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EVALUATION ON THE FATIGUE STRENGTH OF SINGLE-SIDED WELDED JOINTS WITH CERAMIC BACKING MATERIAL

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ABSTRACT

This report presents S-N testing results of the butt and T-joint weldment which are produced by single sided welding with cenramic backing material. The specimen is designed in accordance with JIS Z 3103 and the test is performed by the JSME S002. The nominal and hot spot stress based design S-N curves derived from fatigue tests are compared with the BS design curve. For butt and T-joint, it can be known that the double-sided butt welding process could be replaced by the single sided butt welding.

1. Introduction

An offshore structure is designed so as to serve its function with an adequate safety and economy. For these, offshore structure should be designed in view of structural integrity and the right fabrication process should be established with respect to design guidance. If the design is done appropriately, fabrication process can be a governing factor from the point of economy.

This study was performed in order to increase productivity without any loss in weldment quality and performance by changing the welding procedure. The applicability of developed welding process or procedure was verified through both F.E. analysis and fatigue test.

2. Single Sided Welding

This report presents S-N testing results of the butt and T-joint weldment, which are produced by single sided welding with ceramic backing material. The purpose of these tests is to verify the fatigue life of the single sided welds in comparison with that of the complete joints penetration welds with back gouging.

2.1 Welding condition and specimen preparation

Steel plates of NVE36 with thickness of 25 and 26mm were used for S-N tests. Welding process applied in single sided butt and T-joint welding was flux-cored arc welding process with E81T-K2(Diameter 1.2 mm) electrode according to AWS A5.29.

Welding conditions and joint configuration are shown in table 1 and Fig. 1, respectively.

The dimension and configuration of fatigue test specimen are shown in Fig. 2. Fatigue specimen was designed in accordance with JIS Z 3103. The weld bead of fatigue test specimen was not machined in order to consider the effect of stress concentration at weld toe produced by the bead profile.

2.2 S-N Test

The S-N testing was carried out by hydraulic test machine whose maximum loading capacity is 630 kN. The stress ratio between 0 and 0.1 was applied in S-N testing.

The S-N testing was carried out in the range of 10^4 cycles to 10^7 cycles with the staircase method. At each stress range level, two or three specimens are tested.

3. S-N Curve obtained from test

Results of fatigue tests were plotted on a log σ - log N diagram. A mean line was fitted by

regression analysis of tested data and slope of S-N curve was corrected to be 3 for comparison with the design S-N curve of BS. The S-N curve obtained from S-N test represents a mean curve with 50% failure probability. In order to compare between design S-N curves, the design S-N curve from testing was defined as S-N curve with 5% failure probability which was migrated in parallel downward from the mean curve from testing.

3.1 S-N curve for Butt joint

Fig. 3 shows the mean and design S-N curves based on the nominal stress. The obtained design S-N curve has a margin above 10 % in comparison with DNV or BS D curve. Fig. 4 shows the mean S-N curve calculated from hot spot stress. It can be found that the S-N curve from the hot spot stress is located higher than the S-N curve based on nominal stress range although the more data points used for drawing the mean curve are needed in case of the S-N curve based on the hot spot stress.

Therefore, if the S-N curve for fatigue test on single sided butt weld joint is drawn based on hot spot stress, it can be expected that the derived S-N curve by fatigue tests has more margin to the design D curve than that from nominal stress base curve. In this regard, the double-sided butt welding process could be replaced by the single sided butt welding.

3.2 S-N curve for T-joint

Based on the test results, the S-N curve of single sided welded T-joint was derived as shown in Fig. 5. It can be shown that almost all test data except for three, which derived from hot spot stress range lie between mean curve and design curve of BS D. The design S-N curve from fatigue test that was based on measured hot spot stress was lower than BS D curve. The data with lower SCF(1.12 ~ 1.15) (hot spot stress range / nominal stress range) showed comparatively lower fatigue life than the other data(1.17 ~ 1.3). It can be known that SCF has some

In accordance with BS7608, the single sided T-joint weld can be classified as class F since it is a type of full penetration cruciform joint. Therefore, if the design S-N curve is expressed by nominal stress the obtained design S-N curve for T-joint is superior to BS F curve as shown in Fig. 6..

For the comparison between measured and calculated stress concentration factor, FE analysis was performed. According to DNVs guidance, 0.5t by 0.5t mesh with 8 node solid elements was used in the FE analysis. Fig. 7 shows the FE model and analysis results. FE analyses for both aligned and misaligned model were carried out in order to calculate the effect of misalignment on the stress concentration factor at the hot spot.

Calculated SCFs were 1.25 and 1.20 in case of misaligned and aligned model, respectively. It means that the hot spot stress calculated by FE analysis is higher than the measured value. Furthermore, since the fatigue specimen already have misalignment 0.01 radian, the difference between measured and calculated SCFs can be become larger. If the test data are rearranged with respect to calculated SCF 1.25, the S-N curve can be drawn as shown in Fig. 8. All data points in Fig. 8 lay above the BS design curve and design S-N curve based on calculated hot spot stress was almost same with BS D curve.

