A Fatigue Failure Study on the Fractured Turntable Fixing Bolts of a Mobile Elevated Work Platform

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1. Introduction

The mobile elevated work platforms (MEWPs) are common equipment used for repairing and installing high-level structures. It is aimed at work at a high position, so it is also a structure that requires more safety. Accidents that are caused by fracture of the bolts fixing the extension structure and the turntable are increasing. Generally, MEWPs consist of middle frame, X-shape front outrigger, rear outrigger, turn table, booms, derrick cylinder and work platform as shown in Fig. 1 [1]. Turntable has 20-bolts (M16x55L) to fix swing system and post. The bolts are fastened in a circular arrange as shown in Fig. 2. It was reported that R10 bolt frequently fractured in the operating environment of the MEWPs. In this study, fatigue failure behavior and fatigue life of a turntable fixing bolt subjected to irregular fatigue load were analyzed by FEA. For this purpose, finite element modeling is proposed and structural analysis and fatigue analysis were performed simultaneously for fixing bolts.

2. Test Procedures

MEWPs studied in this paper consist of middle frame, X-shape front outrigger, rear outrigger, turn table, booms, derrick cylinder and work platform as shown in Fig. 1. Turntable has 20-bolts to fix swing system and post. The bolts are fastened in a circular arrange as shown in Fig. 2. It was reported that R10 bolt frequently fractured in the operating environment of the MEWPs.

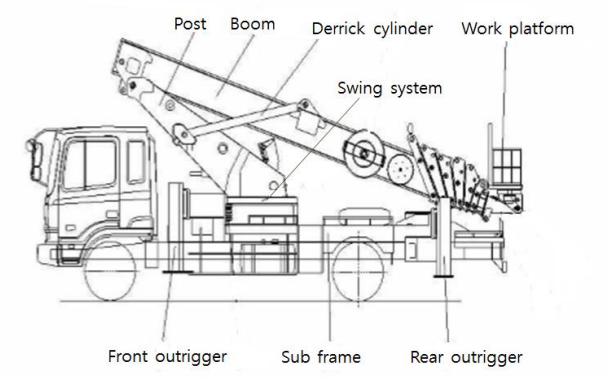

Fig.1 Schematic of mobile elevated work platform working device

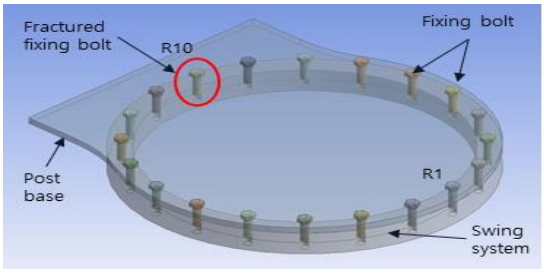

Fig.2 Twenty turntable fixing and fractured bolts

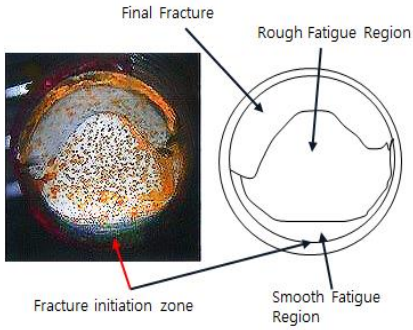

Fig.3 Macrograph and schematic of fracture surface of one of the fixing bolts

2.1 Visual inspection

The visual inspection of the fractured surfaces of the R10 bolts in the turntable was performed. The fatigue crack was initiated at the edge between bolt head and body, and it was propagated to inner body of bolt. It shows typical three regions of smooth fatigue, rough fatigue, and final fracture as shown in Fig. 4.

2.2 Chemical composition analysis

A spectroscope (Thermo Scientific ARL iSPARK 8880) was used to analysis the chemical composition of the fractured bolts. The results can be shown in Table 1. It was found that it satisfied the chemical composition criterion of Korean Industrial Standard (KS B 0233) strength classification 10.9 [2].

2.3 Tensile tests

The tensile properties of fractured bolts were obtained, and the results can be shown in Table 2. The results satisfied the mechanical property criterion of Korean Industrial Standard (KS B 0233) strength classification 10.9[2].

