MANTECH Publications

Journal of Modern Mechanical Systems and Machining

Volume 4, Issue 1, January-June 2021

Impeller with Centrifugal Force: Design and Analysis

Jeetendra Sharma

Department of Mechanical Engineering

Allahabad College of Engineering And Management

Corresponding Author's Email id: *jeetendrasharma17@gmail.com*

Abstract

Centrifugal pumps are widely utilised in a variety of sectors for a variety of applications. Because the blade intake or outlet angle affects the pump's performance, vibrations are a factor. By changing the geometric features of the impeller of the pumps, the performance of centrifugal pumps may be enhanced. The blade exit angle has a significant impact on centrifugal pump performance. The blade exit angle is the primary source of vibration. The blade rotates according to its inherent frequency and mode shapes. A single-entry impeller with radial vanes was chosen for the research. Modeling and simulation of the impeller were carried out using Creo 4.0 and ANSYS Workbench software. Using eigenvalues and eigenvectors, the relative frequencies and associated mode forms of the impeller were determined. The results revealed that changing the impeller blade exit angle had a substantial impact on the impeller's natural frequency.

Keywords: *Ansys, Workbench software, Impeller, Centrifugal force, Vibration*

INTRODUCTION

Vibration is a natural phenomenon that must be taken into account while designing, developing, and maintaining equipment. Machine vibrations can be caused by a variety of factors, including the features of the machinery itself or an external source. The impacts of vibration, regardless of the cause, are extremely disruptive when running a machine and result in low efficiency. Vibration analysis is an essential component in the design and maintenance of machines.

The vibration is caused by the machine's moving components. The natural and excitation frequencies are the same [1]. It's referred to as a resonance or crucial speed. Another sort of machine vibration issue, which is less frequent but more difficult to solve, might arise from the machine structure and its supports' inherent vibration frequencies, even if no imbalance or stimulation is present. The impellers play a major role in centrifugal pump performance. The exit angle of the impeller blade has a major impact on vibration during operation.

The spinning component of a centrifugal pump is an impeller, which drives the pump using a motor to propel the fluid being pushed outwards from the centre of rotation. Modeling of the impeller is done with Creo 4.0, and model analysis is done by altering the different blade angles and calculating the natural frequency, stress, and strain values [2-3].

METHODOLOGY

The techniques utilising the embrace to design and optimise the impeller and improve pump performance are shown in Fig. 1.

The flow pattern inside the impeller vanes of the pump determines the pump's performance. Because the flow pattern is streamline, there are less losses and a higher output head.

It is accomplished by using a streamline flow path to overcome obstacles such as flow separation, secondary flow creation, and eddy generation. This makes it feasible to come up with the optimum design approaches for creating the vane profile.

The design parameters determine the range of operations, which has an impact on pump performance. For a given application and distinct system architecture, the unique solution is rarely achieved [4-5].

To determine the optimum solution through optimization in order to maximise design parameters throughout design construction

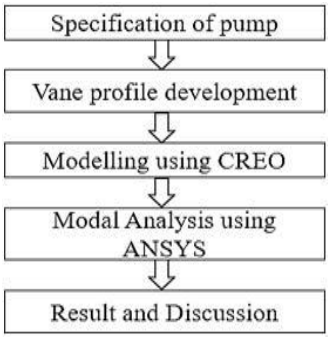

Figure 1: Methodology

Pump Specifications

Table 1 shows the pump specifications.

Table 1: Pump specifications

Head height (H)	11 to 122 m
Discharge (Q)	0.0049 m^3/sec
Temperature of liquid (T)	39 °C
Pump speed (N)	2300–2800 r.p.m

Vane Profile Development

A multiple curvatures profile for the impeller of the pump is considered in this design, as shown in Fig. 2, with four distinct centres of four different radii curvatures of the vane profile for the impeller of the pump.

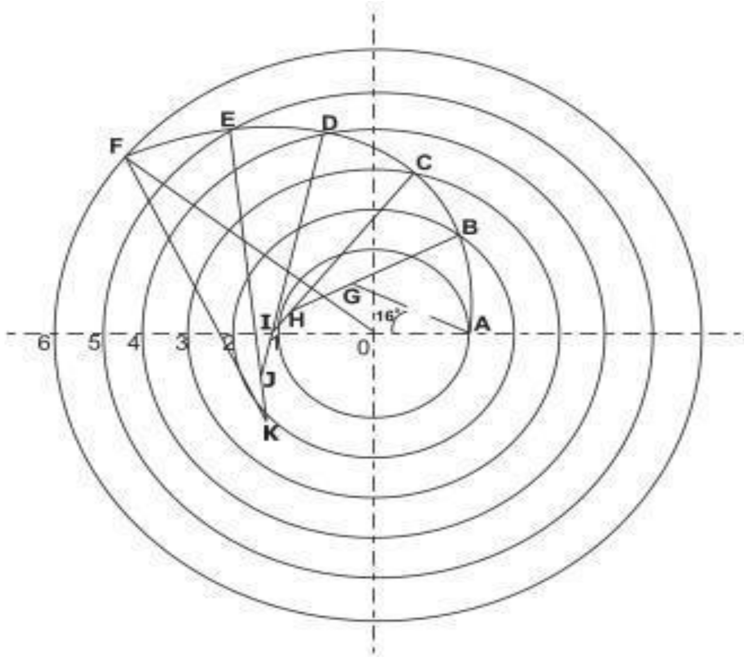

Figure 2: Vane profile construction

The following stages are involved in tracing the vane profile:

