



Conference Article

Examination of Fractures in Excavator Full Guardrails Using Vibration Based Finite Elements Method

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Abstract

There are multiple standards and safety measures in excavator construction machines. In this way, the safety of operators, maintainers or individuals around the work machine is ensured. Guardrails on excavators are also included in these standards. These structures, which are constantly used by operators, maintainers and test workers, are exposed to high vibration. Due to high vibration, fractures or cracks may occur, especially in the railing welding areas. In this article, Modal, Harmonic and Random Vibration analyzes of the full guardrail on a HİDROMEK excavator work machine will be performed. The acceleration values to which the guardrails were exposed during working conditions were measured and tested from different regions. In this study, the test data measured on the machine is analyzed using MSC Nastran-Patran.

Keywords: Guardrails, vibration, excavator



1. Introduction

Excavators are of great importance for use in the construction industry. These powerful machines require serious safety precautions when used. One of these measures is guardrails. Correct use of these guardrails on the machine is highly important. Unsufficient guardrail design may lead failure under working conditions that may also cause human injury. The fact that these railings are sufficient only in terms of static strength is not a correct evaluation criterion. Considering the working conditions of excavators, it is known that guardrails are exposed to constant vibration. Cracks and breaks are observed in these structures, which are exposed to random vibrations under challenging field conditions, especially in the welding areas.



Figure 1: Guardrails on Excavators

Excavators have a very wide range of uses. It can perform multiple tasks with different modifications. While performing these tasks, very high vibration values can be observed. Especially when working with a breaker tool, the structure can reach extreme values in terms of vibration. When the operator uses the guardrails, which suffer part fatigue during this work, breakages can be observed. In this study, the data collected from a HİDROMEK excavator and the improvement works carried out on the guardrails will be discussed.



2. Materials and Methods

In this section, Modal, Harmonic Response and Random Vibration analyzes performed on an excavator guardrail will be shared. The design and finite element meshes of the structure were made with the MSC Apex . After this, finite element solutions were made through MSC Nastran-Patran.

2.1. Vibration Test Application

An excavator model selected for the upper bloom of data analysis from full guardrails was exposed to challenging working conditions according to the test site. During the period when these conditions occurred, acceleration values were collected in three axes from two different regions: over the guardrail and from the guardrail connection points. The accelerometer locations and connection features used while recording the data are shared here.

