Projection of Stress on Slewing Post for Gangway Using Finite Element Method from Experimental Analysis

M. S. Yob\textsuperscript{1,2}*, T. A. Tuan Pail\textsuperscript{3}, N. A. Mat Tahir, O. Kurdi\textsuperscript{4,5}, M. J. Ab Latif\textsuperscript{1,2}, and V. Y. Raj\textsuperscript{2}

\textsuperscript{1}Advanced Manufacturing Centre (AMC), Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100, Durian Tunggal, Melaka, Malaysia
\textsuperscript{2}Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100, Durian Tunggal, Melaka, Malaysia.
\textsuperscript{3}Port Engineering and Maintenance Department, MISC Maritime Services Sdn. Bhd. Level 16, Menara Dayabumi, Jalan Sultan Hishamuddin, 50050 Kuala Lumpur, Malaysia
\textsuperscript{4}Department of Mechanical Engineering, Diponegoro University, Semarang, Indonesia
\textsuperscript{5}National Center of Sustainable Transportation Technology, Indonesia.

*E-mail: mshukriy@utem.edu.my

Abstract. Slewing operation involves a heavy loading and high cyclic movements. With no windows for error, operators and engineers need to operate while maintaining the performance of slewing. Sometimes, the strength of a components changes after repaired or modified. Thus, in order to predict the performance and safety of a gangway after repaired or modifies, this paper intended to predict the factor safety of a slewing post for gangway by using combination of experiment and FEA. This study was conducted on an actual slewing that has been repaired and slightly modified. The slewing was tested on load test for up to 14752 Kg and then the stress data was compared to the FEA analysis. For further analysis, FEA was conducted at 34 tons load and the stress was projected using the factor coefficient obtained in the comparison. The findings shows that the slewing is safe to be operated at 34 tones and below as the overall factor of safety is 1.2.

1. Introduction
Slewing is widely used in ports and on big ships for the transfer of good or personnel. Slewing can be found in gangway or crane depending on its type of application involving, trolleying, slewing and translation [1,2]. Nevertheless, all are design to be operated dynamically with or without load. Since slewing was designed to be working dynamically in a tight and packed area, the design of the slewing is more focusing on its operability and safety in all possible aspects. In other words, a slewing should not only able to operate smoothly, it also needs to be durable, not harmful to the environment, and also need to ensure safety of service and people nearby.

The operation of slewing cranes involves three main motions: the slewing motion of the jib around the vertical axis, the radial movement of the load suspension point (trolley movement or the luffing of the jib) and the hoisting of the load (lifting or lowering) [2–7]. Meanwhile, slewing gangway movement are rather smaller compared to slewing cranes. This is because, once the gangway is attached to the ship or other platform, the movement motion is only affected by the waves motion. The waves motion only creates small inertia and rarely stressing the slewing. Thus, for slewing post for gangway, the stress can
be only concern during moving and extending the gangway. Due to the influence of high operating cycles, harsh environment, high in a complex working condition that causing high load-bearing capacity, and sometimes error by the operators, slewing’s components are susceptible to failures [8]. The most often parts that reported to be failed are bearing, connecting bolt, wear of gear teeth and raceways. This issue is common for heavy duty machinery that requires lot of movement due to high friction between the component’s surface. This problem can be eliminated by regular service and maintaining the lubrication system. Introduction of protective coating such as graphene and diamond-like carbon (DLC) are also effective in reducing friction and wear [9–11].

There are rarely or limited study on failure of the slewing shaft as the shaft are only susceptible to applied load directly on it while the gangway or crane rotates. However, it is possible to occur, and it is highly possible to occur due to human error or accidents. In order to keep productive process smooth and prevent unplanned downtime, it is necessary to monitor the condition and diagnose fault of slewing in a timely manner. With the improvement of science and technology and the progress of human society, scientific or production accidents tend to be more unexpected and potentially catastrophic. With that, application of computer aided, and modelling software come in handy when diagnosing the slewing’s condition in predicting its life cycles.

There are plenty of study that utilize the computer aided software in solving engineering issue. The study emphasizing a computational aided software such as Finite Element Analysis (FEA) highlight the stress distributed in components or elements helps the author determine the strength of the structure to predict the failures [12–19]. Sometimes, due to modification or interference of third body elements, numerical modelling often needs to be altered. However, the properties or the interfering third body are sometimes hard to be determined. Thus, combination of experimental testing and simulations may present as a solution in determining the factor safety and ensuring the smoothness of an operation. In this paper, the slewing post for a gangway were analyzed using combination of experiment and FEA in order to determine the factor safety of the shaft after it was exposed to minor accidents and being repaired.

