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충격하중에 의한 Jib Crane Post 의 피로 수명 평가

A Study on Fatigue Assessment of the Crane Post due to Vibration during the Emergency Stop

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Key Words : Fatigue Assessment(피로 평가), Crane(크레인), Brake test(제동 시험)

ABSTRACT

The tall and slender main crane is generally installed on the upper deck to load and unload the equipment or something heavy in the drilling rig or the ship. So the natural frequency of the crane equipment is very low, therefore, there is some possibility of excessive vibration at the emergency state due to sudden stop during the crane operation. This study describes a fatigue assessment due to heavy vibration during brake test of sudden stop because it is necessary the safety of crane is estimated against the heavy vibration. In order to find out the applied force, the vibration measurement and analysis have been performed.

선박에 설치된 크레인은 일반적으로 기둥의 높이가 높고 상대적으로 가는 진동에 취약한 장비이다. 선박 크래인 운전중 비상사태가 발생하여 브레이크를 사용하면 갑작스러운 충격하중에 의해 크레인 포스트에 과도한 진동이 발생하기도 한다. 이러한 진동에 의한 크레인의 안전성을 평가하는 것이 본 연구의 목적이다. 본 연구에서는 크레인의 비상정지시 발생하는 충격력을 추정하고 이러한 충격력을 이용하여 크레인에서의 응답과 스트레스에 의한 피로수명을 예측하였다.

1. Introduction

During the brake test of the crane, the excessive movement was detected, and so it is necessary to check the safety of the crane. Normally, main crane is generally installed on the upper deck to load and unload the equipment or something heavy in the ship. Because of the slenderness of the post, natural frequency of the crane is very low, therefore, there is some possibility of excessive vibration at the emergency state due to sudden stop during the crane operation.

In this study, a fatigue life due to heavy vibration during brake test is estimated based on basic design S-N curve(1) . In order to calculate the stress of the crane, the applied force is assumed from the vibration measurement and analysis response.

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2. Finite element model

The crane is composed of pedestal, boom and pedestal adapter, as shown in Fig. 1. The main crane for drilling rig is G.A BOS 4200-80 made by LIEBHERR, which is the similar model (G.A BOS 4200-50) of FPSO. The main dimensions of the both cranes are summarized in Table 1.

Therefore, finite element models of both cranes are set up for the dynamic analysis of crane to calculate the displacement of crane during brake test by using PATRAN and NASTRAN[(2)(3)].

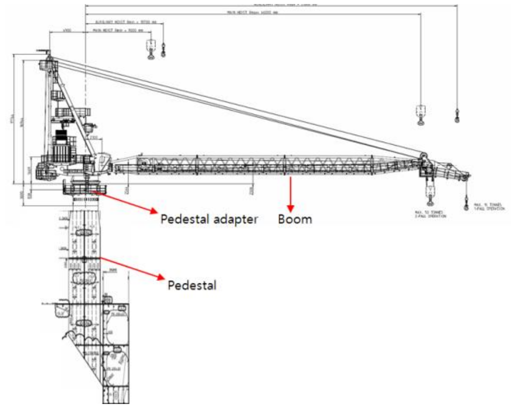

Fig. 1 General arrangement of main crane for drilling rig

Table 1 Main dimensions of drilling rig and FPSO crane

Description	FPSO crane	Drilling rig crane
Model name	G.A BOS 4200-50	G.A BOS 4200-80
Fall operation	2 fall	4 fall
Max. load	50 ton	80 ton
Main hoist Rmax	46m	46m
Main pipe of boom	273x10 mm	273x10mm
Height of pedestal	22 m	8m
Diameter of pedestal	3 m	4m

3. Brake test

The brake test is to be tested with the safe working load(SWL) applied on the crane by braking the motion from maximum speed to full stop 3 times in quick succession during lowering the boom. This test has to be done 3 times releasing the control lever from maximum to neutral position.

This test is carried out for two different hoists and loads such as main hoist with 80 ton and whip hoist with 15 ton. The test load and speed is summarized in Table 2. The whip hoist brake test is selected for simulation, because the momentum is higher than that of the main hoist.