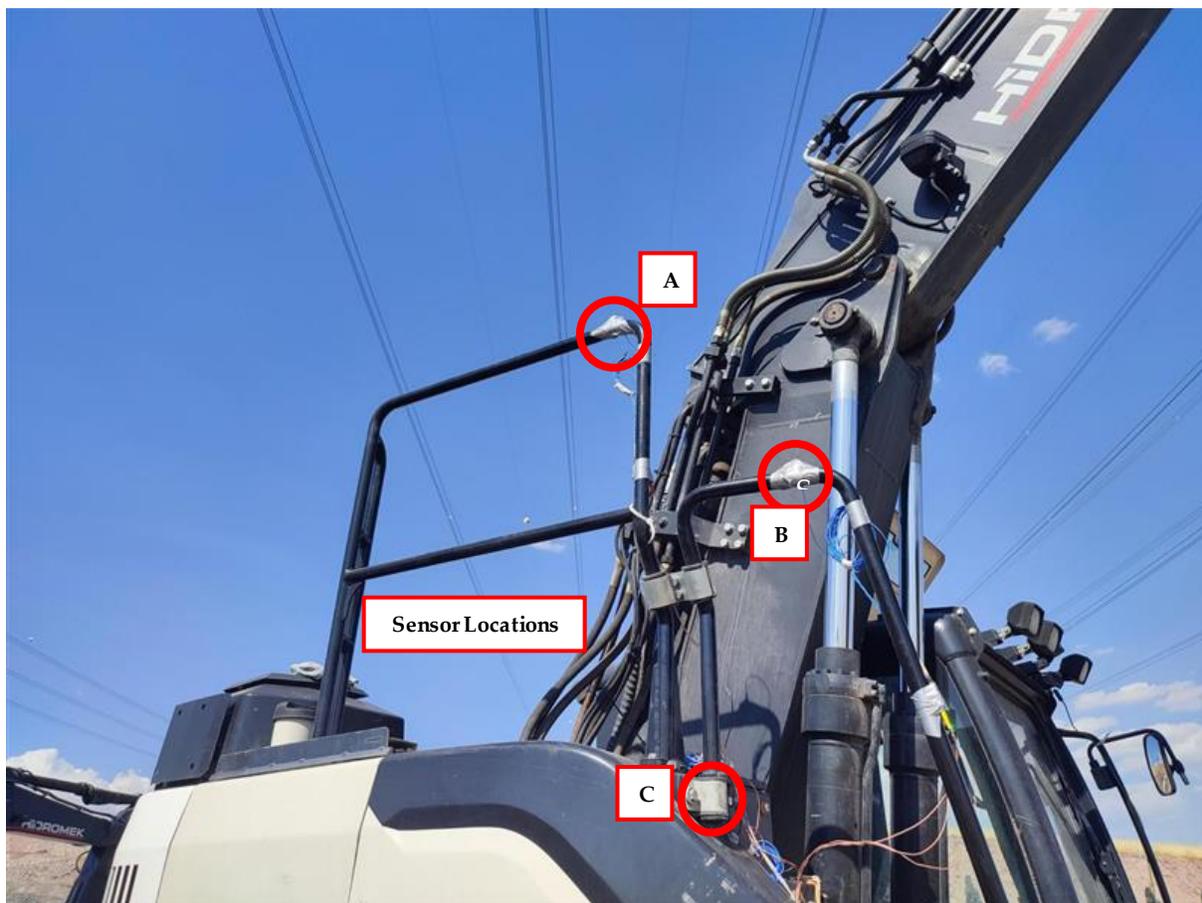


Figure 2: Sensor Locations on Guardrails



3-axis acceleration values taken with accelerometers on the excavator are shared graphically below. The data taken from these graphs were applied to the analysis as a boundary condition. Graphs with high acceleration values were filtered out from the data received, and machine movements were not examined separately in the analysis, as relatively lower values were obtained.

