

## Design and Analysis of Centrifugal Impeller

**Subash K<sup>1\*</sup>, Muthukumar K<sup>2</sup>**

<sup>1</sup>PG Student, <sup>2</sup>Professor

Department of Mechanical Engineering

Bannari Amman Institute of Technology, Coimbatore, Tamil Nadu, India

Email: subash.is18@bitsathy.ac.in

### Abstract

Centrifugal pumps are used widely in different industries for various industrial purposes. Since performance of pump is affected by vibrations and depends on the blade inlet or outlet angle. The performance of the centrifugal pumps can be improved by alternating the geometric characteristics of impeller in the pumps. Centrifugal pump performance mainly depends upon blade exit angle. The vibration is mainly caused by blade exit angle. The rotating of the blade is based on the natural frequency and mode shapes. The impeller chosen for the study was a single- entry impeller with radial vanes. Using Creo 4.0 and ANSYS Workbench software the modeling and simulation of the impeller have been carried out. The respective frequencies and corresponding mode shapes impeller were measured by using eigenvalues and eigenvectors respectively. The results showed that the varying impeller blade exit angle had significant effect on natural frequency of the impeller.

**Keywords:** ANSYS, centrifugal pump, natural frequency, outlet blade angle, pump impeller

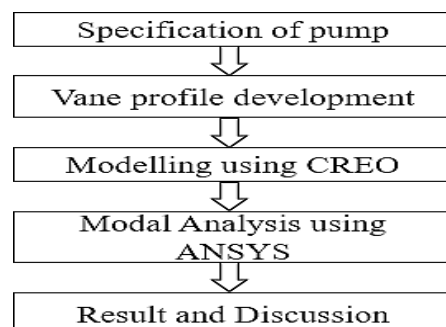
### INTRODUCTION

Vibration is a necessary phenomenon that needs to be well addressed in the design, development and maintenance of machines. The causes of machinery vibrations are plenty; they may arise due to the characteristics of the machinery itself, or from an external source. Whatever the source of vibration, the effects of vibration are very disturbing in operating a machine, and result in low efficiency. For the design and maintenance of a machine the vibration analysis is important factor. The machine moving parts creates the vibration. The natural frequency and excitation frequency are equal[1]. It is called a resonance or a critical speed. Another type of machine vibration problem, less common but more difficult to deal with, can come from the characteristic natural vibration frequencies of the machine structure and its supports, even if no imbalance or excitation is present. The centrifugal pump performance mainly depends on the impellers. Impeller blade exit angle has a significant effect on the vibration during the working conditions. In centrifugal

pump the rotating component is an impeller, it drives the pump with help of motor accelerated the fluid being pumped outwards from the center of rotation. Modeling of impeller is done by using creo 4.0 and model analysis is carried out changing the different blade angles corresponding natural frequency, stress and strain values are taken [2-3].

### METHODOLOGY

The Fig. 1 shows the methods that were involving the embrace to design and optimize the impeller and improving the pump performance.



**Figure 1:** Methodology.

The performance of the pump is depending on the flow pattern inside the pump

impeller vanes. The flow pattern is streamline means the less losses the outlet head is high.

It is achieved by the streamline flow path of overcome the adverse like separation of flows and secondary flows and formation of eddy. This is possible to best design methods for constructing the vane profile.

The range of operations is selected by the design parameters and also it's affecting

the pump performance. For a given application and different system design generally not obtained for the unique solution [4-5].

To find out the best solution through optimization in order to which maximizing the design parameters under construction of design.

**Pump Specifications** Table 1 shows the pump specifications.

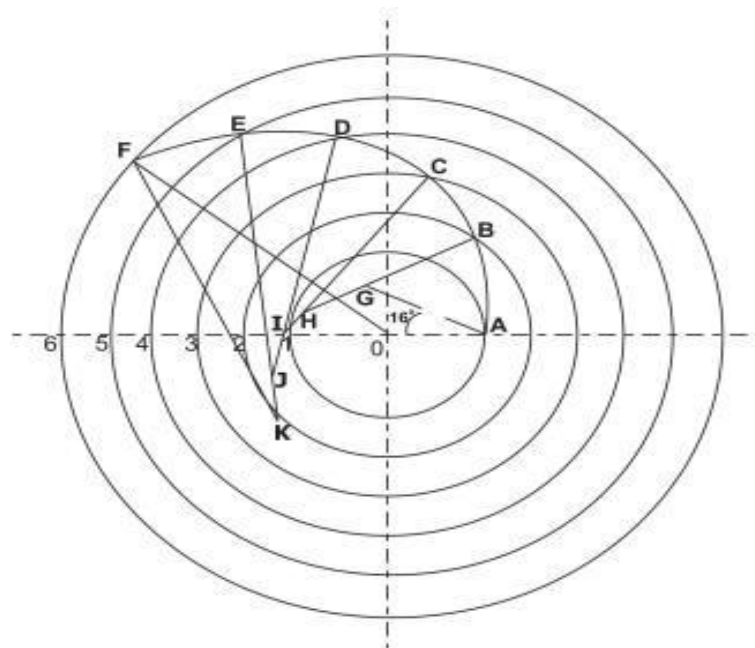
*Table 1: Pump specifications.*

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

### Vane Profile Development

In this design is a multiple curvatures profile with the four different centres of

four different radii curvatures of the vane profile for the impeller of the pump is considered as shown in the Fig. 2.