- The inlet and outlet circles are drawn.
- Two axes of reference have been drawn, one vertical and the other horizontal.
- Four additional circles are drawn, with points one through six on the axis spaced at equal intervals in order to trace the profile with four radii of curvature.
- Curves are drawn from the places G, H, I, J, and K via the points A, B, C, D, and E.
- To calculate the length of the first arc's radius of curvature, draw a line from the place where the inlet circle meets the horizontal axis at a 35° angle.
- Using the matching radius, draw an arc with the end point of this line as the centre until the arc reaches the next circle.
- A line is drawn from the point where the arc meets the next circle to the length of the next radius of curvature, passing through the previous centre.
- An arc is created using this line's end point as the centre and the appropriate radius until the arc reaches the next circle.
- Continue in this manner until all four arcs have been drawn.

Modeling of Impeller

The impeller was modelled in Creo 4.0, and the impeller dimensions are listed in Table 2. The impeller is made of cast iron, and the blades are 2.5mm thick [6-7].

Table 2: Pump impeller dimensions

Blade number (Z)	6
Impeller inlet diameter (D1)	50 (mm)
Impeller outlet diameter (D2)	130 (mm)
Blade discharge angle (β2)	20º
Blade inlet angle (β1)	35º
Blade height (b)	15 (mm)
Blade thickness (t)	2.5 (mm)

The semi open impeller dimension is shown in Fig. 3. Semi open impellers are widely used in the industries because they can be used in medium-diameter pumps.

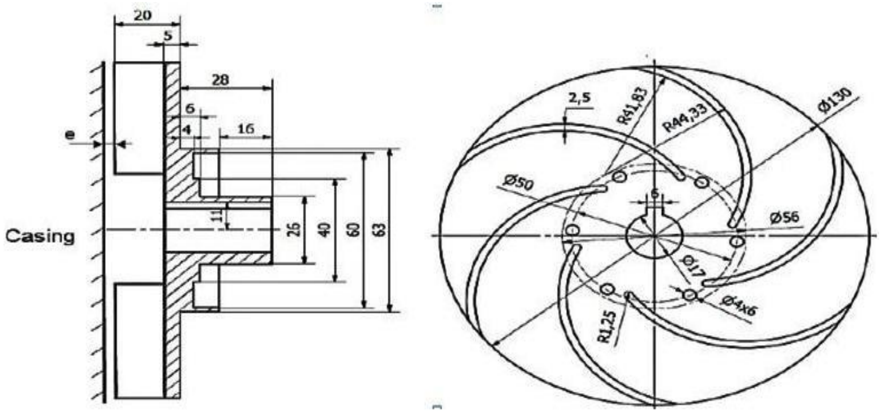

Figure 3: Semi open impeller dimension

Figure 3 depicts the semi-open impeller dimension. Semi open impellers are extensively used in industry because they may be utilised in medium-diameter pumps carrying tiny quantities of suspended particles and also minimise recirculation and other losses. It is critical that the impeller vanes and the casing have a minimal clearance. The creo 4.0 modelled impeller is illustrated in Figure 4.

MANTECH Publications

Journal of Modern Mechanical Systems and Machining

Volume 4, Issue 1, January-June 2021

Figure 4: Modelled impeller

MODAL ANALYSIS BY VARYING ANGLE

Modal analysis is performed by adjusting the blade angles 20º, 21º, 22º, 23º, 24º and

25º. Its natural frequency, stress, and strain levels are all calculated.

Outlet Blade Angle 20º

The natural frequency obtained at a 20o blade exit angle is given below, together with the associated stress and strain values in Figs. 6 and 7.

Different modes of the natural frequency at a 20º outlet vane angle are presented. The natural frequency for mode 1 is 755.29 Hz. The frequency in mode 2 is 756.2 Hz. The native frequency is 916.59 MHz in mode 3.

A natural frequency of 1220.3 Hz is used in mode 4. The natural frequency in mode 5 is 1220.7. The native frequency of mode 6 is 1959.8 Hz [8- 9].