Walking Mode Acceleration

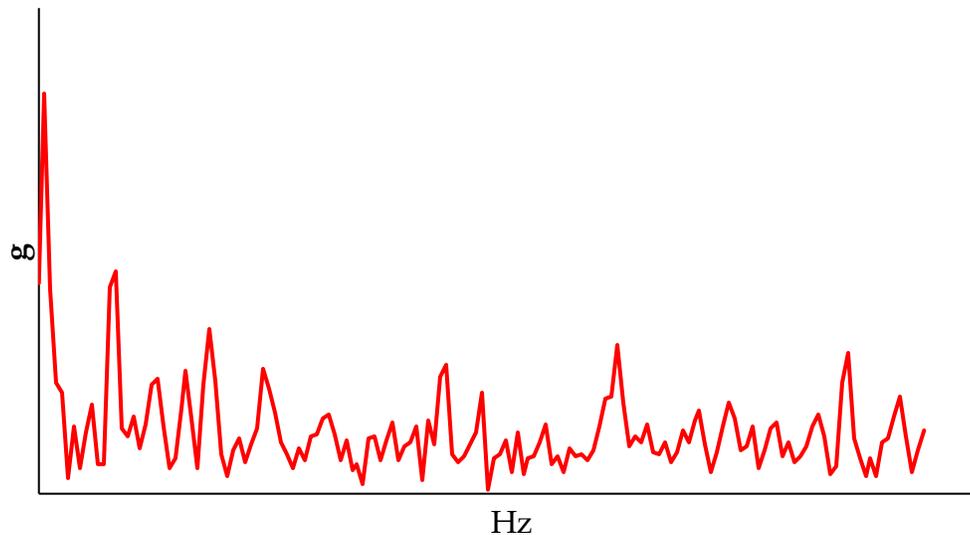


Figure 3: Walking Condition

Excavation Mode Acceleration

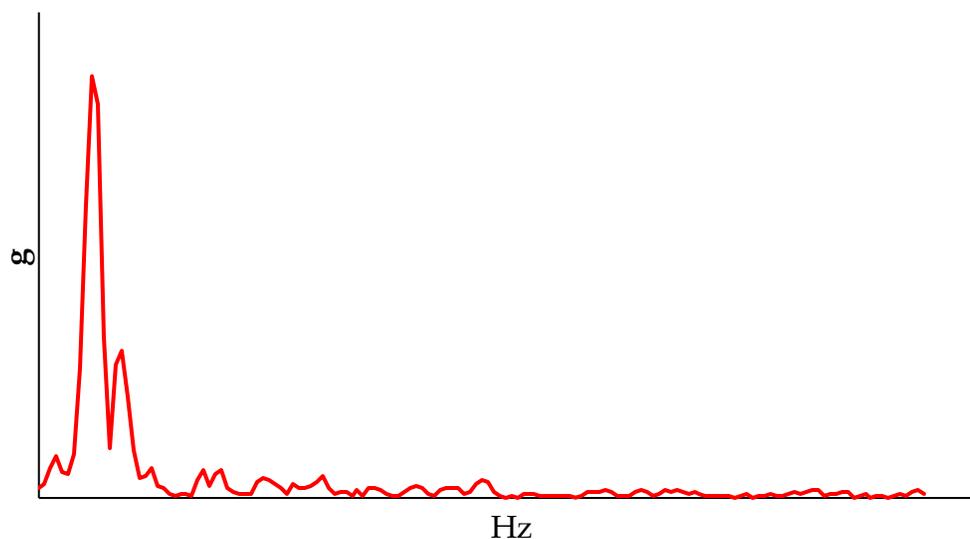


Figure 4: Excavation Condition



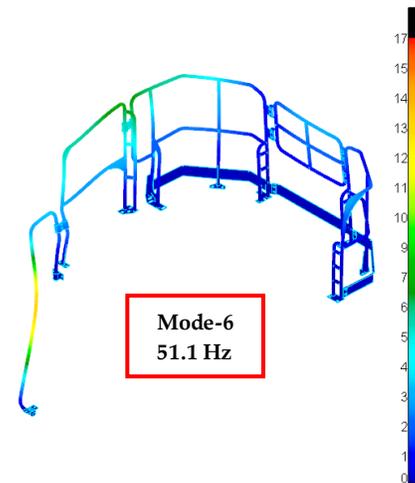
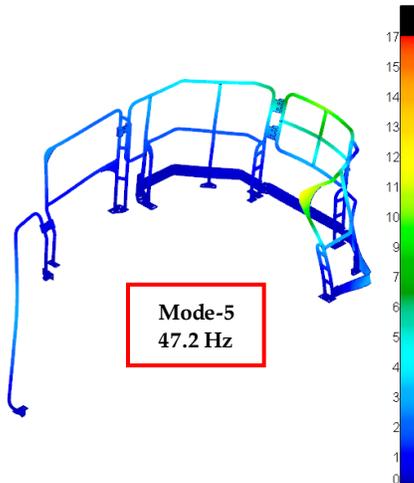
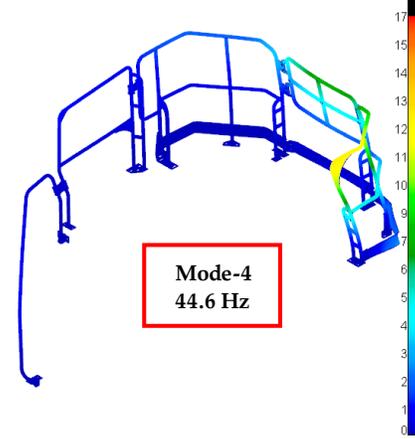
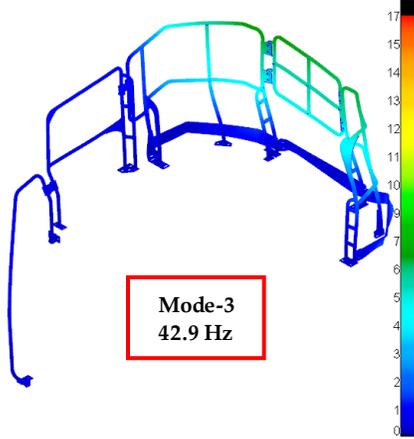
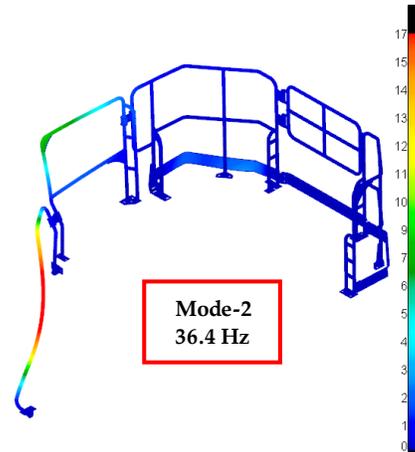
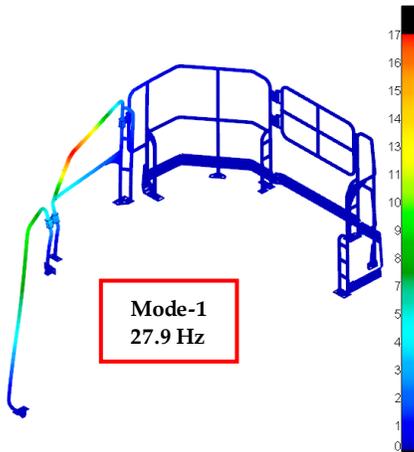
2.2. Modal Analysis

Modal analysis is a method used to determine the natural frequencies of a structure. Modal Analysis, a type of linear dynamic analysis, has an important place among finite element analyses. It is used to determine the resonance zones of structures. Modal Analysis mathematical formula is shared below.

$$[M]\{\ddot{v}\} + [K]\{\dot{v}\} + [C]\{v\} = \{F\}$$

In this formula, [M] is the mass matrix, [C] is the damping coefficient and [K] is the stiffness matrix. $\{\ddot{v}\}$, $\{\dot{v}\}$ and $\{v\}$ are the acceleration, velocity and displacement vector respectively. $\{F\}$ is the force vector. These vectors are written as a function of time. When we pay attention to the equations, we see that a Modal Analysis includes mass, damping and stiffness. It is understood from the formulation that no other effects are included in the equation. Since the damping matrix can be neglected in low-damped structures, it can be seen that the two biggest effects that are important for the structure will be mass and stiffness.