4. Conclusion

From the S-N tests for single sided Butt and T-joint weld with ceramic backing material, several conclusions were obtained as follows.

1) The S-N curve obtained for the single sided butt welding process has above 10% margin in comparison with the design S-N curve D.
2) Based on the hot spot stress measurement during S-N test, it is verified that the stress concentration at weld toe is negligible
3) The design S-N curve from fatigue test that was based on measured hot spot stress was lower than BS D curve. However, if the design S-N curve is expressed by calculated hot spot stress, the obtained design S-N curve for T-joint with ceramic backing material almost coincide with BS D curve.
4) In accordance with BS7608, the single sided T-joint weld can be classified as class F since it is a type of full penetration cruciform joint. Therefore, if the design S-N curve is expressed by nominal stress the obtained design S-N curve for T-joint is superior to

BS F curve.

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Table 1 Welding conditions

Welding conditions						
Layers	Process	Posi-tion	Type & Pol.	Current (A)	Voltage (V)	Speed (cm/min)
Root	FCAW	1G	DCRP	192~220	23.9~26.1	18~24
Fill	FCAW		DCRP	258~291	28.2~30.1	29~40
Cap	FCAW		DCRP	240~269	26.0~28.0	32~44

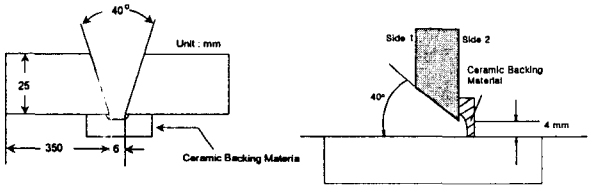

Fig. 1 Joint configuration

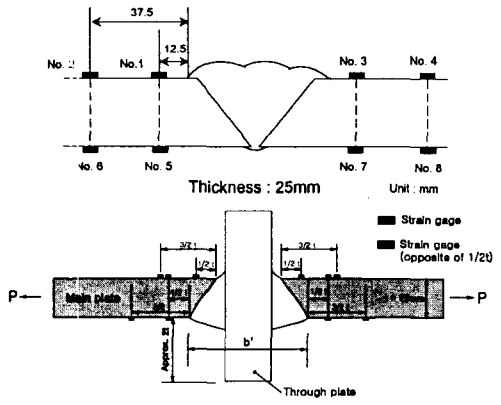

Fig. 2 Specimen configuration

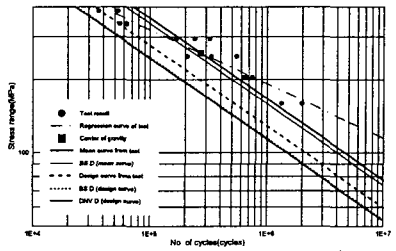

Fig. 3 S-N curve for Butt joint (Nominal)

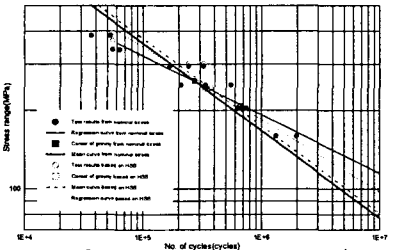

Fig. 4 S-N curve for Butt joint (HSS)

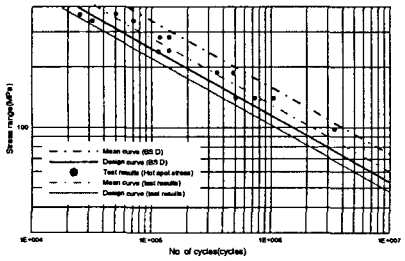

Fig. 5 S-N curve obtained from T-joint (Measured)

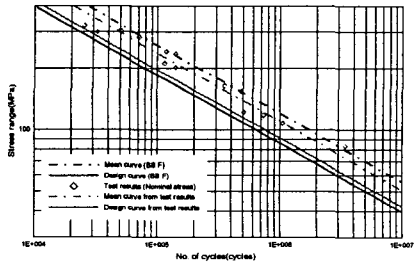

Fig. 6 S-N curve obtained from T-joint (Nominal)

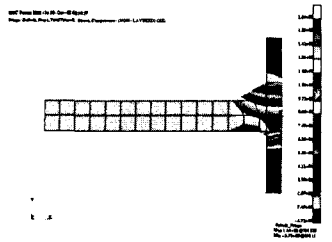

Fig. 7 F. E. Analysis for stress concentration factor

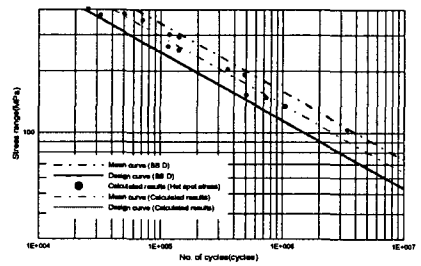

Fig. 8 S-N curve obtained from T-joint(Calculated)