Report of Experiment No. 9

Static and Dynamic Balancing

For the course

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Executive summary

Balancing is one of the most essential concepts in the field of mechanical and civil engineering. Through a thorough understanding of the concept of static and dynamic balancing, several machinery can be developed which can be utilised for the benefit of society. Balancing helps remove unwanted vibrations, forces, or moments in a rotating or reciprocating system. Static balancing has immense applications in automotive industries, industrial fans, washing machines, dryers, etc. Dynamic balancing has applications in the avionics industry, rotating machinery in manufacturing, machine tools, electric motors, marine propellers, etc.

For our experimentation, we were provided with a setup that had a shaft connected to an electric motor, on which we had to perform and calibrate dynamic balancing. We were given four different masses of 280 grams, 277 grams, 270 grams, and 250 grams, respectively. We first understood the concepts of static and dynamic balancing before performing the experiment. We then aligned the three masses at angles of 0°, 90°, and 180° respectively. We then attached each mass at the distance of 0mm, 40mm, 80mm, and 120mm from the initial point of the shaft. After that, we calculated the angle of the last rod and performed dynamic balancing for the testing apparatus.

We observed that when we aligned the last mass exactly according to the calculations, dynamic balancing was achieved, which could be easily disrupted through minor misalignments and cause vibration and noise in the testing apparatus. Thus, a clear understanding of balancing is very important in our day-to-day applications.

Keywords — static balancing, dynamic balancing, vibrations, noise, alignment, calibration

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1. Introduction

Balancing refers to the process of minimising or eliminating unwanted vibrations, forces, or moments in a rotating or reciprocating system. The goal of balancing is to ensure that the mass distribution within a machine or a component is uniform and symmetrical, which helps reduce vibrations and improve the overall performance and durability of the system.

Balancing is crucial in machines for the following reasons:

- Vibration Reduction – Proper balancing reduces vibrations, which can lead to improved comfort, decreased wear and tear, and increased safety in machines.
- Energy Efficiency – Balancing minimises energy losses due to vibrations, resulting in higher energy efficiency.
- Reduced Noise – It helps reduce noise levels produced by machines, making them quieter and less disruptive.
- Enhanced Component Life – Balanced systems experience less stress and wear on components, increasing their lifespan.
- Improved Accuracy – Balancing ensures accurate and precise operation of machinery and equipment.

The issue with balancing is that the balanced part becomes loose over time. Thus, regular maintenance of products is required to properly calibrate and increase the lifespan of these products and machines.

2. Practical applications study

1.1 Application studied (Heading 2) (Arial 11, bold)

A fan was balanced as a practical applications study for the experiment. The three blades of the fan were attached with small masses which were used to balance the fan.

The methodology followed was as follows:

1. An old fan was chosen for the experiment and the blades of the fan were a little bent and thus were not balanced.
2. The fan blades were not in proper shape and thus were converted into the correct shape with hammering.
3. The balancing of the fan is achieved when the blade is rotated and the final position of the blade is not the same as the initial position.
4. Small screws were taken as weights and attached at different lengths after calculation to balance the fan.

The desired outcome for the experiment was the balancing of the fan.

Analysis of the balancing was done after repeated displacement of the fan blades from their initial position and recording their final position.

1.2 Observations and findings

The observations included that the masses that should be chosen for the experiment should be very small and that the length can be adjusted to balance the fan. For our experiment, we observed that the fan was not balanced, and thus the experiment was later repeated with smaller ball bearings after which the fan became balanced.

2. Theoretical and conceptual basics

2.1 Theoretical basis

The following theoretical base is required for performing the experiment

- Static Balancing – Static balancing stands for balancing components or machines rotating in a single plane. It involves balancing the component so that its centre of mass aligns with the axis of rotation. In static balancing, the component is balanced with respect to the gravitational forces only.
- Dynamic Balancing – Dynamic balancing is used for components or machines that rotate in multiple planes and are subjected to dynamic forces and moments during operation. It involves balancing the component in both the mass and geometrical distribution aspects. Dynamic balancing is essential to minimise vibrations.

2.2 Equations

The equation for static balance can be expressed as

$$M_{net} = 0 \tag{1}$$

Where M_{net} is the net moment about the axis of rotation, and it should be zero for static balance.

The equation for dynamic balance can be expressed as

$$M_{net} = F_{net} = 0 \tag{2}$$

Where M_{net} and F_{net} are the net moment and the net force about the plane of rotation respectively and both should be zero for dynamic balancing.