The natural frequencies of the excavator guardrails, for which the analysis model was created through MSC Nastran-Patran, were determined through finite element package programs. The working range of the structure was determined in line with the data obtained from the field. These modes were examined by determining the natural frequencies that overlapped with this determined range. Different designs have been used to remove these natural frequencies from the operating range. As a result of modal analysis, field vibration data was collected from the guardrails that were brought to the desired level. These data were used as input to Harmonic Response and Random Vibration analyses. The natural frequencies within the operating range are determined and shown below. The natural frequencies in the structure were separated according to the mass participation rate, and the participations that were high enough to activate the structure at the moment of resonance were evaluated.



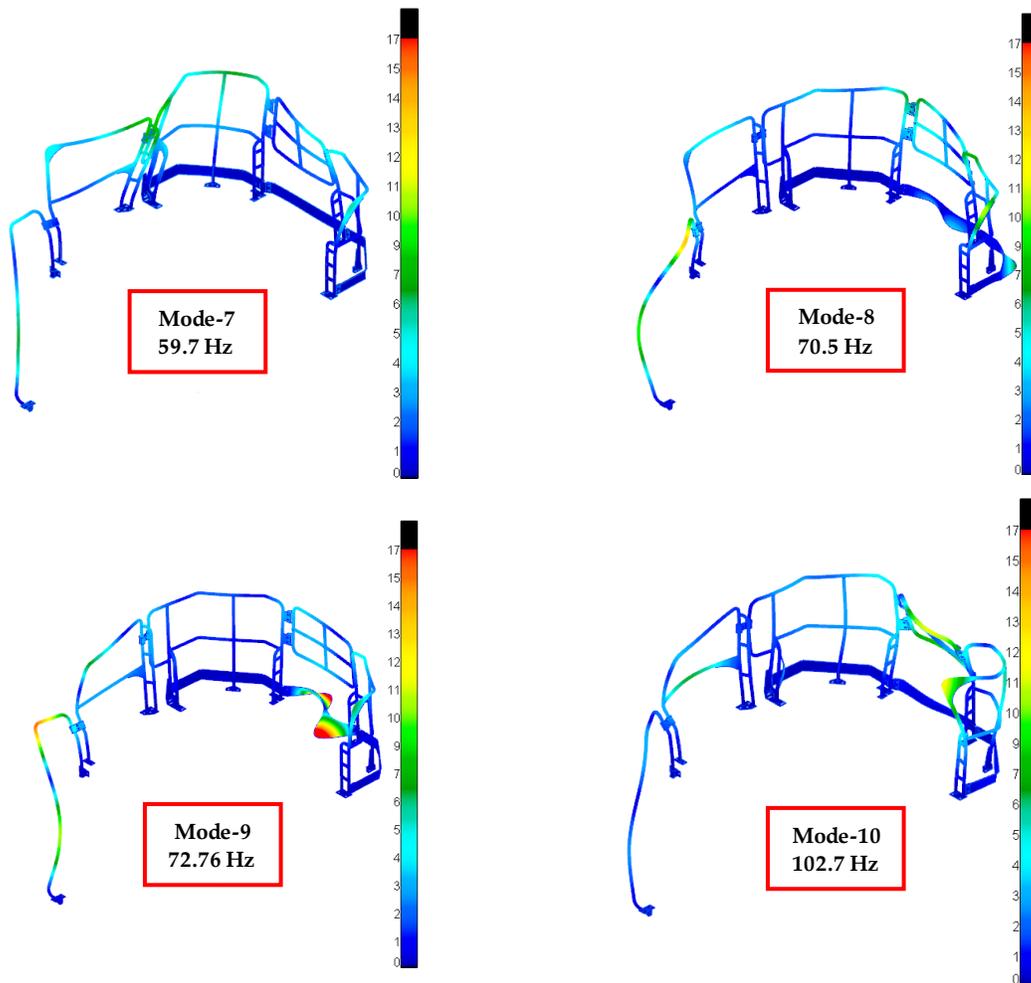


Figure 5: Modal Frequencies

When the modal analysis results are examined, it is seen that some regions have particularly repetitive modes. Special attention was paid to examining these regions. Regions that can be triggered by more than one mode within the operating range are very likely to resonate and break.

