

Name:- Harsh Patel

Student id:- 2309767

**LASER DOPPLER VIBROMETER –BRAKE DISC MODAL
ANALYSIS**

Table of Contents

Introduction	3
Objective	3
Apparatus	4
Method Of The Experiment	5
Measurements and Graphs of Raw Measurements	7
Calculation and Error Estimation.....	8
Result and Discussion	9
Conclusion	13
Reference List	14
Appendices.....	15

Introduction

The examination of the resonant frequency modes and shapes of the brake disc has been experimented with in this report with the help of a Laser Doppler Vibrometer (LDV) system. The result of the disc vibration in brakes could be noise problems and less efficiency even wear. Hence, evaluating brakes completely includes their analysis and characterization. In this experimental investigation, the PolyTEC Scanning Laser Doppler Vibrometer System which contains a non-contact, high-resolution mode, this being used for measuring vibrational characteristics of the mechanical structures was used. The LDV systems are able to easily detect and provide detailed analysis of the dynamics of the brake discs using the precise laser technology which makes the technique apt for the study of complex modes and shapes displayed by the vehicles during the operation. In the automotive braking systems, brake discs undergo numerous dynamic loads from different operating conditions and thus excite a number of resonant frequency modes and shapes. This kind of state and hull coefficient influences a braking system's performance and endurance, so their accurate prediction is key in the design optimization and reliability evaluation.

Objective

Since the LDV system has the ability to conduct high-resolution analysis of the steering wheel with accurate vibration level specs thus it is the main reason to choose the system in this experiment. The LVD system detects the brake disc change of the state of response to the external excitations on which solenoid actuators can create such conditions. Therefore, a precise analysis of the dynamic behaviour of the brake disc can be done in the simulated operating environment. The powerful attributes of the PolyTec Scanning Laser Doppler Vibrometer System have been used in this study which can shed more light on the vibrating behaviour of brake discs being used

on vehicles and thus add to the automobile brake systems engineering, performance optimization, and safety enhancement.

Apparatus

The experimental setup was composed out of several crucial elements, among others the PolyTec Scanning “*Laser Doppler Vibrometer (LDV)*” System which represented the analysis tool of choice, the determination of the vibrational features of the brake rotor. On top of it, the controlled excitation source through the solenoid actuator brought braking force in the brake disc to the level desired. Under this goal, the fuselage disc, the transitive element for the test, was firmly installed within the scheme with the help of special holders and balancing to avoid a wobble during the trial.



Figure 01: Experimental Setup in the Lab

Function Generator provided an alternative to the excitation and control of vibrations, so it was needed to be used for the purpose of interfacing with the Solenoid Actuator (Chatterton *et al.* 2024). Specialized calibration devices served us to check the accuracy and utmost reliability of the data corresponding to the LDV system. The data acquisition was smoothed over due to a succession of several hardware pieces interfaced with a computer equipped with the needed

software for processing and interpreting. ***Polytech Scanning Vibrometer Software*** has been used in the experiment to gather and analyze the experimental Results.



Figure 02: Brake disc

Measurement probes and sensors were thoughtfully installed in order to acquire only relevant data from relevant locations, while signal conditioning equipment providing high quality and integrity of the signals used during the experiment served as a crucial component (Abbas *et al.* 2020). Whilst a standard layout from the LDV system was used, particular adjustments and changes were made in order to connect the tool to the manifold in line with the specific requirements of the brake disc analysis experiment and to ensure a high level of precision and trustworthiness.

Method Of The Experiment

The study started with the launching of the PolyTec Scanning Laser Doppler Vibrometer (LDV) system specifically designed for data collection. The brake disc constituted the minimum of the assembly and made a stable platform during the experimental process. As stated by Mekhsalfia, and Procházka, (2024) proper alignment was strictly undertaken to ensure that the LDV measurements were precise and dependable. Moreover, LVD measurements were done on the brake disc using different screen settings and frequencies for purposes of comparison. Specifically,

measurements were taken at **10 kHz and 20 kHz** frequencies across three mesh settings which are a ***“fine half mesh, a low mesh and regular mesh”***. This returned the samples of six different configurations to be examined. Thus, the probe was set to different mesh sizes as well as the collection of data for various frequency combinations of the anomalies on the brake disc. The PolyTec measurement and data processing software was employed for acquiring the data and determining the resonance frequency and mode shapes.

