# ANALYSIS OF PUMP IMPELLER WITH VARYING NUMBER OF BLADES

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## ABSTRACT

In this study, dynamic analysis of an impeller with load on each paddle was performed by using FEM. The commercial finite element package ANSYS was used for the solution of the problem. An impeller is a rotating component of a pump, made of steel which transfers energy from the motor that drives the pump to the fluid being pumped by accelerating the fluid outwards from the center of rotation. The velocity achieved by the impeller transfers into pressure when the outward movement of the fluid is confined by the pump casing. Impellers are usually short cylinders with an open inlet (called an eye) to accept incoming fluid, vanes to push the fluid radially, and a splined, keyed or threaded bore to accept a drive-shaft. We optimize the number of blades for an impeller. Taking into consideration of forces acting on each paddle of the impeller, the deformation, strain and stress are tabulated.

## INTRODUCTION

### Impellers in pump

The impeller made out of cast iron in many cases may be called rotor, also. Radial impeller right in the support it is fitted on, which is put in motion by the gearbox from an electric motor, combustion engine or by steam driven turbine. The rotor usually names both the spindle and the impeller when they are mounted by bolts. Some impellers are similar to small propellers but without the large blades. Among other uses, they are used in water jets to power high speed boats. Since impellers have no large blades to turn, they can spin at much higher speeds than propellers. The water forced through the impeller is channeled by the housing, creating a water jet that propels the vessel forward. The housing is normally tapered into a nozzle to increase the speed of the water, which also creates a Venturi effect in which low pressure behind the impeller pulls more water towards the blades, tending to increase the speed. To work efficiently, there must be a close fit between the impeller and the housing. The housing is normally fitted with a replaceable wear ring which tends to wear as sand or other particles are thrown against the housing side by the impeller. Vessels using impellers are normally steered by changing the direction of the water jet. Compare to propeller and jet aircraft engines.

## MATERIAL PROPERTIES:

Impellers can be manufactured from a variety of materials.We would like a combination of a hard material to resist wear and a corrosion resistant material to insure long life. This is often a conflict in terms because when we heat treat a metal to get the hardness we need, we lose corrosion resistance. The softer metals can have corrosion resistance, but they lack the hardness we need for long wear life. The best materials that combine these features are called the "Duplex Metals". These duplex materials are now in their second generation. They can be identified by letters and numbers such as Cd4MCu. If a new impeller is required because of cavitation, the new design should incorporate those features we have learned that will increase impeller.

## TABLE 1 PROPERTIES

| | |
|---|---|
| Density | 7.85e-009 tonne mm^-3 |
| Coefficient of Thermal Expansion | 1.2e-005 C^-1 |
| Specific Heat | 4.34e+008 mJ tonne^-1 C^-1 |
| Thermal Conductivity | 6.05e-002 W mm^-1 C^-1 |
| Resistivity | 1.7e-004 ohm mm |
| Compressive Ultimate Strength | 0 MPa |
| Compressive Yield Strength | 250 MPa |
| Tensile Yield Strength | 250 MPa |
| Tensile Ultimate Strength | 460 MPa |
| Reference Temperature C | 22 |
| Force | 780N |
| Rotational Velocity | 2900 rad/s |

## LITERATURE REVIEW

M.G.Patel and A.V.Doshi described about effect of impeller blade exit angle on the performance of centrifugal pump. Changing some geometric characteristic of the impeller in centrifugal pumps improves their performance. It is known that blade exit angle plays very important role in the performance of a centrifugal pump. To investigate effect of blade exit angle on the performance of centrifugal pump by means of experiment is very expensive and lengthy process. Due to expensive and lengthy process, it can be obtained by using mathematical model. In the present study three pumps of different specific speeds are taken for the investigation.