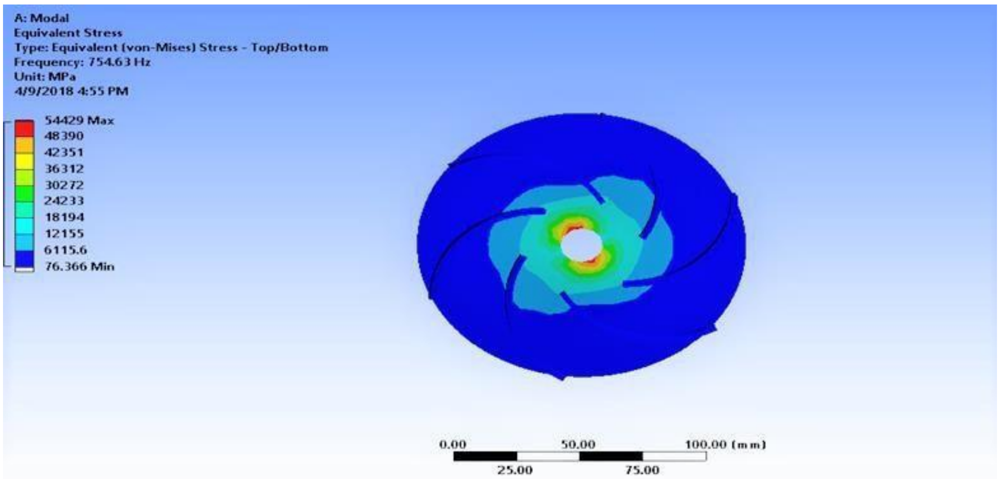

Figure 5: Outlet Blade Angle 20º

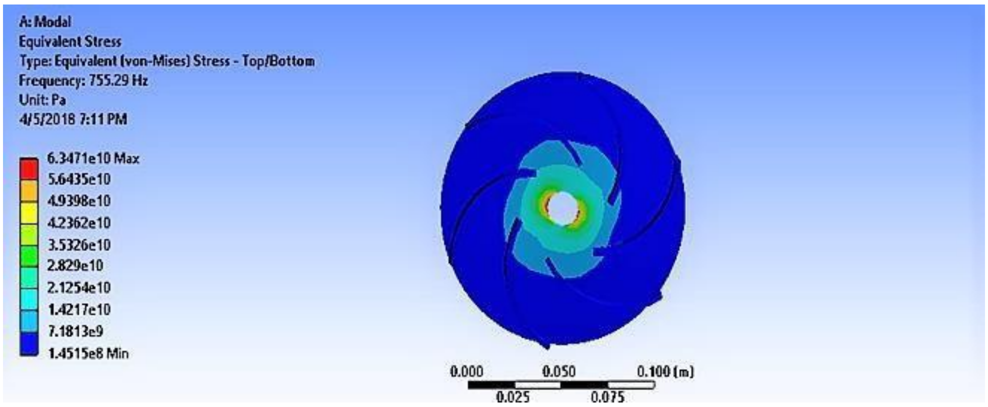

Figure 6: Stress analysis at 20º.

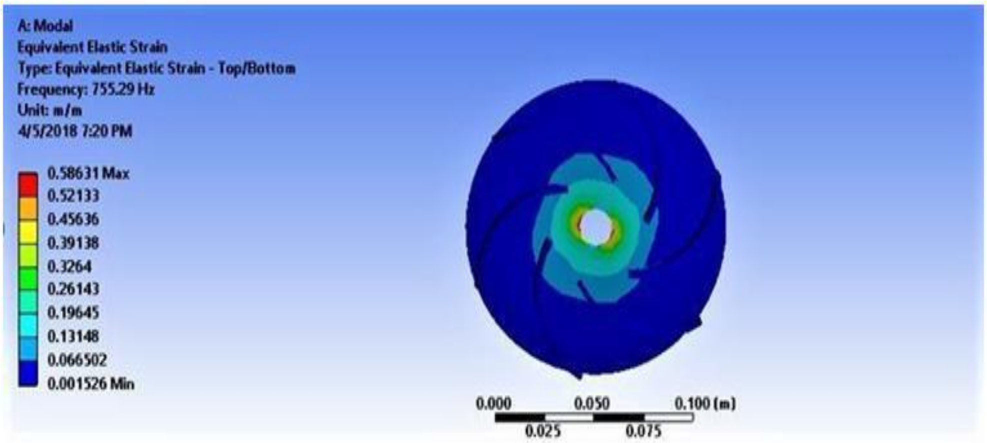

Figure 7: Strain analysis at 20º.

Outlet blade Angle 21º

The natural frequency obtained at 21º blade exit angle is shown below and its corresponding stress and strain values are shown in Fig. 8 and Fig. 9 respectively.