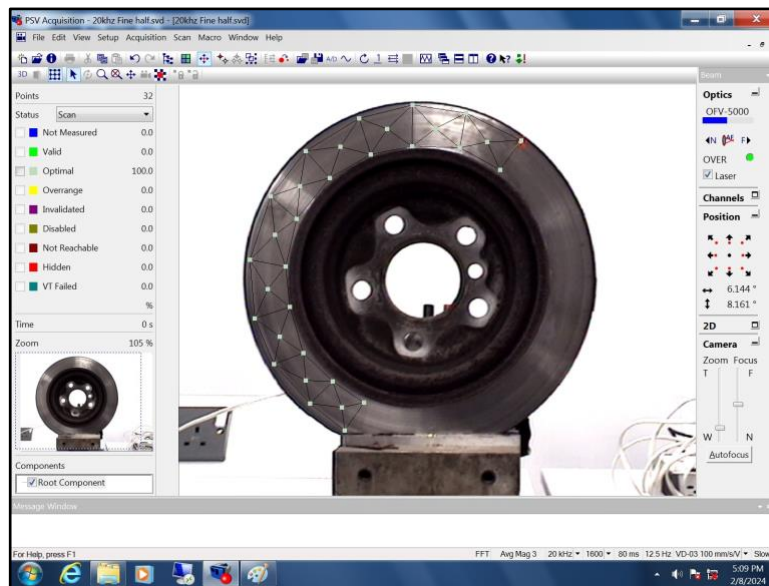


Figure 03: 20khz Fine half mesh

The software has a key feature of frequency analysis amongst other angles, which therefore provided a complete picture of the vibrational behaviour of the brake disc. It was found that varying of mesh settings and frequencies can examine the most of resonant modes and shapes of the brake disc subject to different motion modes and frequencies.

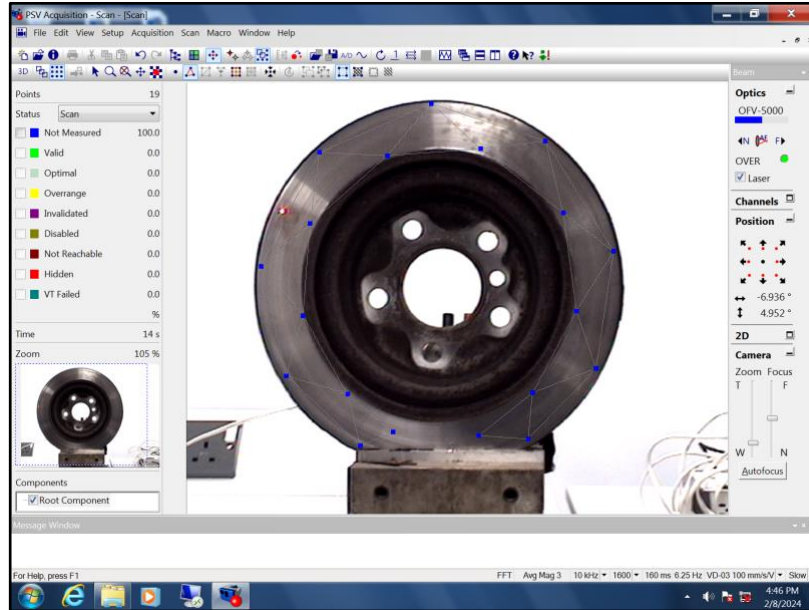


Figure 04: Lower mesh Analysis

During the duration of the experience, precise approach was observed due to the matter that controls over environmental factors as well as the disturbances were monitored. Data were obtained in the systematic way with several measurements at certain configurations during the scanning in order to allow variations and to re-do the experiments to obtain reproducibility. Post execution of the LDV measurements on all the six brake configurations, the data was the compiled and analyzed to identify the principal harmonic resonant modes and the shapes appearing on the brake disc (Singh, 2022). Through software, the results could be displayed and interpreted visually, such that the fluctuations of the brake disc for the various settings of gear meshes and frequencies were comprehensively understood.

Measurements and Graphs of Raw Measurements

The LDV measurements have been recorded in this experiment using different mesh frequencies, pitches, and angles on the wastewaters' reverberators. Frequency measurements were carried out in dual channels of 10 kHz and 20 kHz. Mesh sizes used at these channels were fine half mesh,

low mesh, and normal mesh respectively. The data was recorded specifically the vibration frequencies at the respective deflection angles in the (Z+) direction (Tomasini, and Castellini, 2020). The graphs here get the vibration frequencies recorded, and the settings of mesh when operated with various frequencies. The corresponding angles of deflection also are tabulated.