*Figure 2: Vane profile construction.*

Tracing the vane profile the following steps are involved:

- The inlet and outlet circles are drawn.
- There are two axes of reference are drawn, one is vertical and another one is horizontal.
- Four more circles are drawn, means the points one to six at equal intervals on the axis in order to the tracing the profile with four radii of curvatures.
- Based on the positions G, H, I, J and K through the A, B, C, D and E the

curves are the drawn.

- The length of the radius of curvature of the first arc, a line at an angle of inlet vane angle is the  $35^\circ$  is drawn from the point where inlet circle meets the horizontal axis.
- With the corresponding radius, till the arc meets the next circle an arc is drawn with the end point of this line as the center.
- From the point where the arc meets the next circle, a line is drawn to the length equal to the next radius of curvature

and passing through the previous center.

- An arc is drawn with the end point of this line as the center and with the corresponding radius till the arc meets the next circle.
- This procedure is followed until the four arcs are drawn.

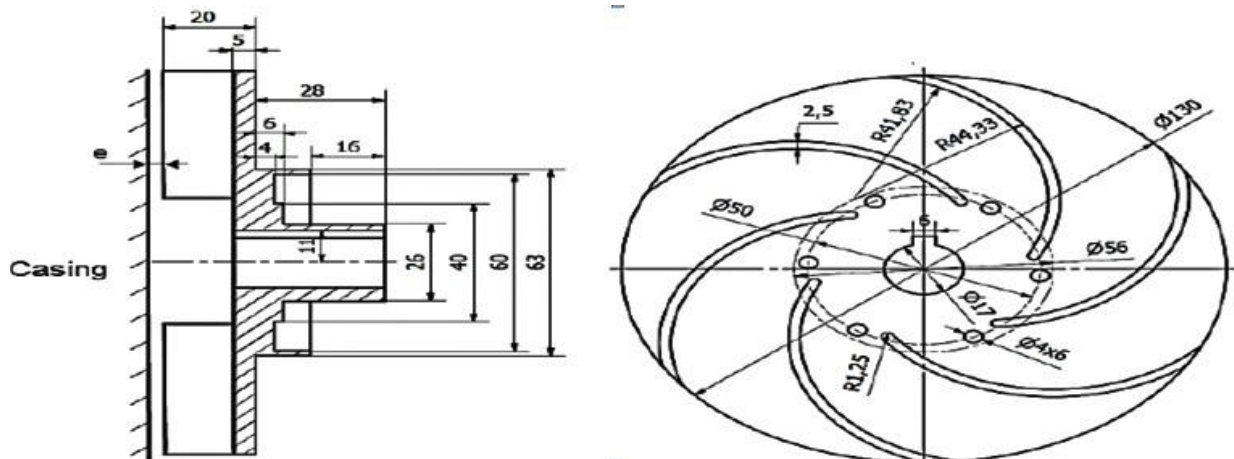
### Modeling of Impeller

The modeling of impeller is made by using creo 4.0 and its impeller dimensions are shown in Table 2. The impeller material is cast iron and the blade thickness is 2.5mm [6-7].

**Table 2: Pump impeller dimensions.**

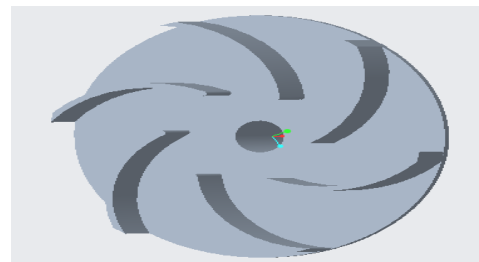
Blade number (Z)	6
Impeller inlet diameter (D1)	50 (mm)
Impeller outlet diameter (D2)	130 (mm)
Blade discharge angle ( $\beta_2$ )	$20^\circ$
Blade inlet angle ( $\beta_1$ )	$35^\circ$
Blade height (b)	15 (mm)
Blade thickness (t)	2.5 (mm)

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.**

containing small amounts of suspended solids and also minimization of recirculation and other losses, it is very important that a small clearance exists between the impeller vanes and the casing. Impeller that were modelled by creo 4.0 is shown in Fig. 4.