The natural frequency at 21º outlet vane angle is shown in different modes. At mode 1, the frequency is 754.63 Hz. At mode 2, the frequency is 755.73 Hz. At mode 3, the frequency is 914.88 Hz. At mode 4, the frequency is 1217.88 Hz. At mode 5, the frequency is 1218.3 Hz. At mode 6, the frequency is 1979.8 Hz.

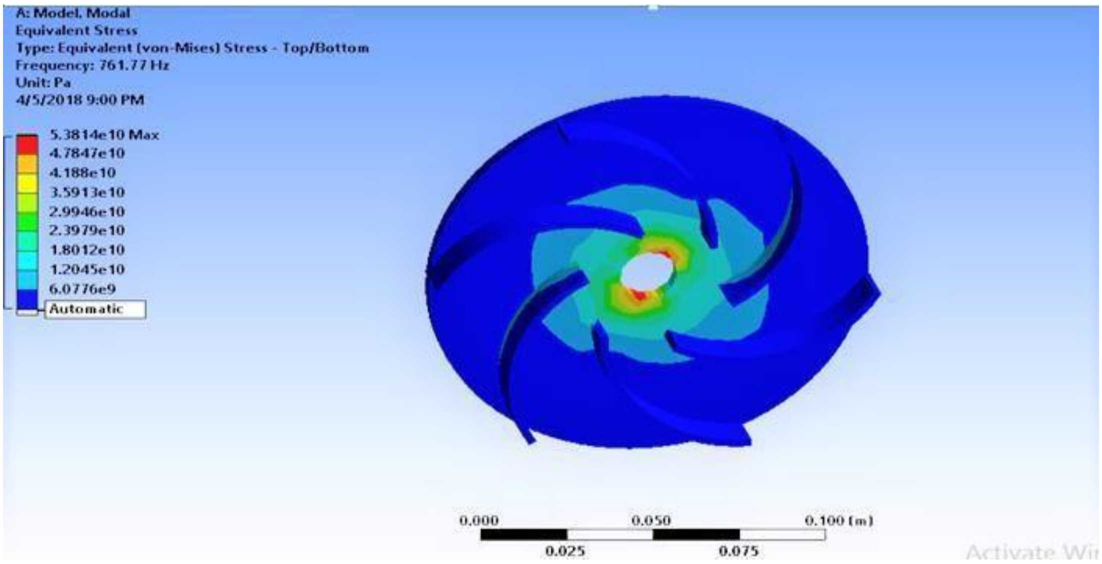

Figure 8: Stress analysis at 21º

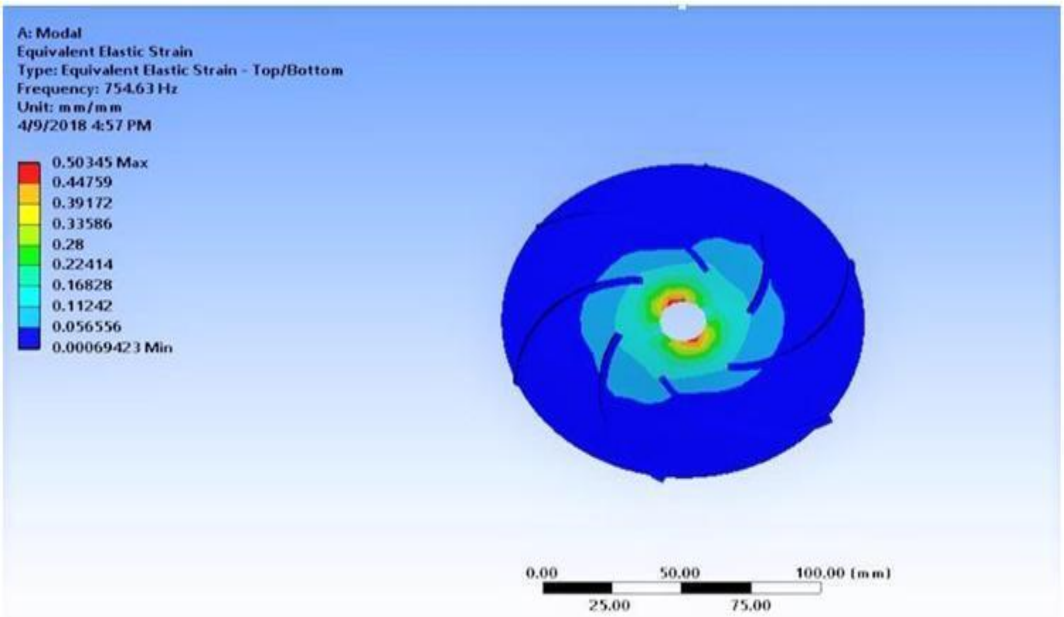

Figure 9: Strain analysis at 21º.

Outlet Blade Angle 22º

The natural frequency obtained at 22º blade exit angle is shown below and its corresponding stress and strain values are shown in Fig. 10 and Fig. 11 respectively.