A Syam Prasad, BVVV Lakshmipathi Rao, A Babji and Dr P Kumar Babu described about static and dynamic analysis of a centrifugal pump impeller. This paper deals with the static and dynamic analysis of a centrifugal pump impeller which is made of three different alloy materials (viz., Inconel alloy 740, Incoloy alloy 803, Warpaloy) to estimate its performance. The investigation has been done by using CAT-IA and ANSYS13.0 softwares. The CATIA is used for modeling the impeller and analysis has been done by using ANSYS. ANSYS is dedicated finite element package used for determining the variation of stresses, strains and deformation across profile of the impeller. HYPER MESH 9.0 is also used to generate good and optimum meshing of the impeller to obtain accurate results. A structural analysis has been carried out to investigate the stresses, strains and displacements of the impeller and modal analysis has been carried out to investigate the frequency and deflection of the impeller. An attempt is also made to suggest the best alloy for an impeller of a centrifugal pump by comparing the results obtained for three different alloys.

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2. Design and Analysis on Hydraulic Model of The Ultra -low Specific-speed Centrifugal Pump presented in International Conference on Advances in Computational Modeling and Simu- lation By Jie Jina Ying Fana Wei Hana Jiaxin Hub Available online at www.sciencedirect.com Procedia Engineering 31 2012 (110 – 114)
3. Optimum design on impeller blade of mixed-flow pump based on CFD, presented in International Conference on Advances in Computational Modeling and Simulation By Jidong Lia, Yongzhong Zenga, Xiaobing Liua, Huiyan Wanga © 2011 Pub- lished by Elsevier Ltd.
4. Numerical study of the effects of some geometric characteristics of a centrifugal pump impeller that pumps a viscous fluid. pre- sented by M.H. Shojaeefard, M. Tahani, M.B. Ehghaghi , M.A. Fallahian, M. Beglari Department of Mechanical Engineering, Tabriz University, Tabriz, Iran Available online 7 March 2012.
5. Improving centrifugal pump efficiency by impeller trimming By Mario Šavar Hrvoje Kozmar Igor Sutlović University of Zagreb, Faculty of Mechanical Engineering and Naval Architec- ture, Contents lists available at ScienceDirect Available online 6 October 2009.
6. Estimation of radial load in centrifugal pumps using computational fluid dynamics by R. Barrio , J. Fernández , E. Blanco J. Parrondo a Departamento de Energía, Universidad de Oviedo, Campus de Viesques, 33203 Gijón, Asturias, Spain Available online 14 January 2011 Contents lists available at Science Direct.