**Figure 4: Modelled impeller.**

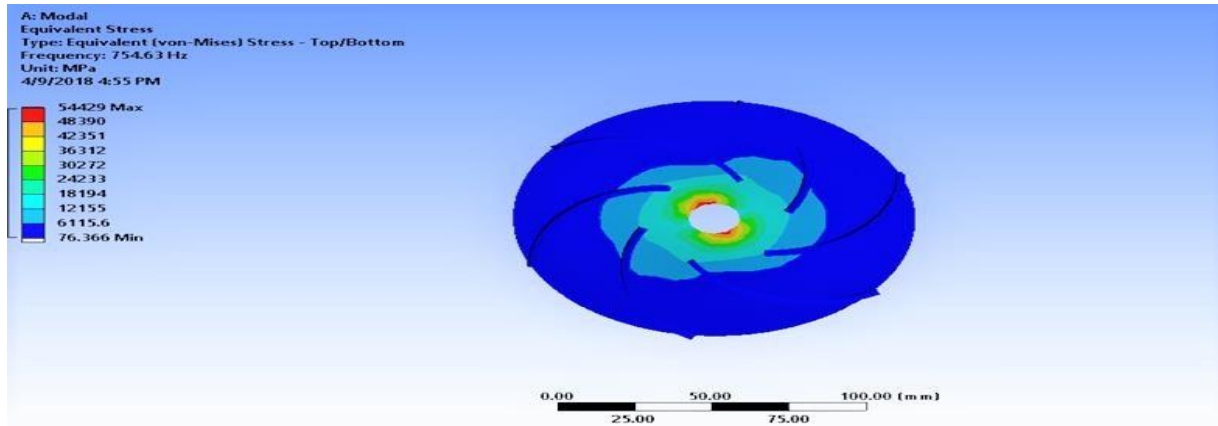
## MODAL ANALYSIS BY VARYING ANGLE

The modal analysis is carried by changing the different blade angles of 20°, 21°, 22°, 23°, 24° and 25°. Its respective natural frequency, stress and strain values are taken.

### Outlet Blade Angle 20°

The natural frequency obtained at 20° blade exit angle is shown below and its corresponding stress and strain values are shown in Fig. 6 and Fig. 7, respectively.

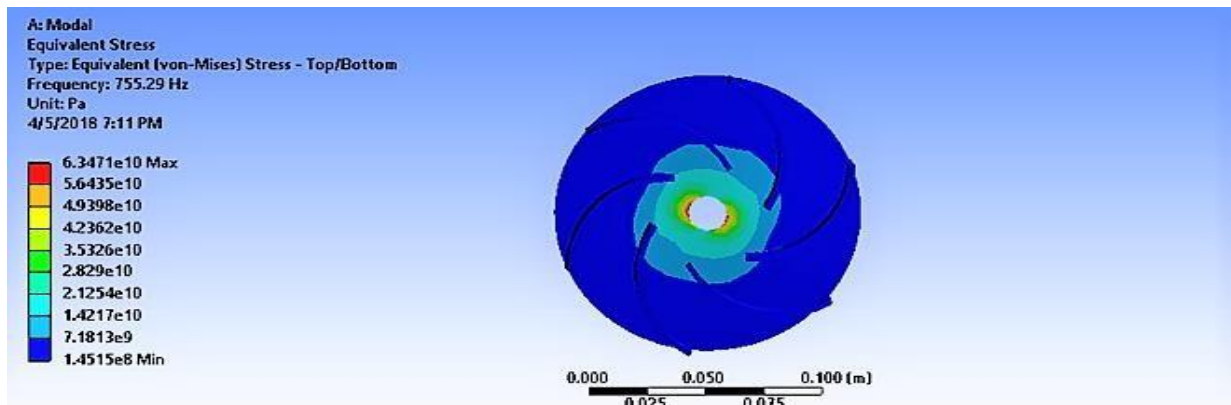
The natural frequency at 20° outlet vane angle is shown in different modes. At the mode



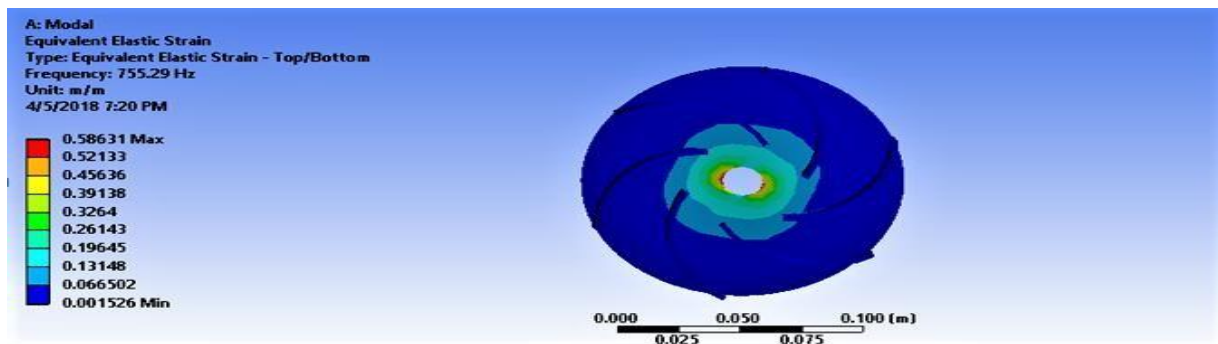
*Figure 5: Outlet Blade Angle 20°*

1, the natural frequency is 755.29 Hz. At mode 2, the frequency is 756.2 Hz. At mode 3, the natural frequency is 916.59. At mode 4, the natural

frequency is 1220.3 Hz. At mode 5, the natural frequency is 1220.7. At mode 6, the natural frequency is 1959.8 Hz [8-9].