The natural frequency at 22º outlet vane angle is shown in different modes. At the mode 1, the frequency is 759.27 Hz. At mode 2, the frequency is 760.0 Hz. At mode 3, the frequency is 915.99 Hz. At mode 4, the frequency is 1220.1 Hz. At mode 5, the frequency is 1220.6 Hz. At mode 6, the frequency is 1986.3 Hz.

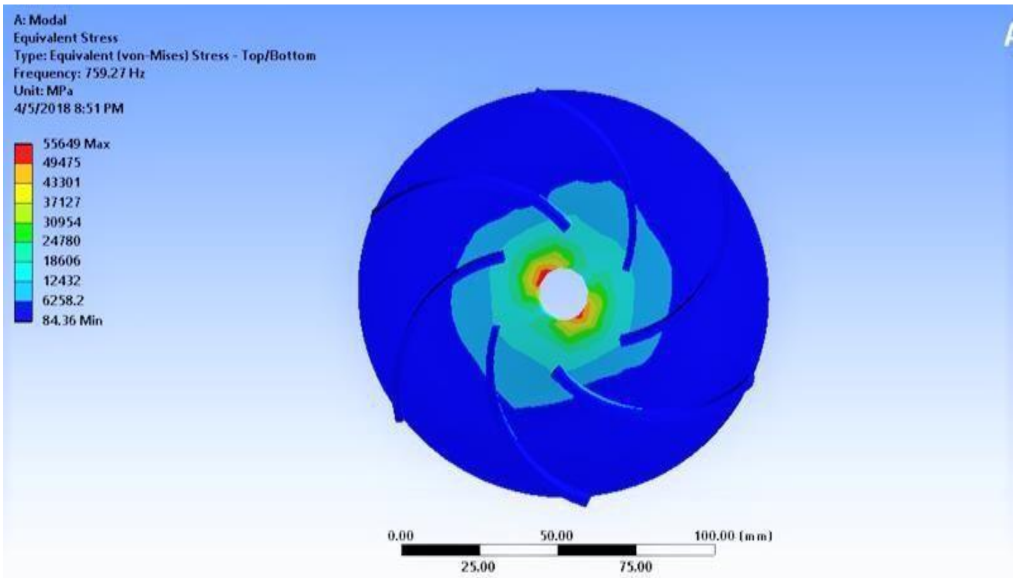

Figure 10: Stress analysis at 22º.

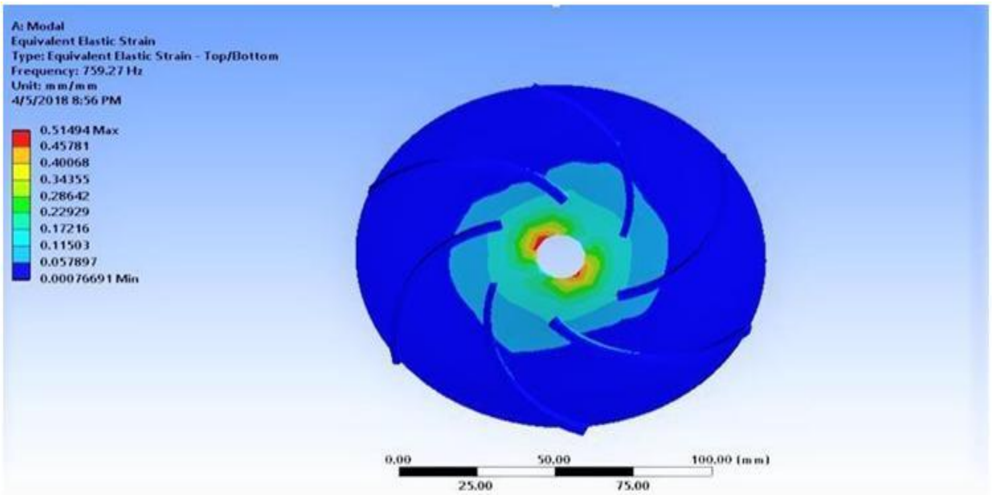

Figure 11: Strain analysis at 22º.

Outlet Blade Angle 23º

The natural frequency obtained at a 23º blade exit angle is given below, together with the associated stress and strain values in Figs. 13 and 14.