## MODELING:

### IMPELLER WITH 6 BLADES:

Figure 1 Impeller with 6 blades

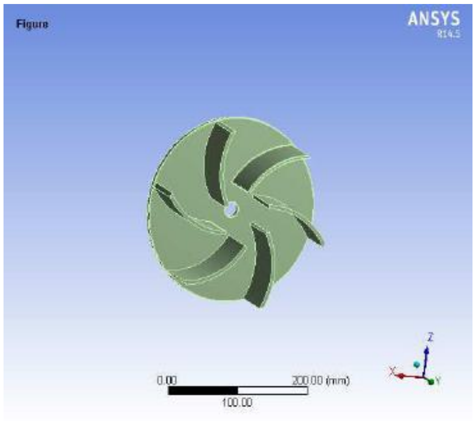


Figure 2 Meshing

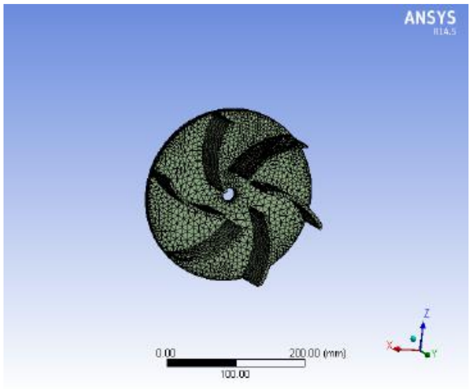


Figure 3 Force act

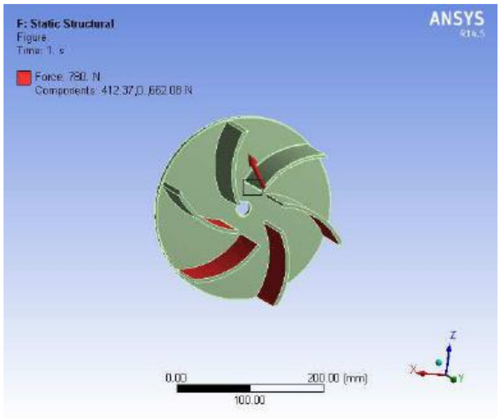


Figure 4 Equivalent Stress

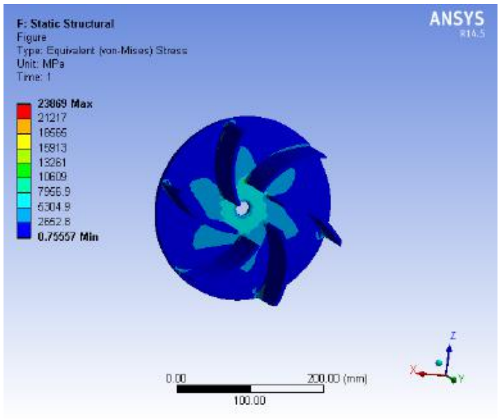


Figure 5 Equivalent Strain

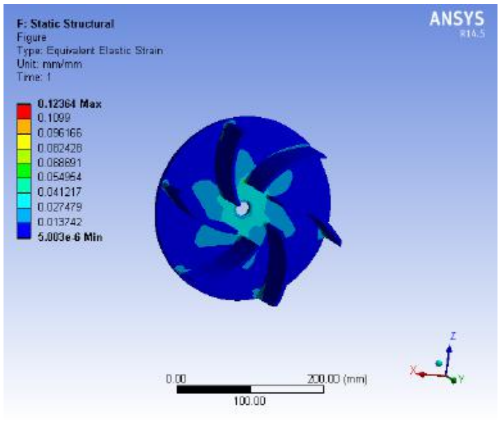
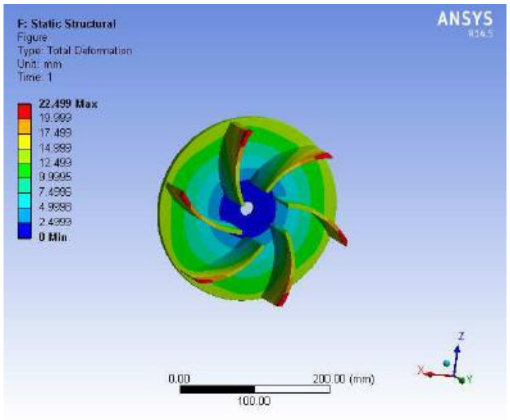


Figure 6  Total deformation of 6 blades



## IMPELLER WITH 7 BLADES

## MODELING AND MESHING:

| | |
|---|---|
| Length X | 252. mm |
| Length Y | 80. mm |
| Length Z | 252. mm |
| Properties | |
| Volume | 7.1927e+005 mm³ |
| Mass | 5.6463e-003 t |
| Centroid X | -6.9357e-004 mm |
| Centroid Y | 17.526 mm |
| Centroid Z | -2.0432e-003 mm |
| Moment of Inertia Ip1 | 24.517 t·mm² |
| Moment of Inertia Ip2 | 43.628 t·mm² |
| Moment of Inertia Ip3 | 24.509 t·mm² |