*Figure 6: Stress analysis at 20°.*



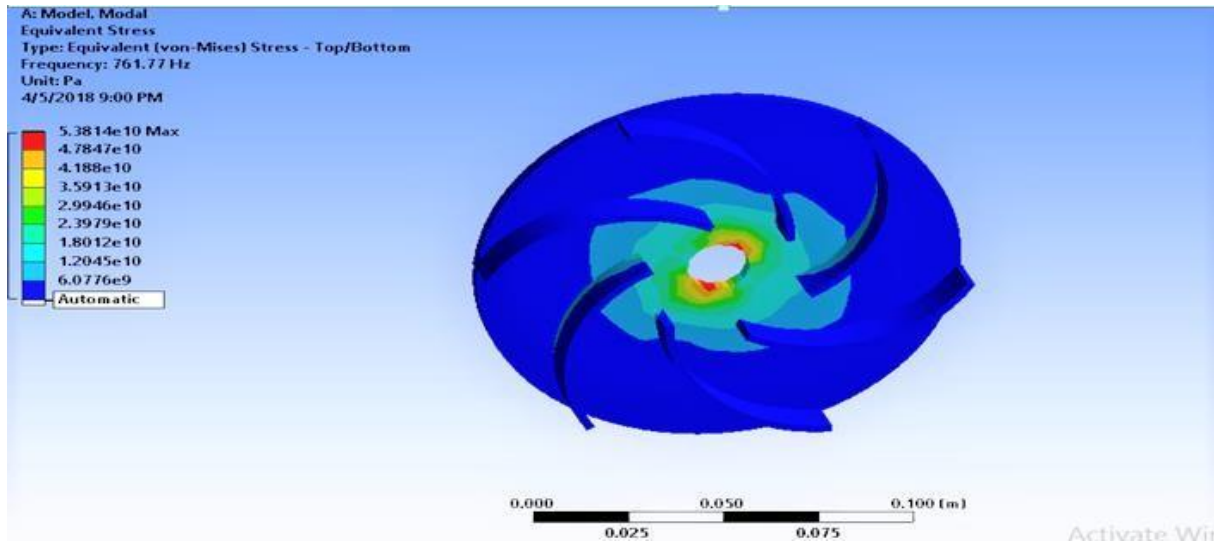
*Figure 7: Strain analysis at 20°.*

### Outlet blade Angle 21°

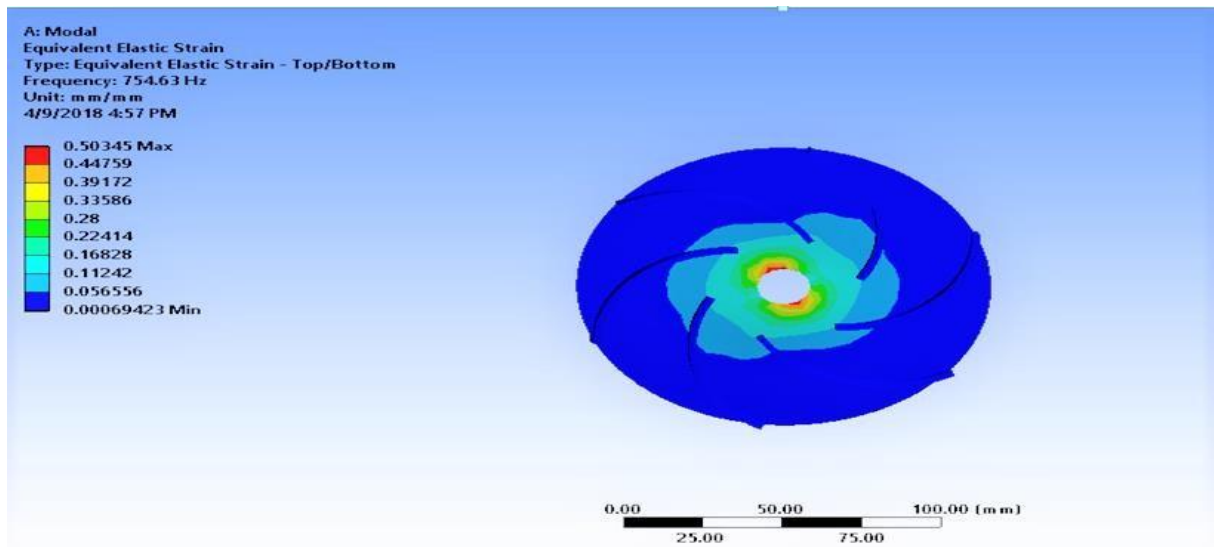
The natural frequency obtained at 21° blade exit angle is shown below and its corresponding stress and strain values are shown in Fig. 8 and Fig. 9 respectively.