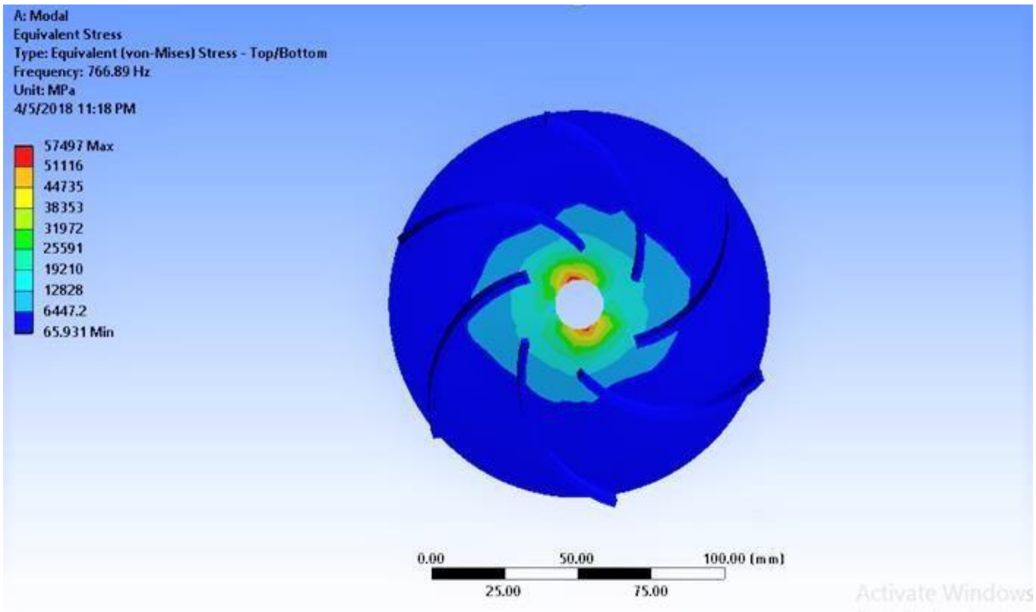

Figure 12: Stress analysis at 23º

The natural frequency at 23º outlet vane angle is shown in different modes. At the mode 1, the frequency is 761.77 Hz. At mode 2, the frequency is 762.74 Hz. At mode 3, the frequency is 916.22 Hz. At mode 4, the frequency is 1221.4 Hz. At mode 5, the natural frequency is 1222.0 Hz. At mode 6, the frequency is 1990.9 Hz.

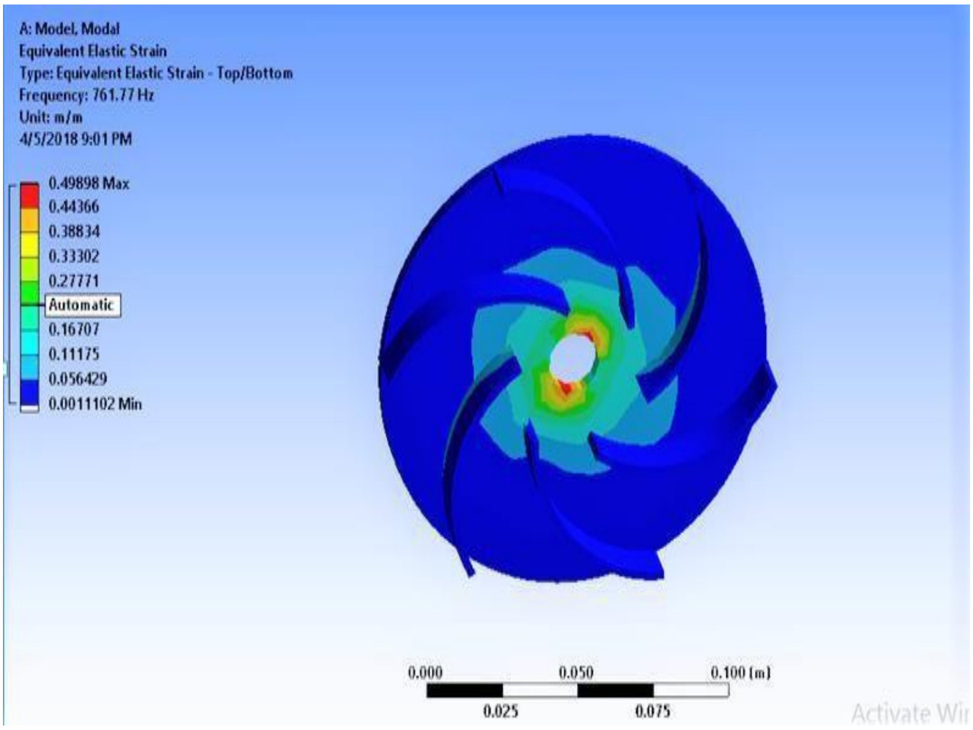

Figure 13: Strain analysis at 23º.

Outlet Blade Angle 24º

The natural frequency obtained at 24º blade exit angle is shown below and its corresponding stress and strain values are shown in Fig. 15 and Fig. 16 respectively.

The natural frequency at 24º outlet vane angle is shown in different modes. At mode 1, the frequency is 766.89 Hz. At mode 2, the frequency is 768.8 Hz. At mode 3, the frequency is 917.88 Hz. At mode 4, the frequency is 1225.7 Hz. At mode 5, the frequency is 1226.2 Hz. At mode 6, the frequency is 1995.7 Hz.

