Registration Number: 170154415

The University Of Sheffield.

MEC327 STRUCTURAL VIBRATION

MODAL ANALYSIS OF A TURBINE BLADE
WRITTEN REPORT TO SUPPORT MATLAB SCRIPT

The purpose of this report it to display results from a modal analysis of a turbine blade obtained through MATLAB. A tap test was carried out on the turbine blade at 10 locations along the blade, where input forces and vibrational responses were measured and recorded along with time. This data was then used to find important dynamic properties, such as natural frequencies, damping ratios and mode shapes, of the turbine blade in order to understand its dynamic response [1].

First FRFs of magnitude and phase were produced for each location, similar to the one shown in figure 1, which is for the first location. Figure 2 shows the magnitudes of the FRFs at each location on one plot, with the peaks circled. It can clearly be seen that the first five peaks occur at the same frequency for each location, therefore identifying the first five natural frequencies. These values can be seen in table 1.

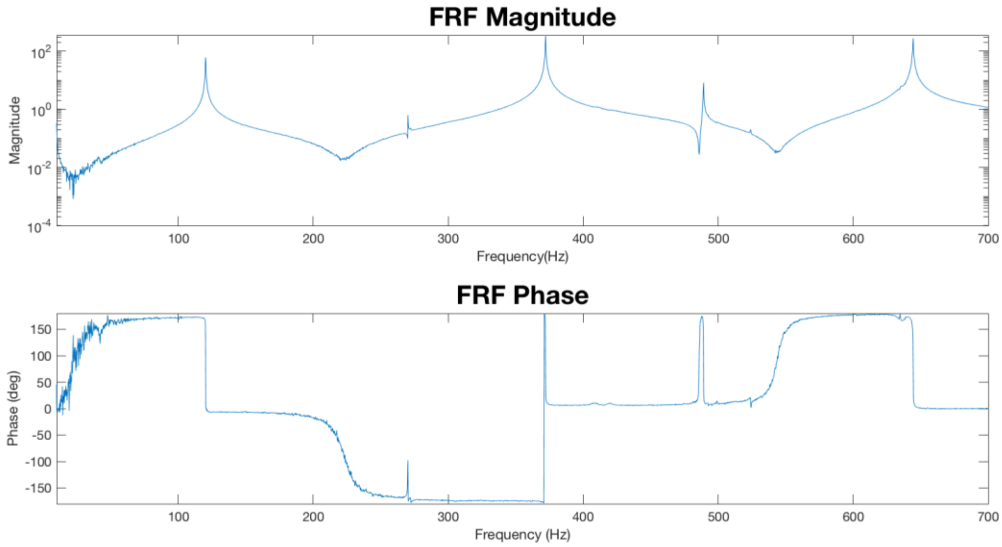

Figure 1. *FRF magnitude and phase for location 1*

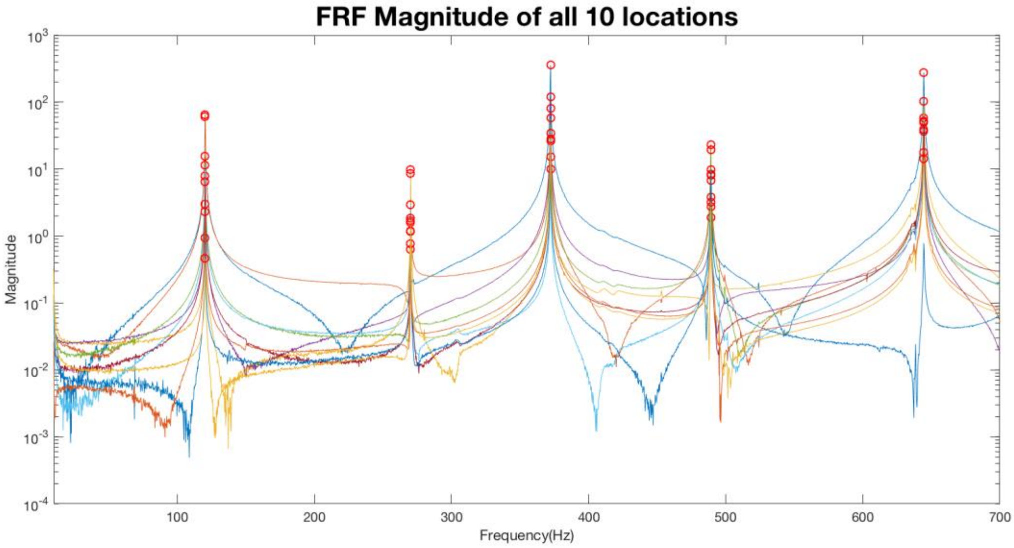

Figure 2. *FRF magnitudes for each location*

Knowing the natural frequencies of a system is crucial for a designer in industry to meet safety standards, by ensuring they are not the same as excitation frequencies [2] therefore avoiding resonance. Table 1 also shows the average damping ratio of the first five modes. These were found using interpolation and the 3dB method. Damping ratios tell us how rapidly oscillations in a system decay after a disturbance [3]. These damping ratio values are all less than 1 therefore telling us that this system is underdamped.

Table 1. *The first 5 natural frequencies and damping ratios of the turbine blade*

Natural Frequencies, Hz	120.25	270.25	372.25	489.25	644.50
Average Damping Ratios	0.0013	0.0003	0.0003	0.0003	0.0003

Although modal analysis can be a useful way of estimating important modal properties of a system, there are some limitations to it. One of the limitations in this test is the difference between how the turbine is set up in the test and in real life. During the experiment the turbine is stationary, hung on springs in a free-free test-set and at room temperature, however in real life the turbine blade would be mounted at the base, rotating at great speeds and much higher temperatures. Therefore, the loads acting on the turbine blade when in operation will be very different from the test, as it will include centrifugal forces, centrifugal bending, steady steam bending, unsteady centrifugal forces due to lateral shaft vibration and alternation bending [4]. These additional forces and the increase temperatures may have effects on the natural frequencies and modal damping [5].

REFERENCES

1 Dr.R.J. Barthorpe, *MEC327 Structural Vibration*, Lecture pack (2019-2020), slide 99

2 A. Harish, *What Is Modal Analysis and Why Is It Necessary?* SIMSCALE Blog (2019), Available at: https://www.simscale.com/blog/2016/12/what-is-modal-analysis/ [Reviewed May 2020]

3 Wikipedia, *Damping Ratio*, Available at: https://en.wikipedia.org/wiki/Damping_ratio [Reviewed May 2020]

4 H.G. Naumann, *Steam turbine blade design options: how to specify or upgrade*, Proceedings of the eleventh turbomachinery symposium (1982), pp. 29-50

5 G.Feltrin, S.Schubert and R.Steiger, *Temperature effects on the natural frequencies and modal damping of timber footbridges with asphalt pavement*, Empa, Swiss Federal Laboratories for Material Science and Technology (2011), Available at: https://www.researchgate.net/publication/278672110_Temperature_effects_on_the_natural_frequencies_and_modal_damping_of_timber_footbridges_with_asphalt_pavement [Reviewed May 2020]