The natural frequency at 21° 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 21°.**



**Figure 9: Strain analysis at 21°.**

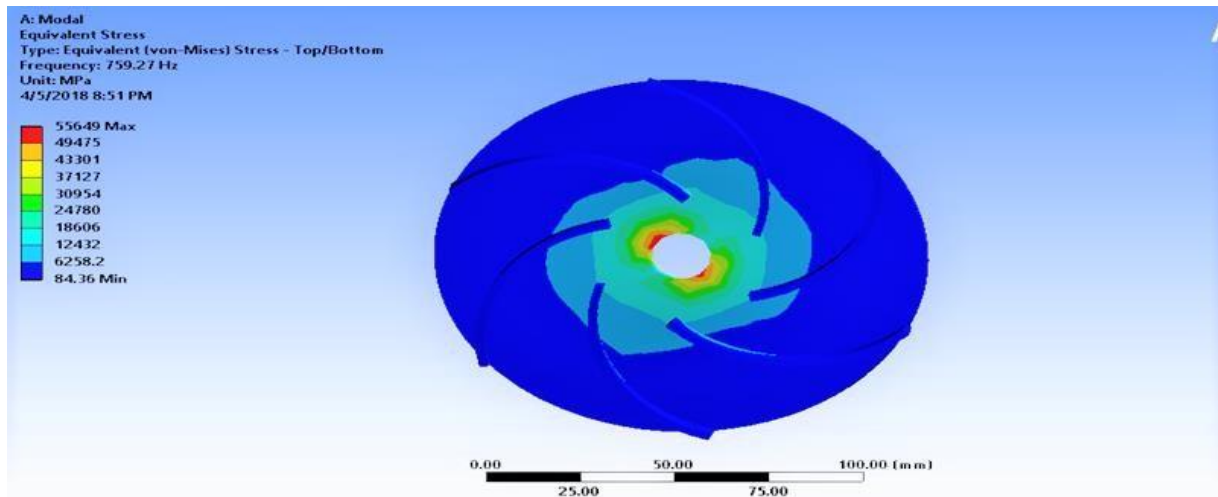
### Outlet Blade Angle 22°

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

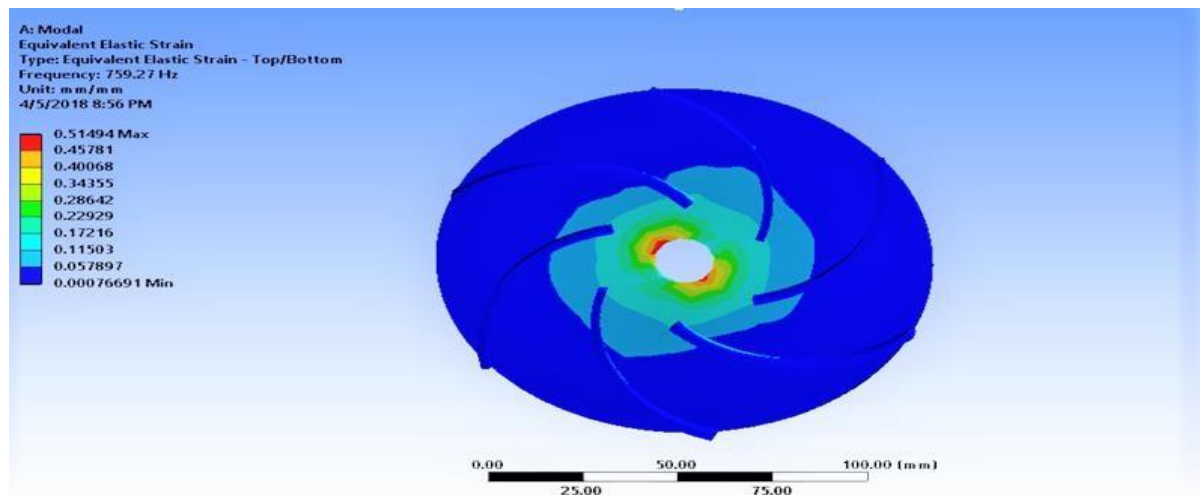
The natural frequency at 22° outlet vane