Outlet Blade Angle 25º

The natural frequency obtained at 25º blade exit angle is shown below and its corresponding stress and strain values are shown in Fig. 17 and Fig. 18, respectively.

The natural frequency at 25º outlet vane angle is shown in different modes. At the mode 1, the natural frequency is 769.07 Hz. At mode 2, the frequency is 770.62 Hz. At mode 3, the natural frequency is 918.01 Hz. At mode 4, the frequency is 1227.4 Hz. At mode 5, the natural frequency is 1227.9 Hz. At mode 6, the natural frequency is 1998.6 Hz.

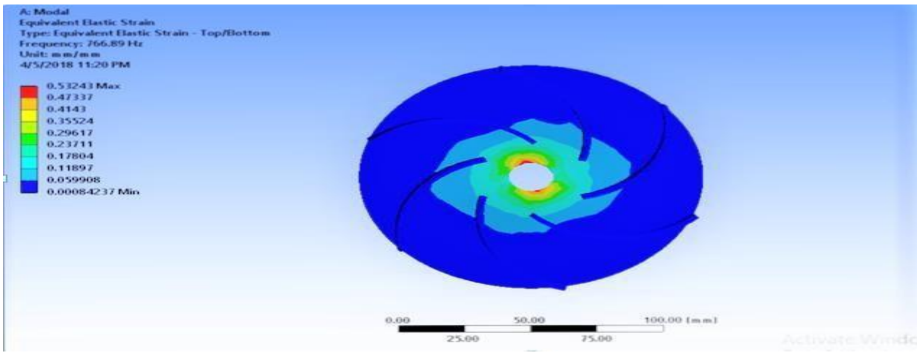

Figure 14: Strain analysis at 24º.

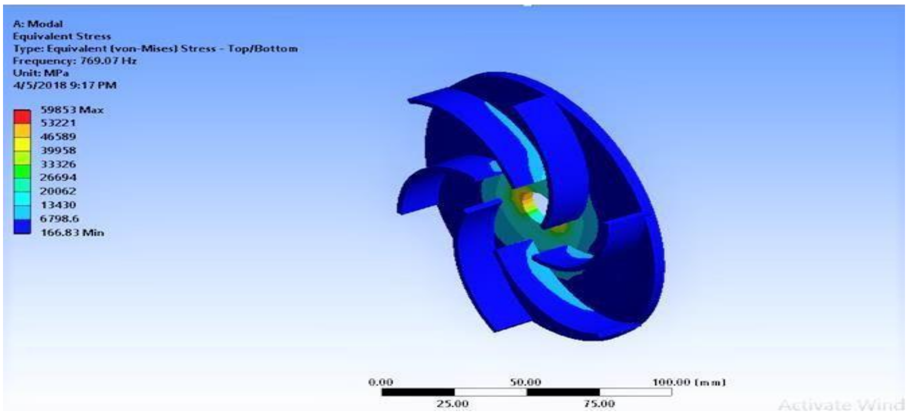

Figure 15: Stress analysis at 25º.

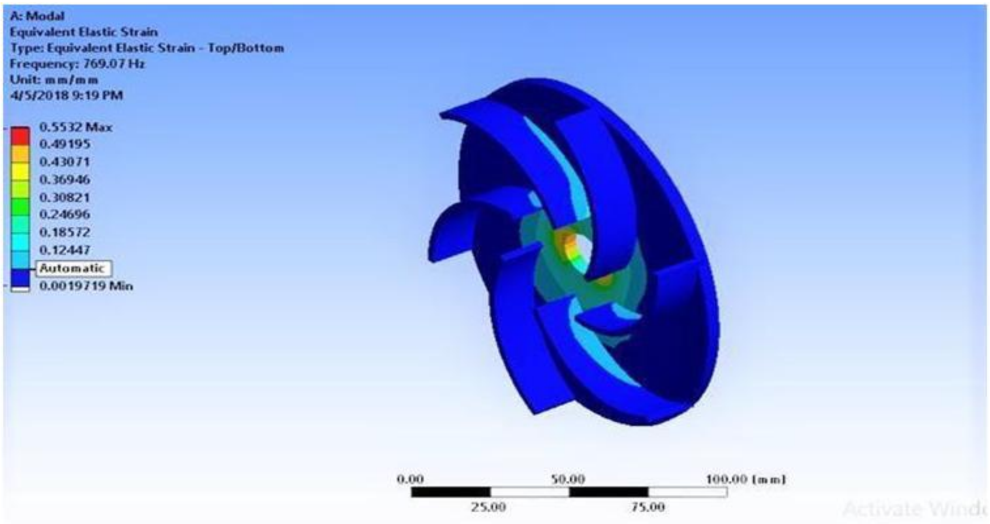

Figure 16: Strain analysis at 25º.