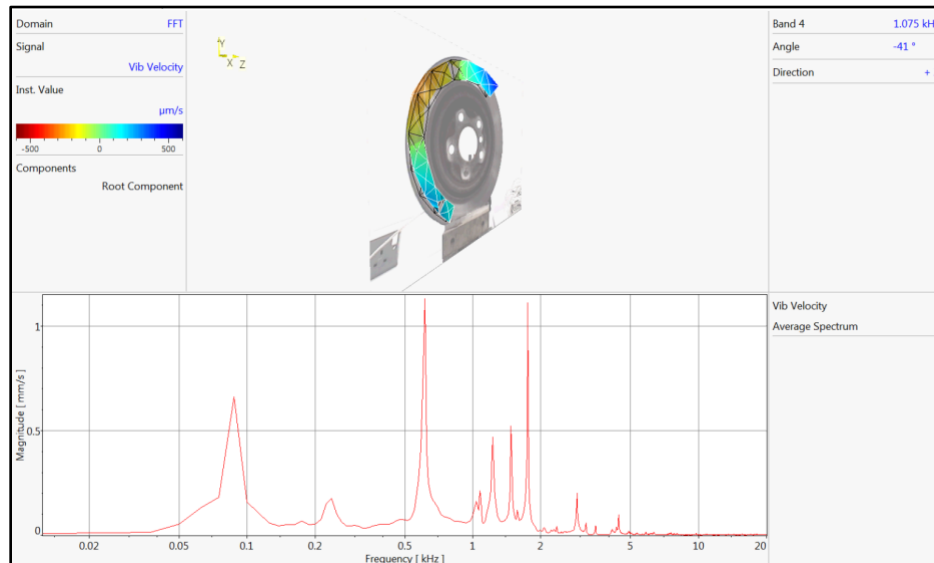


Figure 05: 20 khz fine half mesh

It has been observed that 13 bands have been used in the 10 khz fine half mesh, 10 khz low mesh, and 10 khz normal mesh. Among the 13 bands bands 1 to 3 had low frequencies which are 87.5 Hz, 225 Hz, and 612.5 Hz. Rest band frequencies varied from 1.08125 khz to 4.43125 khz. On the other hand, in 20 khz fine half mesh 15 band types had been used whereas low mesh and normal mesh had 13 band types.

Calculation and Error Estimation

There has been an array of resonant frequencies and angles observed for the mesh types and frequencies tested in the experiment. Based on the obtained data it can be stated that the specific mode of the disc vibration has been discovered in different situations. Afterward, the data processing was used to analyze and explain the result. To compute this, calculating the resonant

frequencies and angles was performed for each band and mesh setting of the waveguide. on the other hand, the uncertainties and mistakes in the measurements have been determined in the study (Chiariottii *et al.* 2020). It was assessed through the statistical study, chiefly by taking into account the equipment precision and the adverse weather conditions. Through these formulae and error estimations, the reliability and precision of the outcomes are ensured to provide a better knowledge of the brake disc's resonant frequency modes and geometrical shapes.