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 22°.*

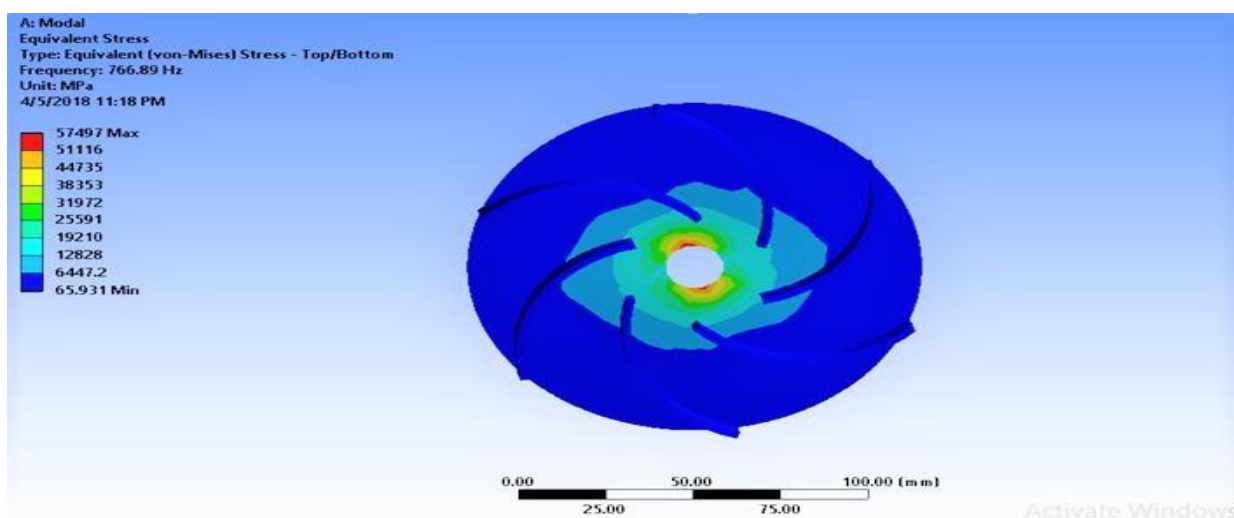


*Figure 11: Strain analysis at 22°.*

### Outlet Blade Angle 23°

The natural frequency obtained at 23° blade exit angle is shown below and its

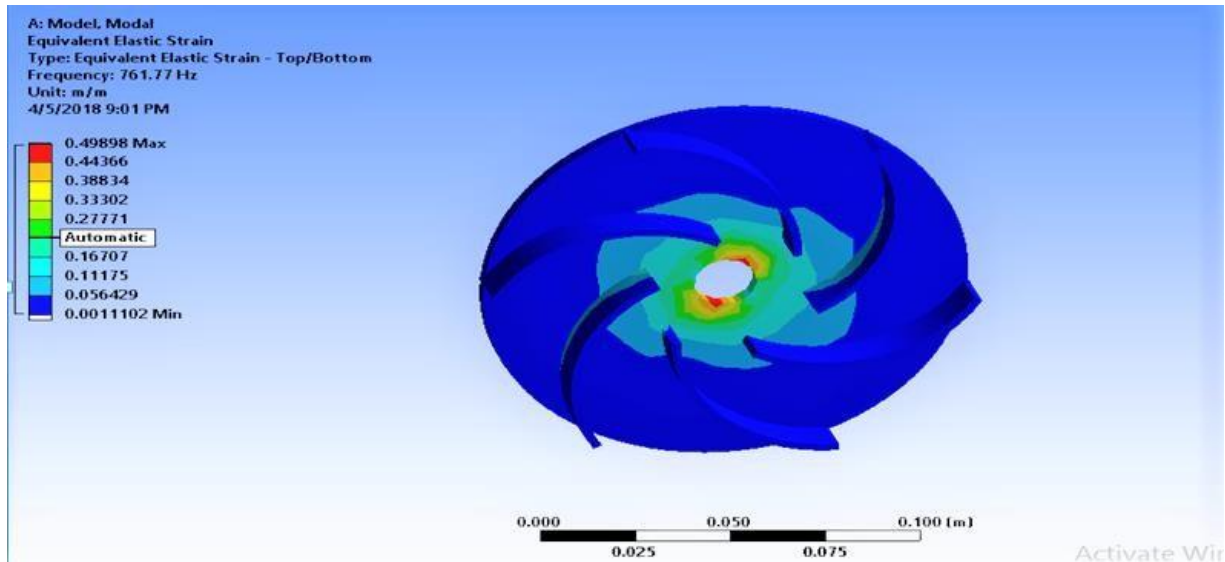
corresponding stress and strain values are shown in Fig. 13 and Fig. 14 respectively.



*Figure 12: Stress analysis at 23°.*

The natural frequency at 23° 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.