Here, for both cases, the dependent variables can be the mass of the weights, the angle of the mass inclination, and the distance of the mass from the initial axis. The independent variable is the speed of the motor, which provides the angular velocity of the shaft. The assumptions for static balancing include that the masses are rotating in a single plane, whereas for dynamic balancing, the same assumption need not be true.

2.3 Validation with theory

$$F_{net} = mrlcos\theta = mrlsin\theta = 0 \tag{3}$$

These are the relations which can be used to calculate the alignment and location of the masses in order for them to be perfectly dynamically balanced.

3. Pre-experiment planning

The things performed and kept in mind before performing the experiment are as follows.

3.1 Safety

The apparatus was thoroughly studied, and a CAD model was created for the same, along with a cage, to ensure complete safety during the experiment. All the connections from the electric motor and the pulley system were checked to ensure that the testing apparatus was safe. All the masses, when attached to the shaft, were checked to be correctly attached, removing the chances of any of the masses flying off during the experiment. The testing apparatus itself was firmly screwed to the table, which removed any chance of an accident. The entire apparatus was thoroughly cleaned, and everything was checked for cracks or other failures.

3.2 Independent and dependent variables

Here, for both cases, the dependent variables can be the mass of the weights, the angle of the mass inclination, and the distance of the mass from the initial axis. The independent variable is the speed of the motor, which provides the angular velocity of the shaft. The assumptions for static balancing include that the masses are rotating in a single plane, whereas for dynamic balancing, the same assumption need not be true. The speed of the motor can be controlled by a foot pedal, which was part of the testing apparatus.

3.3 Result formulae/relations

$$F_{net} = mrlcos\theta = mrlsin\theta = 0 \qquad (3)$$

These are the relations which can be used to calculate the alignment and location of the masses in order for them to be balanced as stated above as well. Here, the radius and the angular velocity ω based on the speed of the motor are independent variables as they are cancelled from both equations and thus aren't mentioned in the previous relation.

3.4 Pre-test uncertainty analysis

Parameter	Uncertainty
Mass	0.1 kg
Length	3mm
Angle	1°

The random standard uncertainty was calculated using the observed experimental imbalance in the system which was observed while performing the experiment for balancing. These include observational uncertainties as well as scale uncertainties. These uncertainty values are adequate to balance the testing apparatus successfully and thus are viable.

3.5 Test matrix

Serial Number	Mass(M)	Length(L)	Angular Velocity (ω)	Angle(**θ**)

For the values of the independent parameters like the radius and angular velocity of the shaft, the values cancel out in the calculations and thus a quantitative analysis was not performed but a qualitative analysis was performed.

The dependent variables include mass, length, and angle, which are all crucial to the balancing of the testing apparatus. All the scales were checked for errors and calibrated. Once we fix two parameters, the third dependent variable can be calculated using the equations mentioned above. The repeatability of the experiment was ensured by realigning the setup and checking for the same.

4. Experiment execution

During the start of the experiment, the security of all the equipment present in the testing apparatus was covered, and all safety precautions were adhered to. The masses were first removed from the testing apparatus, and the balance of the massless shaft was measured using the scales in the testing apparatus. The scales were also recalibrated, and thus, proper functioning of the testing apparatus was ensured. After that, all the masses were weighed and tested. Afterwards, two of the dependent variables were fixed, and the third parameter was calculated on the basis of the equation mentioned above. After calculating the dependent variables, the experiment was performed several times, and the results were concluded as the testing apparatus was balanced.

5. Data analysis and discussion

Serial Number	Mass(M)(grams)	Radius(r)	Length(L)(mm)	Angular Velocity (ω)(rad/sec)	Angle(**θ**)
1	280	r	0	ω	0
2	277	r	40	ω	90
3	270	r	80	ω	180
4	250	r	120	ω	90

As per the test uncertainty matrix the uncertainty in the measurement of these dependent variables can be approximated, calibrated, and ignored as long as the final result of the dynamic balance of the system is achieved.

6. Conclusions

By performing the experiment, we understood the characteristics of rotating masses in the context of static and dynamic balancing. We understood why understanding the physics of balancing is important for the smoother functioning of machines and equipment in various sectors of various industries. Unbalance in a system causes unwanted vibrations in the system along with the increase in the wear and tear of the machines, which in turn reduces the total life expectancy of the machine. As engineers, it is crucial to perform an in-depth study about static and dynamic balancing to make sustainable machines for longer work hours and also maximise safety as the unbalance of a machine can result in a fatality for a consumer.

7. References

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