Result and Discussion

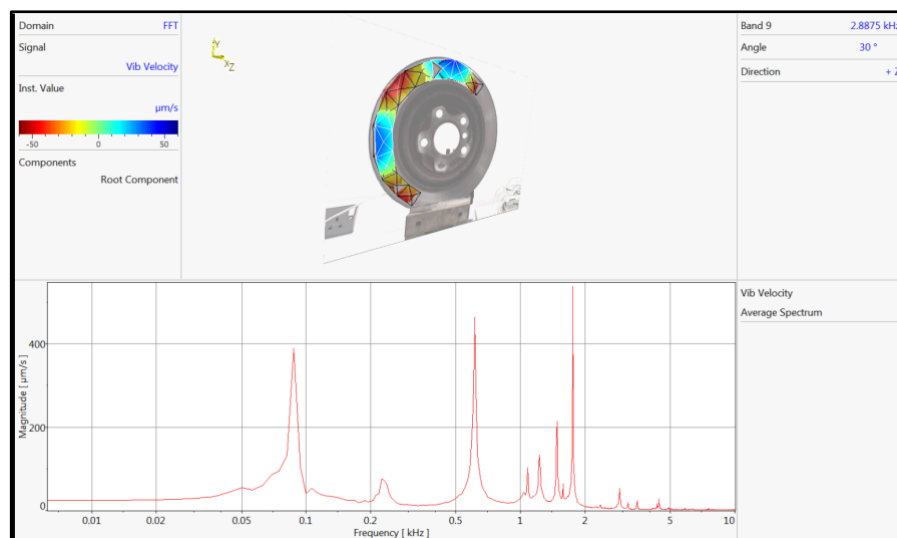


Figure 06: 10 kHz Fine Half Mesh

The LDV research has shown many different resonant frequency modes as well as their corresponding angles of the brake disc. This occurred after a study that was conducted on impact with a fine half mesh setting of 10 kHz. Furthermore, when the same band, Band 5, was measured, it was found to have a resonant frequency of 1.22 kHz when the angle was 160 degrees, directed in the positive Z direction. One wavelength of 1MHz reflective material is at -84° with a resonant frequency of 1081.25kHz. Sympathetic vibrational installations were brought about by frequencies ranging between 1.48125 kHz and 4.43125 kHz with their angles from -178 degrees to 167

degrees. Moreover, the disc modes of vibrations have resulted in quite a few resonating frequencies from 87.5 Hz which corresponds to the Band 1 to Band 3. The last one was 612.5 Hz which confirmed the added vibrational behavior of the disc across the different frequencies and meshes.

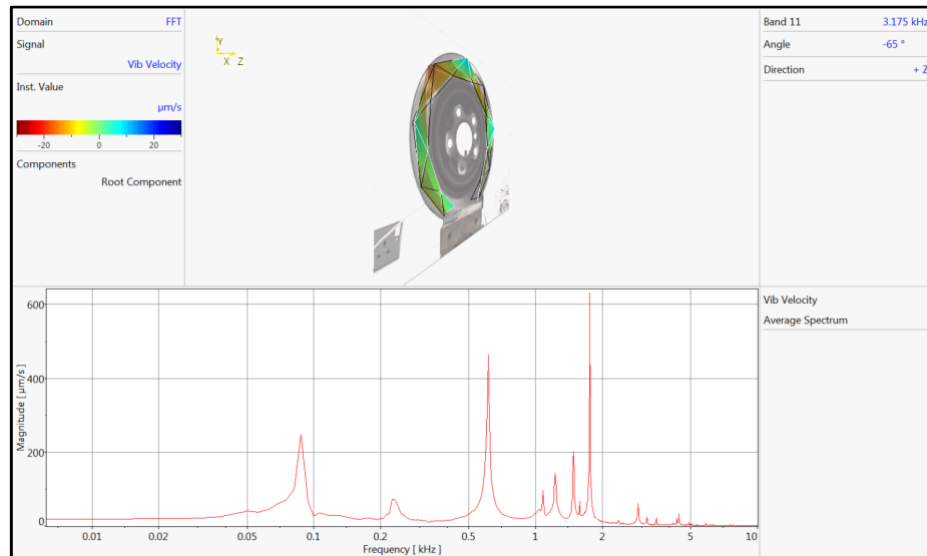


Figure 07: 10 khz low mesh

The measured performances for the LDV experiment at the fine half mesh settings of 10kHz and the low mesh settings of 10 kHz revealed the existence of important and resonant frequency modes for the brake disc. It was, however, the particular case of Band 5 at the finer half mesh that showed a resonant frequency of 1.22 kHz for an angle of 160° in the positive Z direction. Only at the lower mesh size, Band 5 showed a somewhat higher resonance frequency of 1,225 kHz at an angle of 100 degrees to the positive Z axis. The other bands present in with mesh settings of low ranged in frequency of 703 m. The corresponding angles varied from -161 degrees to 138 degrees. Furthermore, lower frequency bands (Band 1 to Band 3) were resonant frequencies of 87.5 Hz to 612.5 Hz, besides the brake disc demonstrates a complex vibrational behavior under different mesh setups.