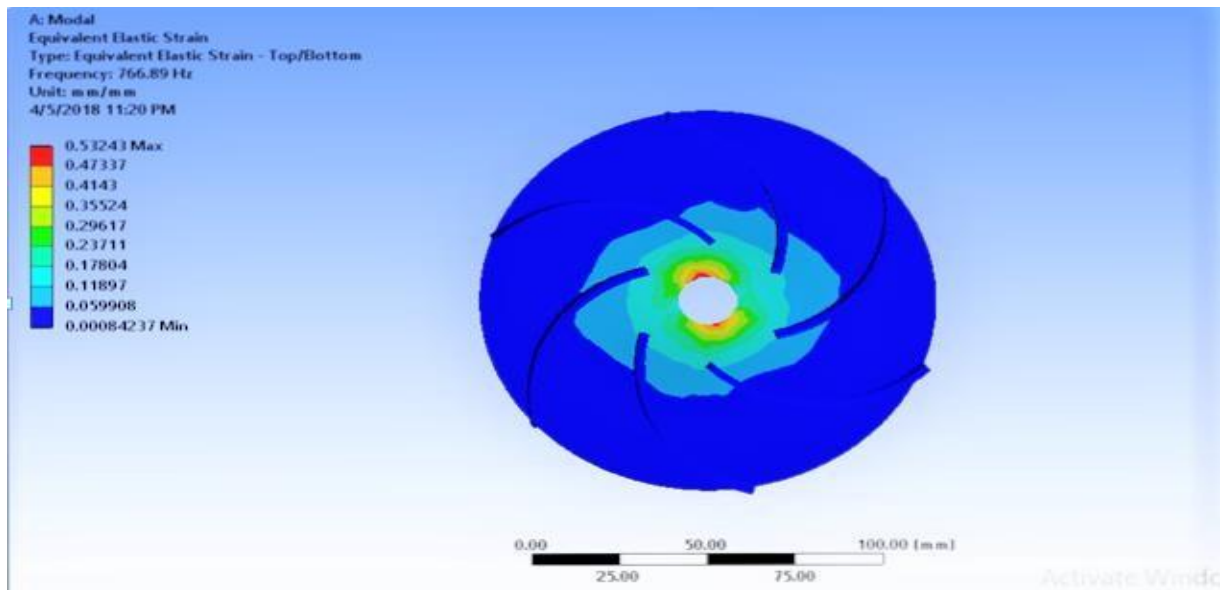


*Figure 13: Strain analysis at 23°.*

#### Outlet Blade Angle 24°

The natural frequency obtained at 24° 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 24° 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.