Table 1 Chemical compositional analysis results of the fractured bolts (mass, %)

Elements	C	Mn	P	S
Bolt(R10)	0.20452	0.79529	0.01741	0.00342
Required values (KS B 0233)	015~035	≥0.7	≤0.035	≤0.035

Table 2 Mechanical properties of the fractured bolts (MPa)

Material	Tensile strength	Yield strength
Bolt(R10)	1,217	1,092
Required values (KS B 0233)	≥1,000	≥900

Table 3 Material properties used in FEA

Materials	Young's Modulus (GPa)	Poisson's ration	Density (kg/m^3)	Yield Strength (MPa)	Tensile Strength (MPa)
ATOS80	207	0.29	7,850	813	880
SS400	200	0.29	7,850	250	460
SM45C	207	0.3	7,600	490	686
S45C	205	0.29	7,850	1,092	1,217
S48C	200	0.27	7,700	365	610

3. Finite Element Analysis

To calculate the stress values for turntable bolts, finite element analysis (FEA) was conducted. Turntable, post, 1st-6th boom 3D models were designed and used. The materials for post, base, boom, bolts, and turntable bearing are SM45C, SS400, ATOS80, S45C, and S48C, respectively. The material properties can be shown in Table 3. The boundary and load conditions were applied to the MEWPs model and it can be shown in Fig. 4. Considering the operating condition of MEWPs, the static and fatigue analysis were conducted.

4. FEA Results

Fig. 5 shows FEA results for R10 bolt. The calculated Max. Mises equivalent stress was 960.84 MPa, and it is less than the yield strength of the material. Fig 6 shows fatigue analysis results. The calculated fatigue life was 9.9124x10^4 cycles at the region that Max. Mises stress occurs. The fatigue life for bolt hear region was 8.9137x10^4 cycles. Since the design fatigue life is 1x10^5 cycles, it was confirmed that the design of the studied MEWP system studied does not meet the safety design criteria for fatigue life.

5. Conclusions

The fatigue analysis for MEWP system was conducted to verify the design safety. The obtained

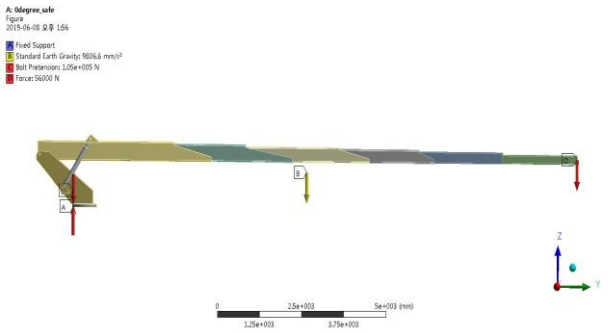

Fig.4 Boundary and load conditions

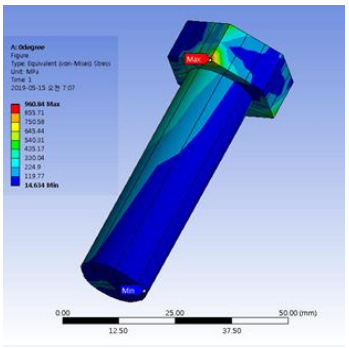

Fig.5 Max. Mises stress for the fixing bolt.

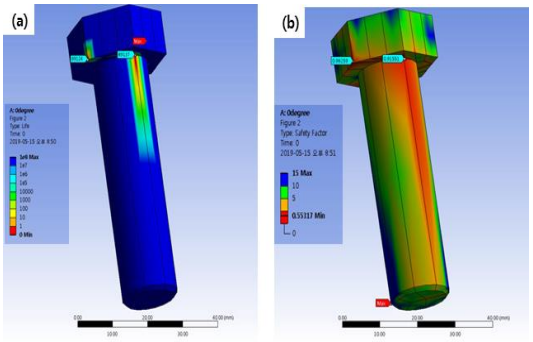

Fig.6 Life (a) and safety factor (b) calculation

conclusions are as follow:

1. Mechanical and chemical analysis of fractured fixing bolt satisfied the Korean Industrial Standards.
2. The calculated Max. Mises stress of fixing bolt was not greater than the yield strength of the material. It is considered that the MEWP system design for static condition is safe.
3. The fatigue life FEA results show that the calculated fatigue life does not meet the design fatigue life of 1x10^5. It was confirmed that fatigue fracture can be occurred by repeated work with designed MEWP.

References

[1] HANSIN SPECIAL EQUIPMENT CO., "Instruction Manual and Repairing Guide"
[2] KS B 0233, Mechanical properties of steel bolts and screws, (2005).