Table 2 Brake test

Description	Main hoist	Whip hoist
Operating load	4 fall 80 ton	1 fall 15 ton
Operating speed	1/6 m/s	1 m/s
Momentum Mass x velocity	13,333 kg m/s	15,000 kg m/s

4. Applied force during brake test

During the brake test, 15ton mass block is falling with the constant velocity(1m/s), and then the crane is braking the motion of the mass block. The applied force is increasing until the crane pedestal has maximum displacement. Based on above assumption, the force is assumed simple triangular shape and the duration of the input force is to be half of the period of crane vibration (1.6 sec). The magnitude of the force is 24390 kgf obtained from comparison between the analysis response for unit force and test results of FPSO crane, as shown in Fig. 2~in Fig. 3. The structural damping of 0.04 is used and it is converted into critical damping 0.02 in calculation at the dominant natural frequency of the crane (0.6Hz). The maximum measured and calculated vibration level at the crane pedestal top of FPSO crane is 17mm/s and 19.5mm/s, respectively. The analysis results are in a good agreement with measured data within 6% deviation.

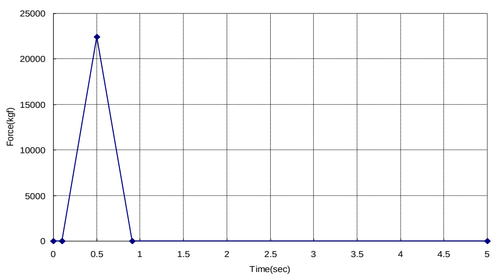

Fig. 2 Input force during the brake test of FPSO crane

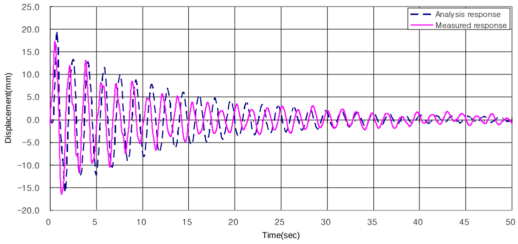

Fig. 3 Measured and analysis response of the crane pedestal in FPSO

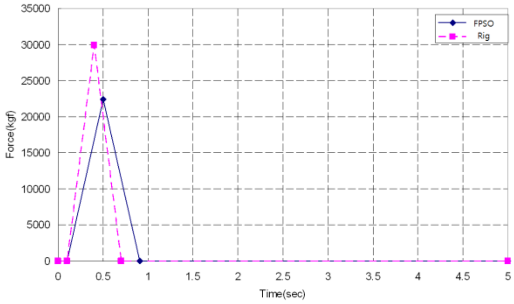

Fig. 5 Input force during the brake test

The applied force for Drilling rig crane is extracted from the test and analysis results of FPSO crane, because the operating load and speed is the same for maximum momentum condition. Vibration analysis has been carried out for the main crane in Drilling Rig. As shown in Fig. 4, the natural frequency of the crane is 0.8 Hz, therefore, the duration of impulsive force is 0.6 sec which is slightly different with that (0.8sec) of FPSO crane. And the maximum force is slightly increased from 22440kgf to 29920 kgf in order to meet the equal momentum and the impulse, as shown in Fig. 5.

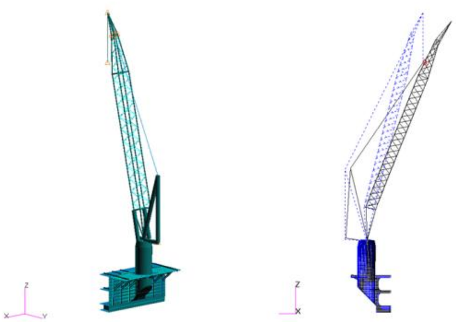

Fig. 4 F.E model and mode shape of drilling rig crane(Natural frequency : 0.8Hz)

5. Stress analysis

The calculated displacement of the pedestal is decayed with time as shown in Fig. 6.

According to the stress analysis, the maximum principal stress due to maximum measured vibration displacement(4.3mm) is 37 Mpa and the endurance cycle at crane pedestal is 6.9x 10^6 using DNV S_N curve C1. (Refer to Fig. 7~Fig. 8).

