicability of the new method and CBM to yard production.

CONCLUSIONS

The build-up welding of weld scallops has the possibility of causing weld defects. These defects reduce fatigue strength and fracture toughness. In this study, a new method to remove weld scallops is investigated. The weld scallops are removed using an elongation of the v groove of the web plate to the face plate. In order to remove a weld scallop, a new wedge type CBM is developed. Through several tests, a wedge shaped CBM with proper length is designed. Welding experiments in normal conditions and abnormal conditions are carried out and the new method is proven to be applicable to yard production. Also, application results to yard are satisfactory.

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