Figure 7 Impeller with 7 blades

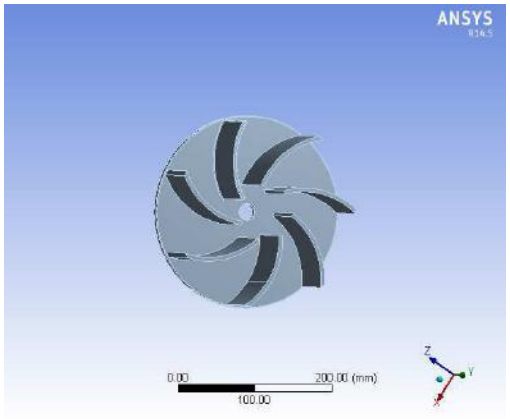


Figure 8 Equilent Strain

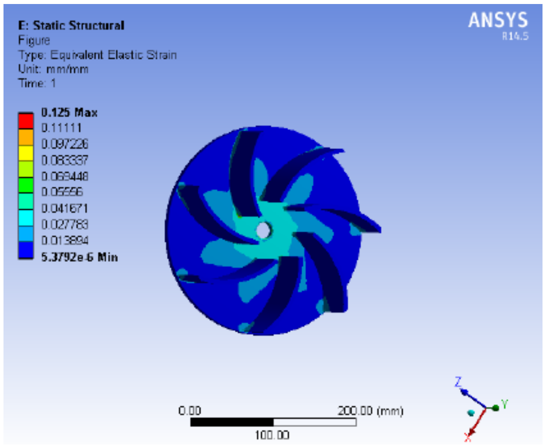


Figure 9 Equilent Stress

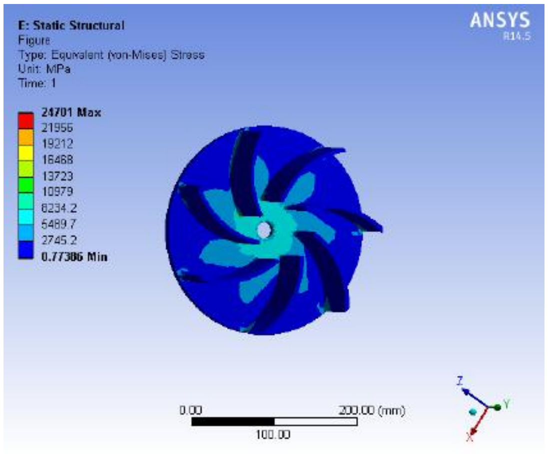
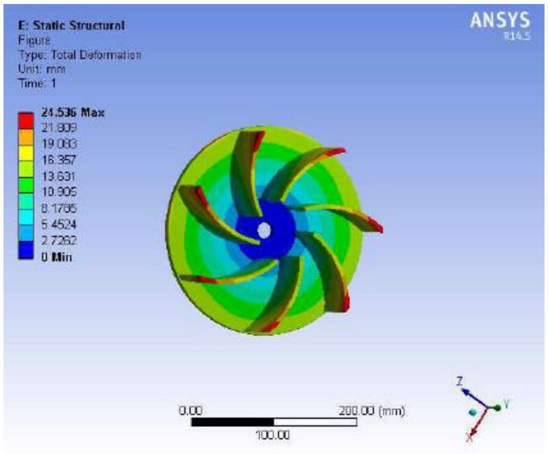