2.3. Harmonic Response Analysis

Harmonic Response Analysis is a type of linear dynamic analysis used to understand the behavior of structures and examines the response of the system with a sinusoidal loading. By stimulating the natural frequency values with this type of loading, the stress, displacement and acceleration values of the structure in case of a possible resonance can be seen and optimizations can be made if necessary. The way P harmonic load is applied to the structure is expressed mathematically as follows.

$$A \sin(\omega t + \varphi) = \{P\}$$

Here A is amplitude, ω is frequency, t is time and φ is phase angle. An example harmonic loading and phase angle change is shown in Figure 2.

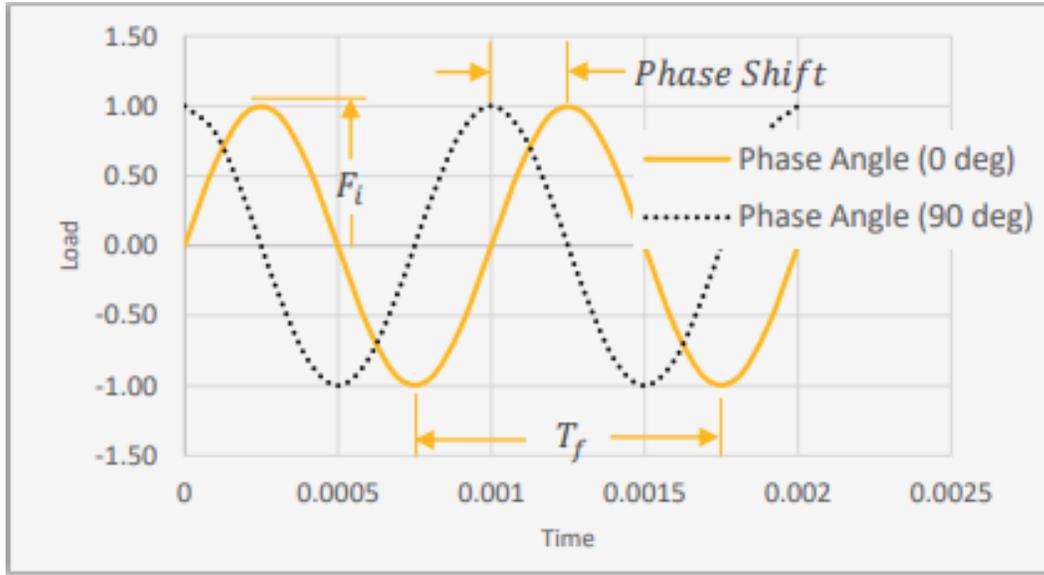


Figure 6: Harmonic Load and Phase Angle

The Harmonic Analysis mathematical model is written in modal form as follows;

$$y_{jc} = \frac{f_{jc}}{(\omega_j^2 - \Omega^2) + i(2\omega_j\Omega\zeta_j)}$$

y_{jc} komplex modal kordinatlar, f_{jc} komplex modal kuvvet, Ω dairesel frekans olmak üzere modal temelli Harmonik Analiz formülü yazılmaktadır.

The modes of the structure were determined in line with the examinations made in the Modal Analysis section. The inspection range was created by determining the mode values that fall within the machine operating range determined by vibration tests. In order to see the stimulating effect that will activate the mode values in this range, the collected acceleration data was filtered and applied harmonically to the structure. As input to the Harmonic Analysis, the frequency values of the critical modes of the structure and the operating range of the structure are divided by a certain ratio and entered separately. It was stimulated simultaneously in 3 axes with the acceleration data taken from the guardrails. The behavior of the structure appeared harmonic and the data received from it created a source of random vibration.