2. Methodology

2.1. Test start-up

In this study, an actual slewing post that has been repaired was put to test. The test was conducted by installing the slewing post to a customized jig. Next, strain gauge was attached to two different points on the surface body of slewing post as shown in Figure 1(b). The slewing post were then subjected to load by 30 tons jack (attached to load cell). To mimic the actual operating condition, the shaft of the slewing post was chained to a pivot. The actual and schematic diagram of the test were shown in Figure 1.

2.2. Test conditions

The load test conducted was between 2000 – 14752 kg. The stress value collected were then compared with stress analysis gained through FEA analysis. The factor (difference between testing and FEA) were then averaged. The study was then continuing with higher load by using FEA. The projection stress, \(\sigma_p\) was calculated by using equation (1).
Figure 1. Load test on slewing post (a) actual, and (b) schematic diagram

\[ \sigma_p = \sigma_{\text{max}} \times \mu \]  \hspace{1cm} (1)

Where, \( \sigma_p \) is the projection stress, \( \sigma_{\text{max}} \) is the maximum stress, and \( \mu \) is the highest average factor between upper shaft and lower shaft.

3. Finding and analysis

The data collected from the experimental load test was compared with the FEA data as shown in Table 1. The data were then illustrated into Figure 2 and 3.

| Load (Kg) | Point 1 (lower shaft) | Point 2 (upper shaft) |
|-----------|-----------------------|-----------------------|
|           | Stress (MPa)          | Factor                | Stress (MPa) | Factor |
|           | Testing | FEA     |           | Testing | FEA     |           |
| 0         | 0       | 0       | 0.00     | 0       | 0       | 0.00     |
| 2000      | 0.4     | 0.99    | 0.40     | 2.0     | 1.27    | 1.57     |
| 4000      | 1.0     | 2.01    | 0.50     | 3.8     | 2.65    | 1.43     |
| 6000      | 2.0     | 3.19    | 0.63     | 5.6     | 4.33    | 1.29     |
| 8000      | 2.4     | 4.11    | 0.58     | 6.8     | 5.46    | 1.25     |
| 10000     | 2.8     | 5.23    | 0.54     | 8.4     | 7.07    | 1.19     |
| 12000     | 3.6     | 6.44    | 0.56     | 9.8     | 8.8     | 1.11     |
| 14000     | 4.2     | 7.3     | 0.58     | 9.8     | 9.82    | 1.00     |
| 14752     | 4.2     | 7.51    | 0.56     | 10.0    | 10.1    | 0.99     |

Average Factor 0.54  Average Factor 1.23
From graph in Figure 2, it can be seen that FEA predict higher stress at lower shaft constantly. However, in Figure 3, FEA predict lower stress compared to the testing. Here, it can be said that the invert pattern indicates that the chain placement is slightly off where it might be a little bit more towards upper shaft (point 2). Another possible reason as why the data did not show the same pattern is due to the placement of the strain gauge. Due to small gap between the shaft and the slewing body, the gauge placement is slightly shifted to the nearest available point.

From testing result, it is found that the deviation between FEA and testing is about 23%. Based on that percentages, all the reading from FEA will be factored with 1.23. The analysis on the FEA was continued to 34 tons (the actual load supported by slewing during operation). The highest stress obtained at the shaft from the analysis is 116.54 MPa at the lower shaft. Upper shaft only records 66.09 MPa as its highest stress. Interestingly, other part shows higher stress (as high as 273.04 MPa) compared to both upper and lower shaft. Figure 4 and 5 shows the FEA findings.

It has come to our attention that from figure 5, the highest stress was projected by other components (besides lower and upper shaft). It was believed that the component possessed high stress due to its low thickness and contact area with the slewing body. Locking the components to the outer body also one for the contributed factor. Nevertheless, the stresses are also under the allowable stress. By taking account that the components were made by using AISI 4140 steel (yield strength = 415 MPa), the factor of safety are calculated as shown in Table 2.
In order to eliminate failure due to experimental error, all maximum stresses are multiplied by the highest average factor. The factor of safety is calculated from yield strength of AISI 4140 steel and the projection stress. From Table 2, it can be seen that the factor of safety for both lower and upper shaft are more than 2.5 meanwhile the overall factor of safety is 1.2. Thus, it can be said that the slewing post is authorized to operate within its limit (34 tons).

4. Conclusion
From the findings, it can be concluded that the projection of stress by using combination of experimental test and FEA is possible. The differences between the experimental testing and FEA analysis is about 23%. By translating the differences into factor, the test can be carried to another load applicable. The projected stress was then can be calculated by multiplying the maximum stress with the factor. In this case, the projected stress is below the allowable stress of AISI 4140 steel where the slewing is concluded safe to be operated. For future reference, it is suggested that the area presented with high stress are reinforced with gusset or other reinforcing method.

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