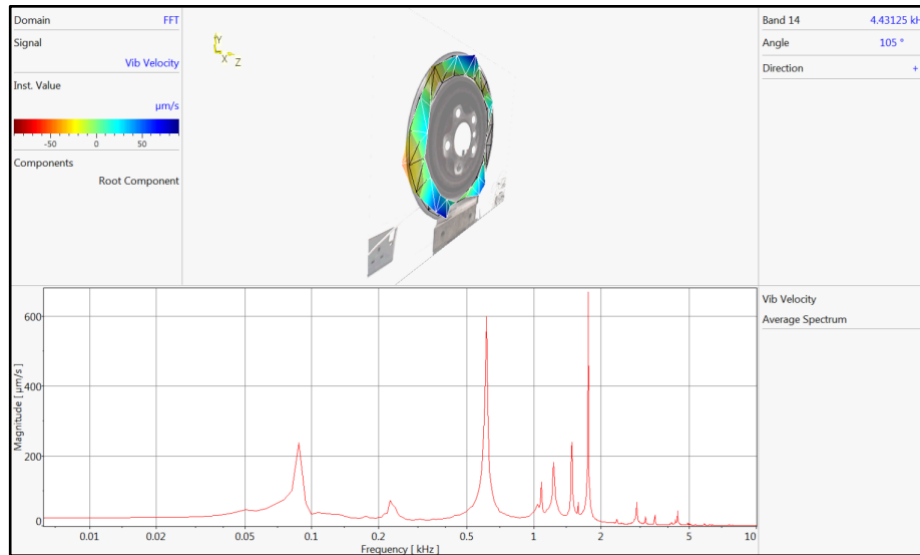


Figure 08: 10 khz normal mesh

Immensely, at a normal mesh setting of 10 kHz, several resonant frequencies were seen from Bands 4 to 13, which ranged from 1.08125 kHz to 4.43125 kHz, and their respective angle correlated from -172 degrees to 105 degrees in the positive Z direction. As opined by Stamm *et al.* (2021), this inference pertains to the variation of vibration within the brake disc due to normal friction, which indicates that the brake disc has a complex nature of modal features.

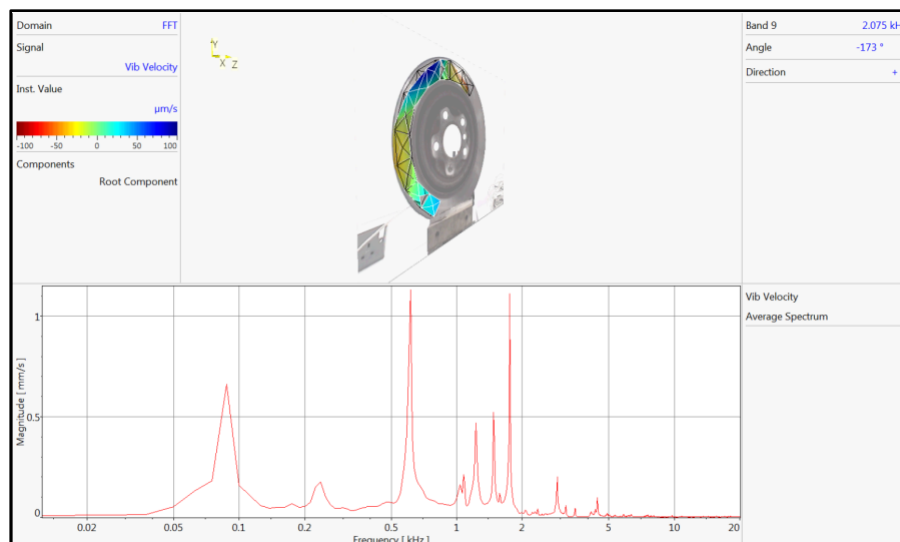


Figure 09: 20 khz fine half mesh

Comparably, at a fine half mesh of 20 kHz, Bands 4 to 15 had the most marked resonant frequencies ranging from 1.075 kHz to 4.9125 kHz, and the corresponding angles in the positive Z direction spanning from -173 degrees to 167 degrees. As stated by Chen, and Zhu, (2021), it means that a lot of the resonance frequency modes and shapes exist in the brake disc at and around the fine half mesh, implying that the disc is quite sensitive to the changes in the mesh state and frequency.