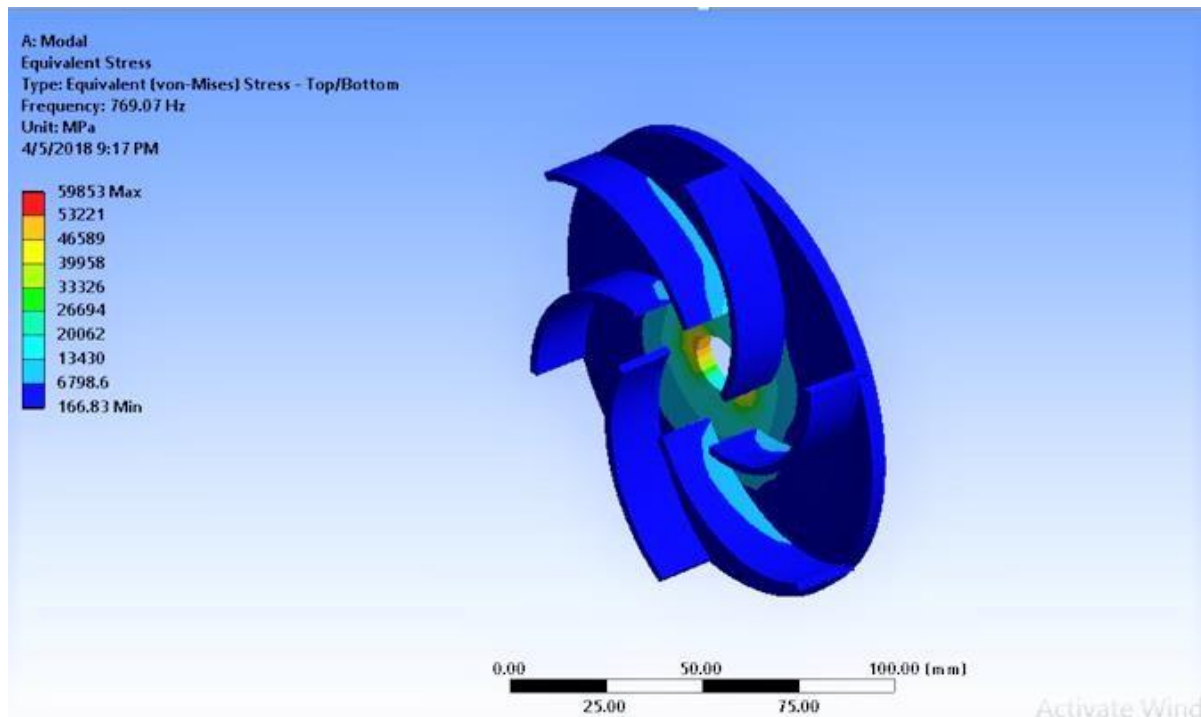
*Figure 14: Strain analysis at 24°.*

#### Outlet Blade Angle 25°

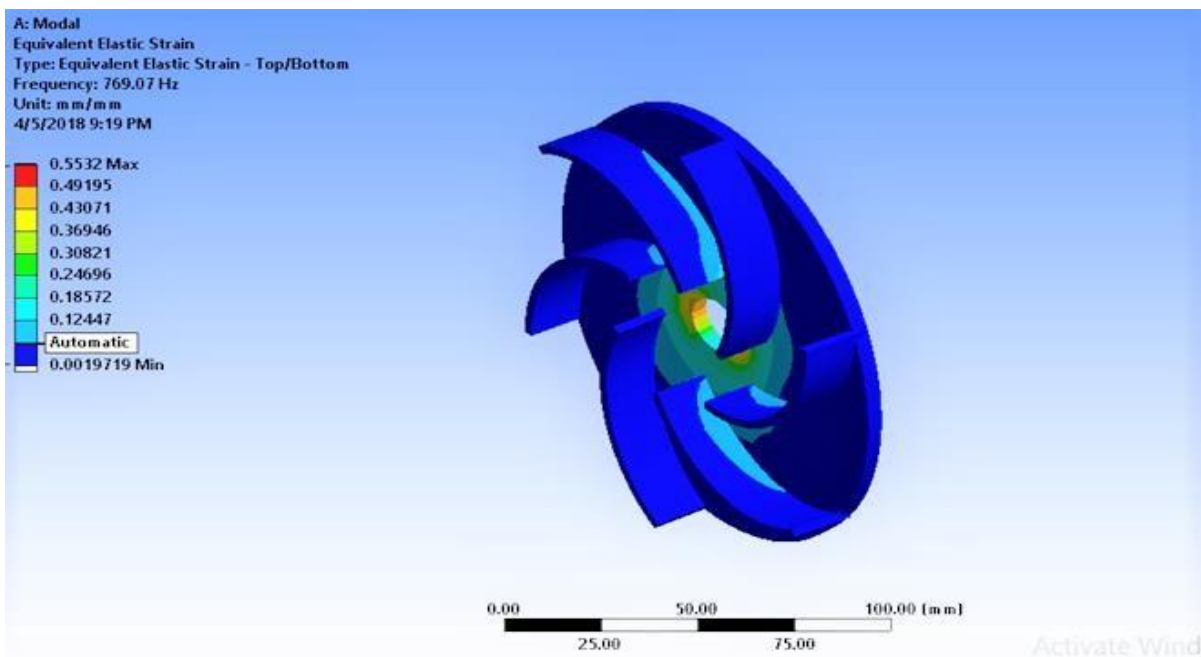
The natural frequency obtained at 25° blade exit angle is shown below and its corresponding stress and strain values are shown in Fig. 17 and Fig. 18, respectively.

The natural frequency at 25° 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 15: Stress analysis at 25°.**



**Figure 16: Strain analysis at 25°.**



## RESULTS AND DISCUSSION

The results obtained are analyzed and we come to know that, by changing the blade exit angle of the blade, the natural

frequency of the impeller is changing.

### Results from Varying Blade Angle

The natural frequency of six modes from different blade angle is mentioned in Table 3.

**Table 3:** Natural frequency from varying blade angle.

Mode	Frequency (Hz)					
	$\beta = 20^\circ$	$\beta = 21^\circ$	$\beta = 22^\circ$	$\beta = 23^\circ$	$\beta = 24^\circ$	$\beta = 25^\circ$
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

The natural frequency is increasing with increase in impeller blade exit angle. Initially at  $20^\circ$  blade exit angle, frequency is 755.29 Hz, which is minimum natural frequency value, and maximum value obtained is 1959.8 Hz. Finally, at  $25^\circ$  blade exit angle, frequency is 769.07 Hz, which is minimum frequency, and maximum frequency is 1998.6 Hz. At  $25^\circ$  blade angle, the flow region becomes narrow compared to  $20^\circ$  blade angle and fluid flowing has less disturbance. Hence, natural frequency increases. Further increase in blade exit angle will decrease its efficiency.

From the above Table 3, it is clear that chance for the resonance to occur has been increased and any disturbance of 769.07 Hz only will cause the resonance to occur. This value is a safe value and prevents the pump from the damage and performance loss.

## CONCLUSION

The modal behavior of the impellers for different blade angles ranging from  $20^\circ$  to  $25^\circ$  with increments of  $1^\circ$  has been analyzed.

Finally, this vibration analysis on the centrifugal impeller with different blade exit angles concluded the following:

- The natural frequency increases as the blade exit angle of the impeller

increases.

- The increase in the natural frequency may be attributed to the increase in the stiffness of the structure, in comparison to the mass added to the impeller.
- The natural frequency values of any blade angle was nearly same for modes 1 and 2.
- The natural frequency values of any blade angles was slightly increased for modes 3 and 4.
- The natural frequency values of any blade angles rise steeply for modes 3 and 4 and modes 5 and 6.

Since, the natural frequency varies with the blade exit angle, the failure of the impeller by resonance can be avoided, by selecting the impeller of a particular blade angle, which does not match with the operating frequency of the pump.

## 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. 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.
3. 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.
  4. 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.
  5. 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.
  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. 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.
  8. 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.
  9. Manish Dahich, Sheetal Kumar Jain, Vikas Sharma, Sanjay Kumar sharma, Dhirendra Agarwal, (2015) “Fatigue (FEA) and Modal Analysis of a Centrifugal”,
  10. 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.