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# The Foundation of Structural Vibration Frequency Analysis and Its Applications in Structural Design

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**Abstract- Thanh Tran Xuan, 2 Phương Ngo NamVibration is a common phenomenon in nature and in engineering. All structures subjected to external forces will vibrate and may experience the phenomenon of resonance during operation. Vibration and resonance are often the cause of, or at least a contributing factor to, many operational problems in structures and machinery, leading to shaking, noise, and even component failure, even when the applied force has not exceeded the material's strength limit. When designing structures, machinery, and civil works, engineers routinely account for the effects of vibration. This includes calculating the structure's natural frequencies, predicting the operational frequency range of the structure, and designing the structure to mitigate adverse effects while utilizing beneficial vibratory characteristics. To fully understand the vibration and resonance issues of a structure, the factors causing vibration and resonance must be identified and quantified. A common approach to achieve this is to study the dynamic properties of the mechanical structure under dynamic excitation: its natural frequencies, corresponding mode shapes, and damping ratios.**

**Keywords - Vibration, natural frequency, damping ratios.**

## I. INTRODUCTION

### Theoretical basis of structural vibration frequency analysis

The simplest model for structural vibration frequency analysis is the Single-Degree-of-Freedom (Single-DOF) system. The motion of a single-DOF system with mass m, viscous damper with damping coefficient c, and spring with stiffness k under the excitation force f(t) is described by the following differential equation:

$m\ddot{x}+c\dot{x}+kx=f(t)$.

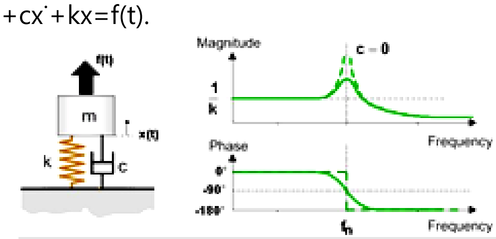


Figure 1: Single-Degree-of-Freedom (Single-DOF) system

For a Multi-Degree-of-Freedom (Multi-DOF) system, the differential equation of motion for the mechanical system is:

$[M]\ddot{x}(t)+[C]\dot{x}(t)+[K]x(t)=f(t)$.

[M], [C], and [K] are the mass matrix, damping matrix, and stiffness matrix, respectively;

x(t) and f(t) are the displacement column matrix and the force column matrix, respectively.

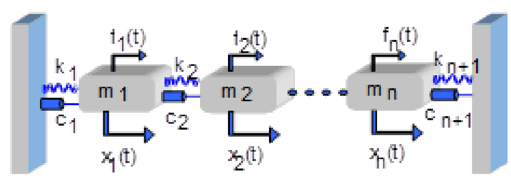


Figure 2: Multi-Degree-of-Freedom (Multi-DOF) system

### Applying the Fourier transform, we obtain the Frequency Response Function (FRF)

The structural vibration frequency analysis of a machine can be briefly described as follows: Excite the structure at a specified location (F); collect data including information on both excitation and response; perform multiple experiments at different locations, process the collected data, and perform analysis (H).

### Structural vibration frequency analysis

Structural vibration frequency analysis involved in frequency analysis and to analyze the results of natural frequencies and resonance frequencies

The Finite Element Method (FEM), nodes, surfaces
Using the Finite Element Method (FEM), nodes, surfaces, and connections are created to establish the computer model of structure. Using digital signal processing software for result analysis: To perform a vibration frequency analysis, it is essential that the response at all points (degrees of freedom) on the structure be measured due to the excitation at other points. The result is a full matrix of Frequency Response Functions (FRFs). Digital signal processing on the computer allows us to obtain graphs of the structural vibration FRFs, in which the poles are identified as the resonance points.

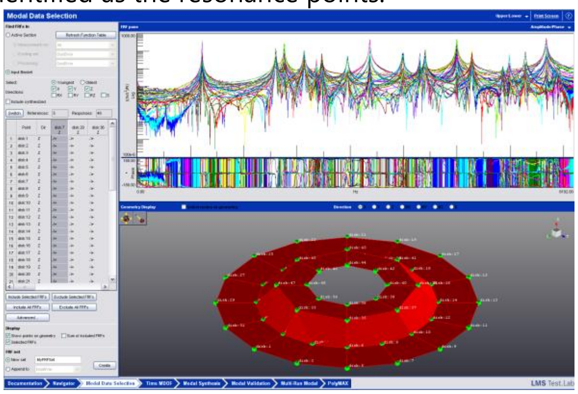

Figure 3: Simulation graph and result FRFs

**The result**

The specific result of a resonance frequency mode and its interaction causing deformation on the car brake disc structure is explicitly shown in the stress analysis diagram.

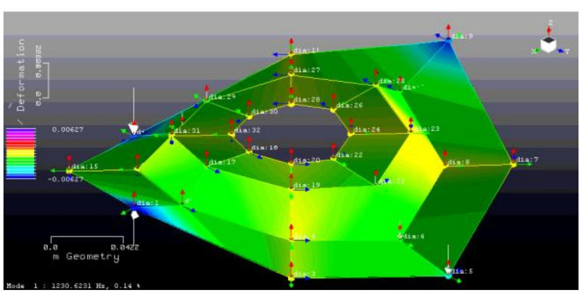

Figure 4: Vibration Frequency 1: 1230.623 Hz; Damping Coefficient: 0.14%.

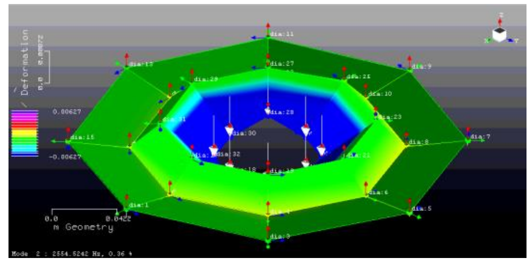

Figure 5: Vibration Frequency 2: 2554.524 Hz; Damping Coefficient: 0.36%.

Based on the results, we have the following observations: If the structure's operating frequency range is around 1200 Hz, the car brake disc structure will be affected in the outer region of the disc (Vibration Frequency 1). If the structure's operating frequency range is around 2500 Hz, the car brake disc structure will be affected in the inner rim region of the disc (Vibration Frequency 2). Thus, to reduce the detrimental effects of vibration, designers typically control the system's natural frequencies to avoid resonance under external excitation or prevent excessive vibration of the system.

## II. CONCLUSION

Structural vibration frequency analysis techniques have been researched and widely applied globally. Researching and accessing this technique is highly useful in studies related to resonance, natural vibration, noise, and shaking. However, the importance of vibration parameters extends beyond design calculations to avoid resonance and excessive vibration. Special methods can allow for real-time condition diagnosis of the structure without the need for disassembly and inspection. By using a vibration analyzer to record and store the frequency spectra of the structure in good condition and then comparing it with the corresponding spectrum of the same structure when a fault develops, we can detect the location of the damaged component. This allows for the regular monitoring of changes in the machine during operation, enabling the detection of faults right from their inception and tracking their subsequent progression. The measured vibration levels can be analyzed to forecast the time when vibration levels will reach unacceptable values and when the machine will require maintenance. This significantly reduces costs by minimizing serious failures, allows for better utilization of spare parts, eliminates unnecessary maintenance, and accurately determines the timing of structural failure.

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