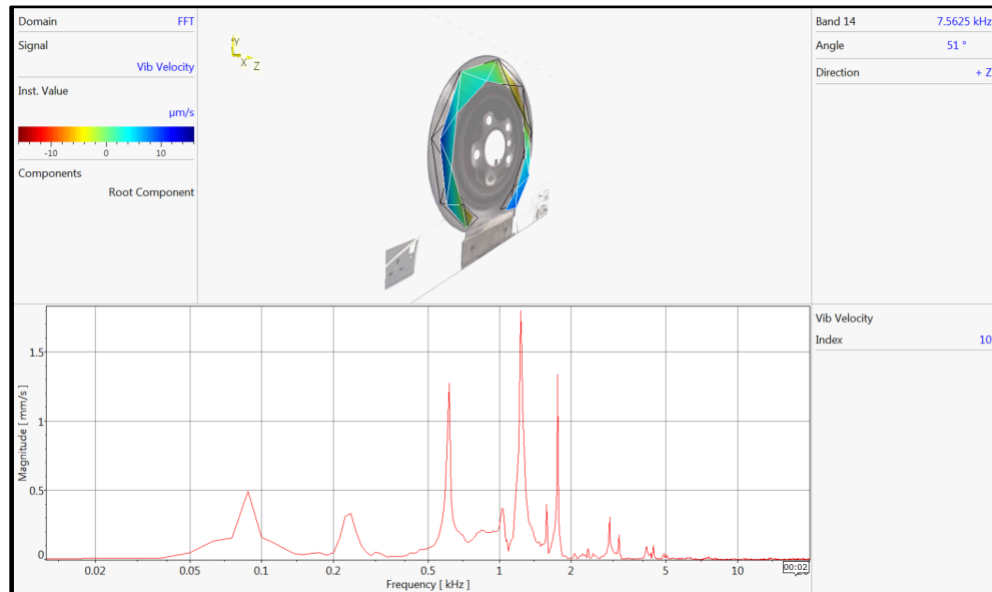


Figure 10: 20 khz low mesh

For the 20 kHz low mesh setting the frequency range was from 1.08125 kHz to 4.43125 kHz covering Bands 4 to 13 and angles increasing with the kilohertz up to 135 degrees in the positive Z direction. That states that there is a constant pattern of resonant frequency modes and shapes for the different levels of mesh, which in turn testifies to the dependability of the brake disc's vibrational behavior under varying experimental conditions. The magnitude vs frequency graph for 10 and 20 khz meshes has been presented precisely in the above image. It has been observed that the highest magnitude of the fine half-mesh ranged between 400-500 $\mu m/s$ whereas it went

above $600\mu m/s$. On the other hand, the magnitude graph varied in 20 khz fine half, low, and normal meshes between 1-1.5 mm/s.

Conclusion

The summary of the experiments done using Laser Doppler Vibrometer (LDV) revelations and the modes and shapes resonating of brake discs as they change driving frequencies and mesh-set settings were well captured and highlighted by the end of this investigation. Through the PolyTec Scanning LDV instrument, the study was able to conduct precise measurements and the analysis of the vibration of the brake disc as it varied under different operating conditions thereby clearly exposing the disc's dynamics. On account of the fact that intricate oscillations and shapes of the brake disc layer were found to increase, meaning that factors like mesh type and frequency matter.

Reference List

- Abbas, S.H., Jang, J.K., Kim, D.H. and Lee, J.R., 2020. Underwater vibration analysis method for rotating propeller blades using laser Doppler vibrometer. *Optics and Lasers in Engineering*, 132, p.106133.
- Chatterton, S., Dassi, L., Gheller, E., Ghisi, T., Vania, A. and Pennacchi, P., 2024. Torsional Vibration Analysis Using Rotational Laser Vibrometers. *Sensors*, 24(6), p.1788.
- Chen, D.M. and Zhu, W.D., 2021. Investigation of three-dimensional vibration measurement by three scanning laser Doppler vibrometers in a continuously and synchronously scanning mode. *Journal of Sound and Vibration*, 498, p.115950.
- Chiariotti, P., Rembe, C., Castellini, P. and Allen, M., 2020. Laser doppler vibrometry measurements in structural dynamics. *Handbook of Experimental Structural Dynamics*, pp.1-45.
- Mekhalfia, M.L. and Procházka, P., 2024, February. Analytical and Experimental Modal Analysis of a Bladed Disk. In *Journal of Physics: Conference Series* (Vol. 2698, No. 1, p. 012015). IOP Publishing.
- Singh, A., 2022. Investigation of the chatter and squeal phenomenon in bicycle disc brakes.
- Stamm, M., Schlemme-Weber, S., Appl, S., Köser, J. and Pfeiffer, H., 2021. Fast loose rivet detection by using scanning laser Doppler vibrometry. *J. Nondestruct. Test*, 3, pp.2843-2853.
- Tomasini, E.P. and Castellini, P., 2020. *Laser Doppler Vibrometry*. Springer Berlin Heidelberg.

Appendices

Appendix 1: Error bars