RESULTS AND DISCUSSION

The acquired data are examined, and it is discovered that adjusting the blade exit angle of the blade changes the natural frequency of the impeller.

Results from Varying Blade Angle

Table 3 shows the natural frequencies of six modes at various blade angles.

Table 3: Natural frequency from varying blade angle

Mode	Frequency					
	$\beta =$	$\beta = 21^o$	$\beta =$	$\beta =$	$\beta = 24^o$	$\beta = 25^o$
1	755.29	754.63	759.27	761.77	766.89	769.07
2	756.2	755.73	760.0	762.74	768.8	770.62
3	916.59	914.88	915.99	916.22	917.88	918.01
4	1220.3	1217.8	1220.1	1221.4	1225.7	1227.4
5	1220.7	1218.3	1220.6	1222.0	1226.2	1227.9
6	1959.8	1979.8	1986.3	1990.9	1995.7	1998.6

With increasing impeller blade exit angle, the natural frequency rises. The least natural frequency value obtained is 755.29 Hz at a 20o blade exit angle, while the maximum value achieved is 1959.8 Hz. Finally, at a 25o blade exit angle, the minimum frequency is 769.07 Hz, and the maximum frequency is 1998.6 Hz. In comparison to 20o blade angle, the flow area becomes narrower at 25o blade angle, and fluid flow is less disturbed. As a result, natural frequency rises. The effectiveness of the blade will be reduced if the exit angle of the blade is increased further.

Table 3 shows that the likelihood of the resonance occurring has risen, and that any disruption of 769.07 Hz will cause the resonance to occur. This is a safe setting that protects the pump against damage and loss of performance.

CONCLUSION

The impellers' modal behaviour was investigated for varied blade angles ranging from 20^{o} to 25^{o} with 1^{o} increments.

Finally, this vibration study of a centrifugal impeller with various blade exit angles came to the following conclusion:

- As the impeller's blade exit angle increases, the natural frequency rises.
- The rise in natural frequency can be attributed to the structure's rigidity, which is greater than the mass supplied to the impeller.
- For modes 1 and 2, the natural frequency values of any blade angle were almost identical.
- Any blade angle's natural frequency values were somewhat raised for modes 3 and 4.
- Any blade angle's natural frequency values rose rapidly for modes 3 and 4 and modes 5 and 6.

Because the natural frequency changes with the blade exit angle, resonance failure of the impeller can be prevented by selecting an impeller with a blade angle that differs from the pump's operating frequency.

REFERENCES

1. Anirudha S. Bhosale, Gore P. N. (2017), “A Review Paper on Improvement of Impeller Design a Centrifugal Pump using FEM and CFD”, International Journal for Innovative Research in Science & Technology, Volume 4, Issue 4, pp. 06−08.

2. Farid Ayad.A, AbdallaH. M, Abo El- Azm A.S. (2015), “Numerical Study of the Semi- Open

Centrifugal Pump Impeller side Clearance", Aerospace Sciences and Aviation Technology, Volume 16, pp. 145−159.

3. Muhammad Ashri, Saravanan karuppanan, Santosh Patil, Idris Ibrahim. (2014), "Modal Analysis of a Centrifugal Pump Impeller Using Finite Element Method", EDP Sciences, Volume 13, pp. 403−418.

4. Chetan Kallappa Tambake, Prof. Salunke P. V. (2015), "Design, modelling and Analysis of Monoblock Centrifugal Pump Impeller", International Journal of Mechanical Engineering and Information Technology, Volume 03, Issue 06, pp.1346−1354.

5. Ghanshyam G. Iratkar, Prof. Gandigude A. U. (2017), "Structural Analysis, Material Optimization using FEA and Experimentation of Centrifugal Pump Impeller", International Journal Of Advance Research, Ideas And Innovations In Technology, Volume 3, Issue 4, pp. 97−105.

6. Mani Pranav Rajanand. (2016), "Design and Analysis of Centrifugal Pump Impeller by FEA", International Research Journal of Engineering and Technology, Volume 03, Issue 01, pp. 420−428.

7. Kaliappan S, Rajkamal M. D, Balamurali D. (2016), "Numerical Analysis of Centrifugal Pump Impeller for Performance Imporvement", International Journal of Chemical Science, Volume 14, Issue 2, pp. 1148−1156.

8. Mani Pranav Rajanand. (2016), "Design and Analysis of Centrifugal Pump Impeller by FEA", International Research Journal of Engineering and Technology, Volume 03, Issue 01, pp. 420−428.

9. Manish Dadhich, Dharmendra Hariyani, Tarun Singh. (2012), "Flow Simulation (CFD) & Fatigue Analysis (FEA) of a Centrifugal pump", International Journal of Mechanical Engineering and Technology, Volume 3, Issue 3, pp. 67−83.