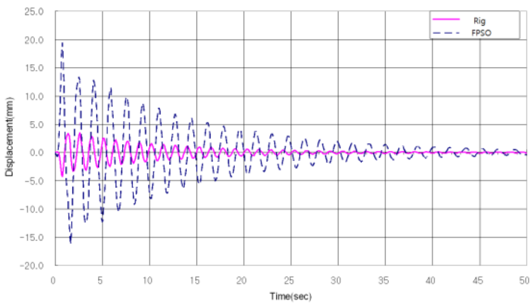

Fig. 6 Displacement curve for main crane

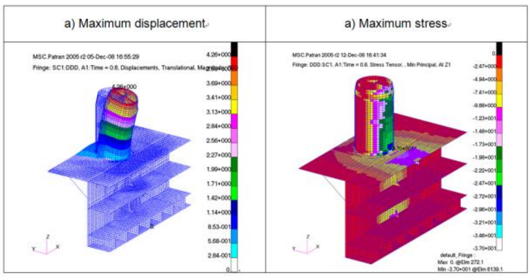

Fig. 7 Maximum displacement and stress during brake test

6. Fatigue assessment

According to DNV S_N curve C1, the maximum stress range is 40Mpa without fatigue damage which is considered safe region of fatigue damage.

As shown in Fig. 9, the maximum stress of crane decays with time as the displacement decreases. In this figure, the green region is the safe zone for fatigue damage based on DNV S_N curve C1. Therefore the effective cycle for fatigue damage is 5 numbers for 1 brake event.

This event (emergency brake test) will seldom occur at normal operating condition. Even if we assume the event occurs once a month, the number of expected emergency brake event during the design fatigue life is 1200 cycle (12/year x 20yr x 5 effective vibration cycle), which is calculated as follows.

- 12/year: emergency brake event (once a month)
- 20yr: Fatigue design life
- 5 vibration cycle: Considering the first 5 effective amplitude. (Refer to Fig. 9)
- 1200 cycle is much lower than the lowest endurance cycle of 6.9×10^6 due to vibration at crane pedestal.

Therefore, any fatigue damage due to vibration will not occur on the crane as shown in Table 3.

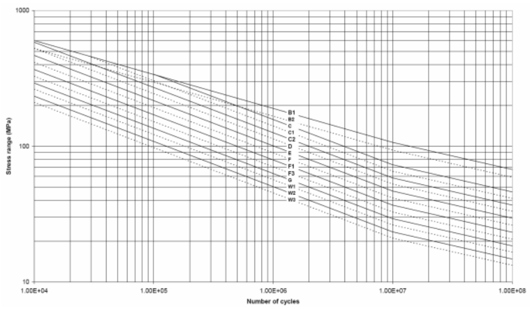

Fig. 8 Basic design S-N curves

Table 3 Fatigue assessment

Description	Displacement	Max. stress	Stress range	Endurance cycles	SN curve
Maximum crane load	4.3 mm	37 Mpa	74 Mpa	6.9×10^6	C1
The number of expected emergency brake event				1200	

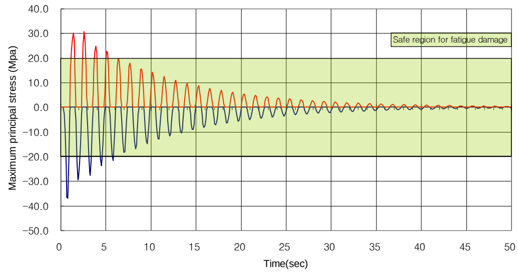

Fig. 9 Maximum principal stress due to break test

7. Conclusions

An analytical method to assess the fatigue life of crane post due to emergency brake stop is suggested. Based on the procedure, the fatigue life of crane post is estimated. The calculation results show this crane is safe against the excessive vibration motion when emergency stop carrying with heavy things during the fatigue design life. In addition, the impulse force is estimated from comparison with the analysis response and the measured one during the brake test. By using the estimated force, the maximum displacement and stress range of crane is calculated, and fatigue life is evaluated, based on basic design S-N curve.

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