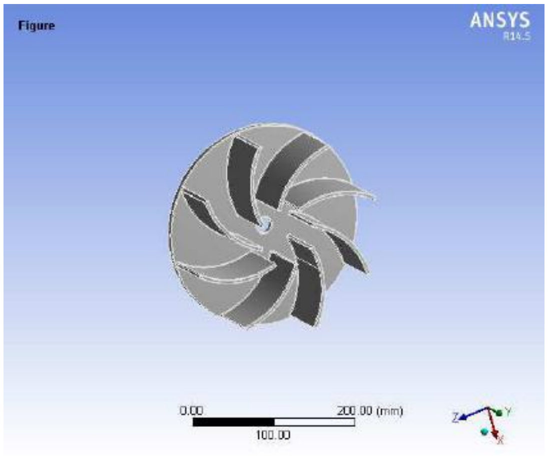
Figure 10 Total Deformation of 7 blades



## IMPELLER WITH 8 BLADES

## MODELING AND MESHING:

Figure 11 Impeller with8 blades



| Properties | |
|---|---|
| Volume | 7.9324e+005 mm³ |
| Mass | 6.2269e-003 t |
| Centroid X | -3.4028e-002 mm |
| Centroid Y | 20.064 mm |
| Centroid Z | 8.6931e-003 mm |
| Moment of Inertia Ip1 | 27.24 t·mm² |
| Moment of Inertia Ip2 | 47.813 t·mm² |
| Moment of Inertia Ip3 | 27.219 t·mm² |