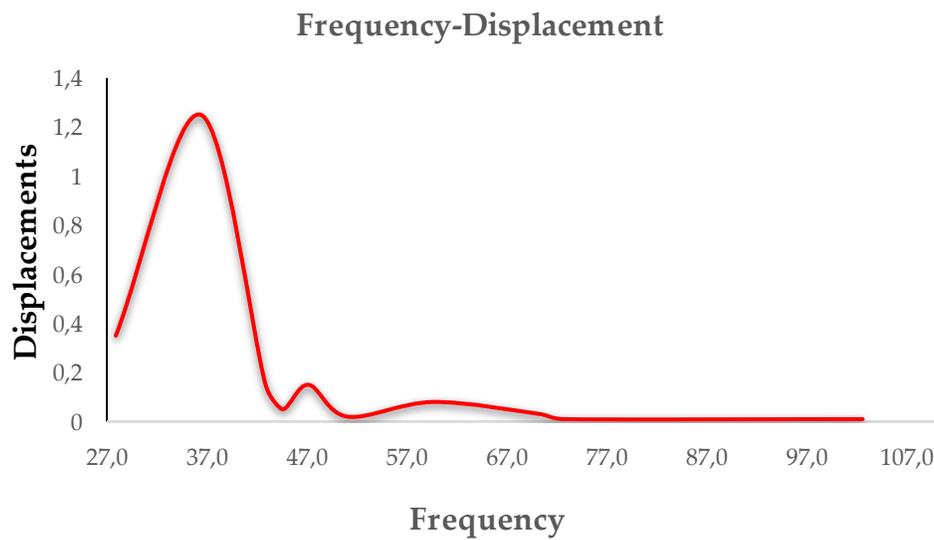


Figure 8: Displacements-Frequency

The frequency-based displacement results obtained in line with the Harmonic Response analysis, in which the structure is stimulated with a harmonic acceleration load, are shared in Figure 3. When these data were examined, it was observed that there was a significant displacement in the structure, especially at 36.4 Hz. The region affected by this mode value has been examined in detail.

2.4. Random Vibration Analysis

Random Vibration Analysis is a type of linear dynamic analysis in which data where the vibrations on structures do not comply with any pattern or order are examined. In this type of analysis, Power Spectral Density (PSD) is used as input. PSD is a measure of the power content of the signal versus frequency. PSD data from the guardrails is shown below. PSD data was obtained by processing the received test data through test devices. These data were processed in the Random Vibration module via MSC Nastran-Patran. The vibration data used in the analysis is shared below.



Walking Mode PSD

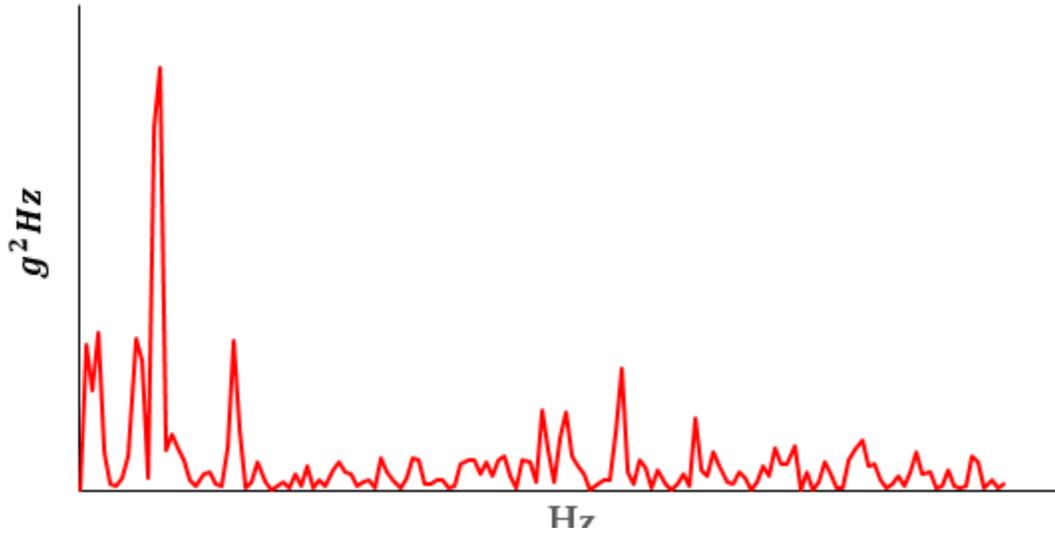


Figure 9: Walking Mode PSD

Excavation Mode PSD

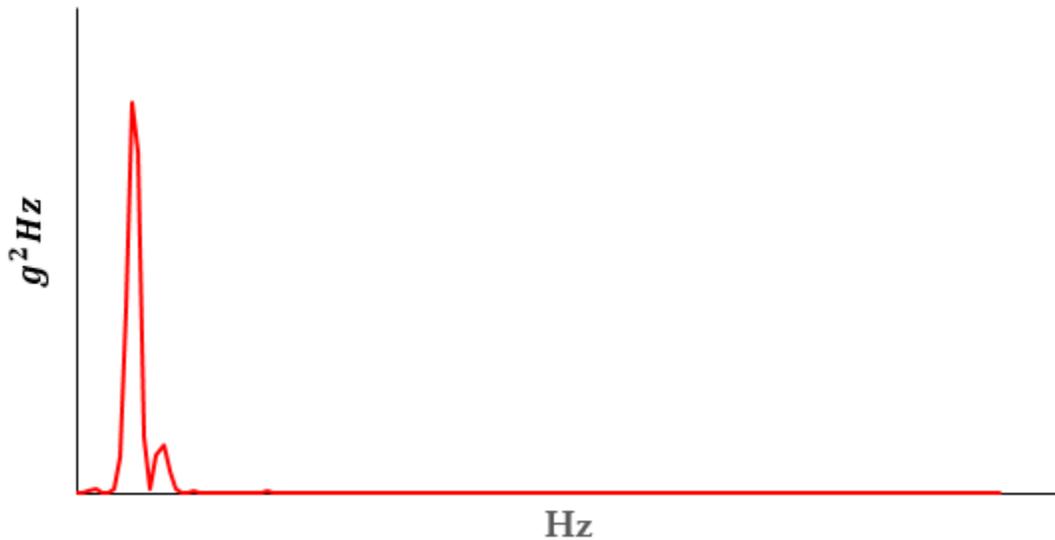


Figure 10: Excavation Mode PSD

3. Result

When the Harmonic and Random Vibration analysis results were examined, high stresses were observed in the important connection areas of the structure and at the sheet metal