| Statistics | |
|---|---|
| Nodes | 132228 |
| Elements | 73145 |

Figure 12 Mesh

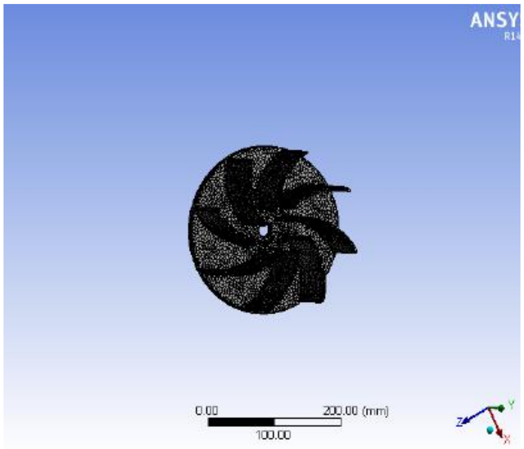


Figure 13 static structure

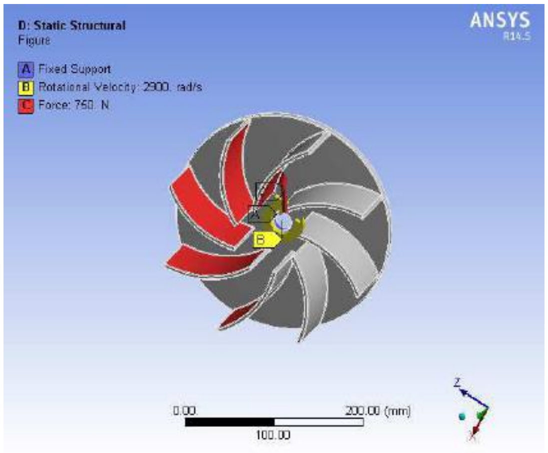


Figure 14 Equivalent Stress

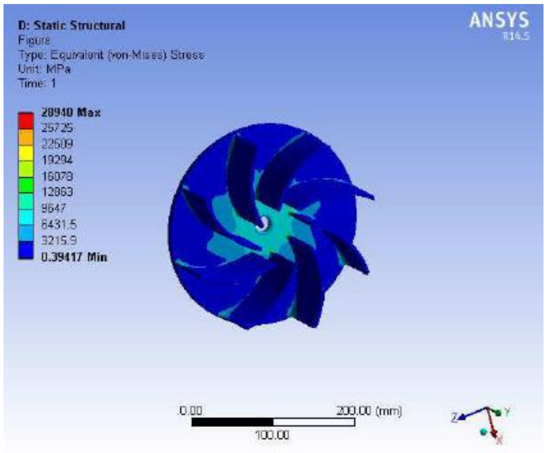


Figure 15 Equivalent Strain

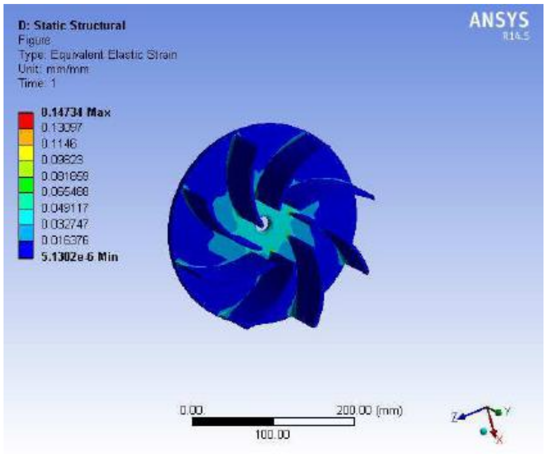


Figure 16 Total deformation

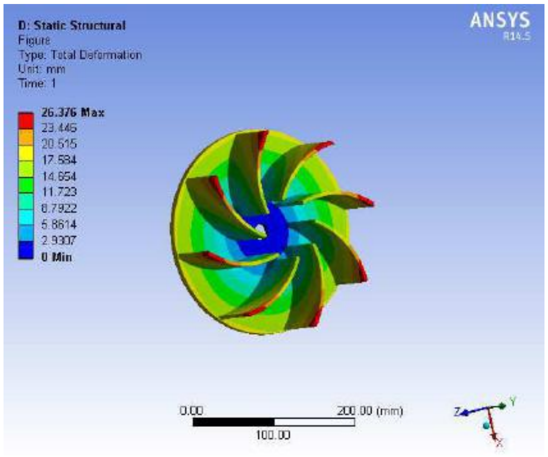


Table 2 Alternating Stress Mean stress

| Alternating Stress MPa | Cycles | Mean Stress MPa |
|---|---|---|
| 3999 | 10 | 0 |
| 2827 | 20 | 0 |
| 1896 | 50 | 0 |
| 1413 | 100 | 0 |
| 1069 | 200 | 0 |
| 441 | 2000 | 0 |
| 262 | 10000 | 0 |
| 214 | 20000 | 0 |
| 138 | 1.e+005 | 0 |
| 114 | 2.e+005 | 0 |
| 86.2 | 1.e+006 | 0 |

Table 3 Strain life parameters

| Strength Coefficient MPa | Strength Exponent | Ductility Coefficient | Ductility Exponent | Cyclic Strength Coefficient MPa | Cyclic Strain Hardening Exponent |
|---|---|---|---|---|---|
| 920 | -0.106 | 0.213 | -0.47 | 1000 | 0.2 |

| Temperature C | Young's Modulus MPa | Poisson's Ratio | Bulk Modulus MPa | Shear Modulus MPa | Relative Permeability |
|---|---|---|---|---|---|
| 22 | 2.e+005 | 0.3 | 1.6667e+005 | 76923 | 10000 |

## RESULTS FOR ANALYSIS OF PUMP IMPELLER WITH INCREASING NUMBER OF BLADES

### 8 BLADES

| | MIN | MAX |
|---|---|---|
| **Equivalent Elastic Strain (mm/mm)** | **5.1302 X $e^{-6}$** | **0.14734** |
| **Equivalent stress (MPa)** | **0.39417** | **28940** |
| **Total deformation (mm)** | **0** | **26.36** |

**7 BLADES**

| | MIN | MAX |
|---|---|---|
| Equivalent Elastic Strain (mm/mm) | 5.3792 X $e^{-6}$ | 0.125 |
| Equivalent stress (MPa) | 0.755 | 24701 |
| Total deformation (mm) | 0 | 23.56 |

**6 BLADES**

| | MIN | MAX |
|---|---|---|
| Equivalent Elastic Strain (mm/mm) | 5.003X $e^{-6}$ | 0.12346 |
| Equivalent stress (MPa) | 0.75579 | 23869 |
| Total deformation (mm) | 0 | 22.496 |

## CONCLUSION

An Analysis Pump Impeller with Increase number of blades force is listed in the Table. Static structural analysis has been carried out by increasing number of blades. The results for static structural such as equivalent elastic strain, and equivalent stress are determined for impeller. Then structural inputs are given to the to find strain and total deformation. When apply the total load on the each 8 impeller blades, 7 impeller blades and 6 impeller blades. So we conclude that 8 impeller blades are most suitable for the pumps.

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