bending points. In particular, it is seen that the fracture and crack areas coming from the field are compatible with the high stress areas. The stress values obtained as a result of the analyzes are shared below.

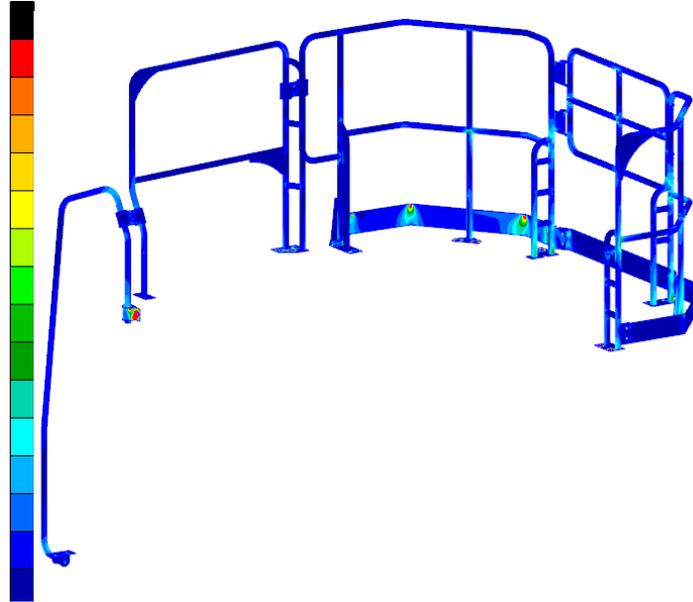


Figure 11: Von Mises Stress

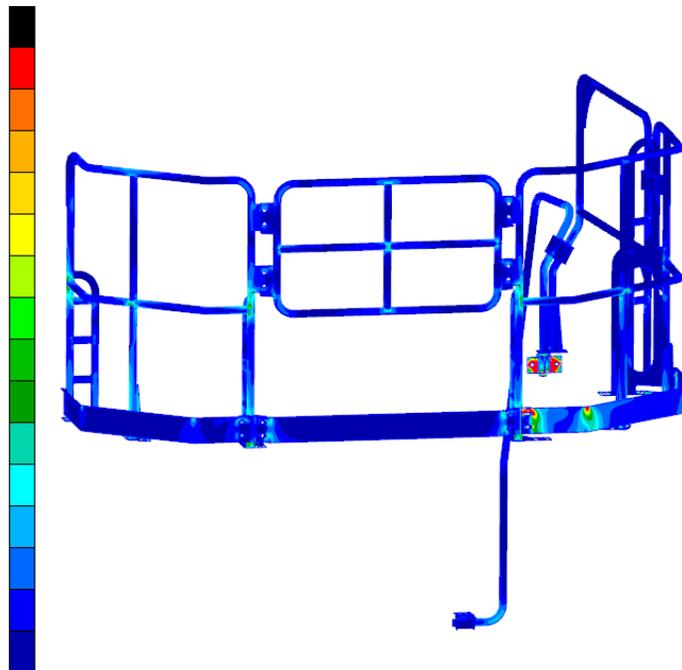


Figure 11: Von Mises Stress

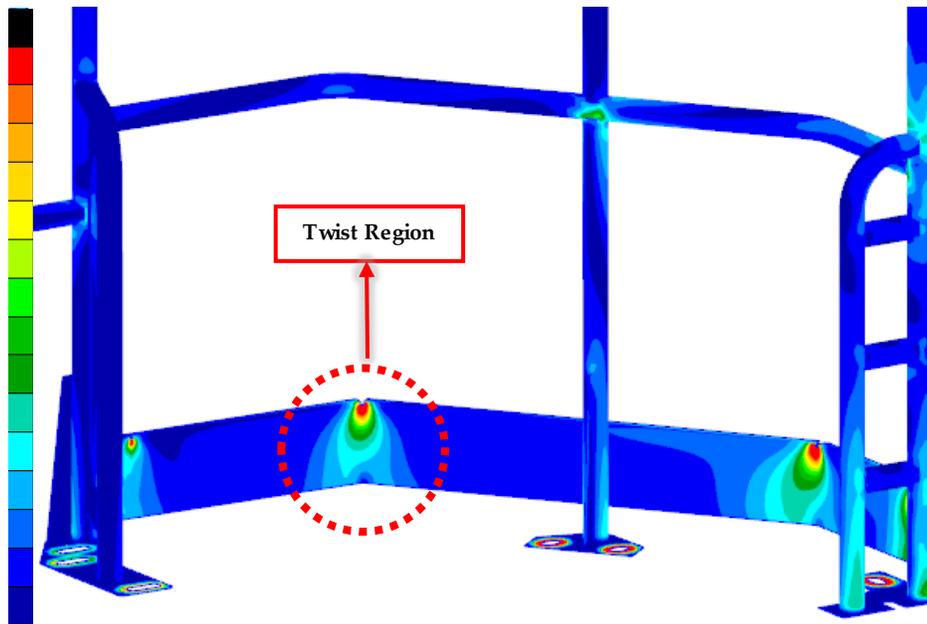


Figure 12: Von Mises Stress Detail View

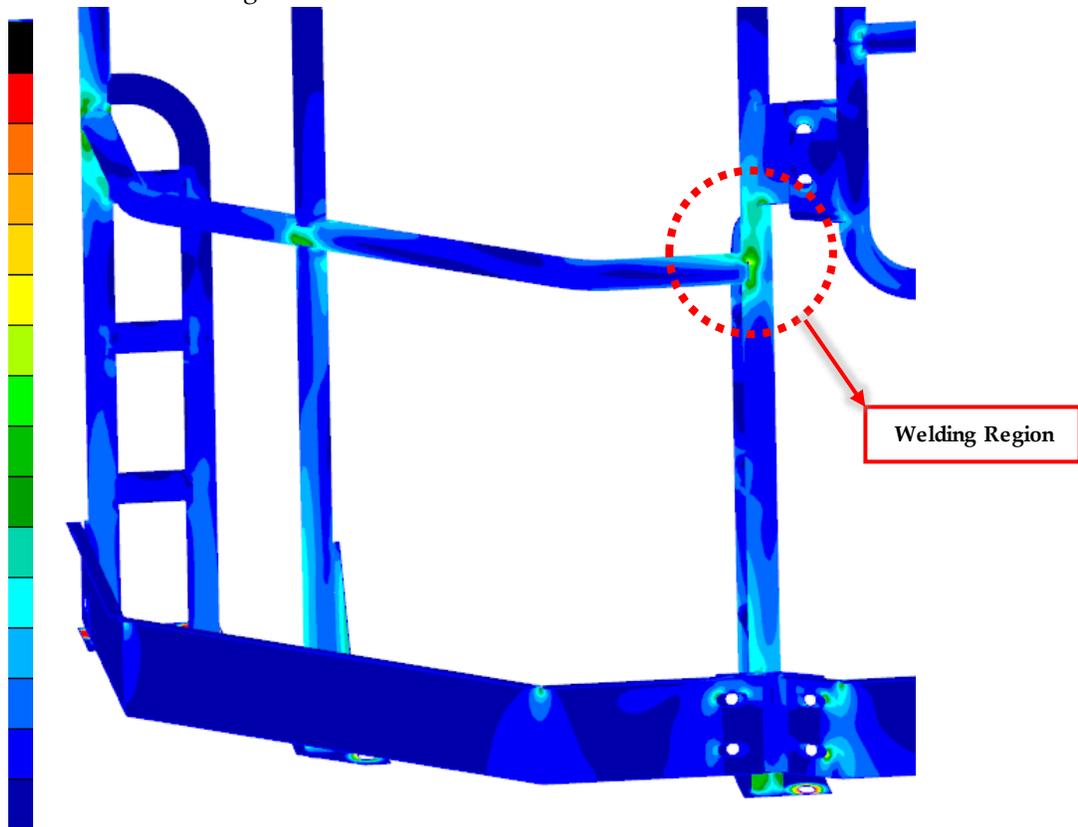


Figure 13: Von Mises Stress Detail View



4. Discussion And Conclusion

In this article, full guardrails used in excavators are examined on a vibration based. First of all, the guardrails, whose natural frequencies were determined by Modal Analysis, were activated harmonically in order to determine their behavior at these frequency values. Behavior outputs from Harmonic Analysis together with PSD data formed input to Random Vibration. The stress data taken from the Random Vibration module was evaluated and presented in the results.

Arrangements have been made to prevent high stresses seen in the welding areas and sheet metal bending points in the structure. In order to reduce the stresses in the welding areas, changes should be made to reduce the freedom of the structure. Welding stresses, especially in the areas where the structure is fixed, can be eliminated by reducing the tilting movements of the structure. Using softer transitions in bending areas will reduce the stresses in this area.

5. Acknowledge

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