DESIGN AND ANALYSIS OF IMPELLER FOR CENTRIFUGAL PUMP

S.Mayakannan[*],V.Jeevabharathi[1],R.Mani[2], M.Muthuraj[3]

[*,1,2,3]*Assistant Professors, Department of Mechanical Engineering, Vidyaa Vikas College of Engineering and Technology, Tiruchengode, Tamilnadu, India-637214*

ABSTRACT

The objective of this paper is to be design the impeller for a centrifugal caustic slurry pump to increase its power and efficiency, and showing the advantage of designing parameters (six blade turbine ,design changes from impeller) comparing with the old material of a TURBINE. An investigation in to usage of new materials is required. In the present work impeller was designed with two different materials. The investigation can be done by using SOLIDWORKS and ANSYS WORK BENCH software. The SOLIDWORKS is used for modeling the impeller and analysis is done in ANSYS WORK BENCH. ANSYS is dedicated finite element package used for determining the variation of heat flux and directional deformation across profile of the impeller. An attempt has been made to investigate the effect of temperature, pressure and induced stresses on the impeller. By identifying the true design feature, the extended service life and long term stability is assured is defined. A thermal analysis has been carried out to investigate the heat flux and direction heat flux of the impeller is defined. An attempt is also made to suggest the best material for an impeller of a turbine by comparing the results obtained for two different materials inconel alloy 783, inconel alloy 740,for centrifugal is to made it. Based on the results best material is recommended for the impeller of a turbocharger.

Keywords: Inconel *Alloy, Centrifugal Force, Thermal Analysis*

1. Introduction

Centrifugal pump are a class of machinery intended to increase the power of turbine. This is accomplished by increasing the pressure of intake air, allowing more fuel to be flow coition. In the late 19th century, Rudolf Diesel and Gottlieb Daimler experimented with pre-compressing air to increase the power output and fuel efficiency. The first exhaust gas turbocharger was completed in 1925 by the Swiss turbine Alfred Buchi who introduced a prototype to Increase the power of a compressor by a reported 76%.

The idea of salary coition at that time was not widely accepted. However, in the last few decades, it has become essential in almost all diesel compressors with the exception of very small diesel turbo charger.Their limited use in gasoline compressors has also resulted in a substantial boost in power output and efficiency. Their total design, as in other turbo machines, involves several analyses including: mechanical, aerodynamic, thermal, and acoustic. Turbo chargers and researchers still seek ways to improve their designs while governed by rules of cost and manufacturing capabilities. At first, scientists simply attempted to develop the conceptual designs into reliable products for end users.

2. Problem Identification

a) Cavitations—the net positive suction head (NPSH) of the system is too low for the selected pump.
b) Wear of the Impeller—can be worsened by suspended solids.
c) Corrosion inside the pump caused by the fluid properties.
d) Overheating due to low flow.
e) Leakage along rotating shaft.
f) Lack of prime—centrifugal pumps must be filled (with the fluid to be pumped) in order to operate.
g) Surge.

3. Specification of caustic slurry pump and impeller

Different specifications of the caustic slurry pump and impeller is shown in the table.1. Different specifications of the impeller is shown in table.2.

4. Methodology

Methodology of this study is shown in Fig 1 shows the methodology of this study. This study starts with the various types failures occurred in impeller which is used in caustic slurry pump. After finding the various types of failures, typical problem has been defined to rectify it. Third step goes with the selection of materials for the defined failures to overcome the past problems with impeller, from the past literatures inconel 740 and 783 alloys has been chosen as a alternative impeller material. After the successful completion of material selection suitable design parameters has been selected to create the impeller design. The design of impeller is made by using SOLIDWORKS software. Analysis of impeller is done by using ANSYS 12.0 software, geometric model is imported into ANSYS software and then the full geometric model is meshed in ANSYS software. After the import of the impeller model transient thermal analysis is carried out in ANSYS software and the results have been discussed to optimize the suitable material.

Table 1 Specifications of the pump

S.No	Name of equipment	C.O. Feed pump
1	Pump purpose	Causticised slurry feed
2	Pump make and model	RECO/44/150 WPP
3	Pump tag number	503-PM 24/25
4	Pump capacity	140 m^3/hr
5	Pump head	50 m
6	Impeller diameter/number of	410/400 semi open
7	Bearing non drive end	NU 314-1 no.
8	Bearing drive end	7314-2 nos.
9	Lock nut	KM14
10	Lock washer	MB14
11	Mechanical seal type / size	Gland packing
12	Shaft diameter	48 mm
13	Shaft keyway	14*3.5 mm
14	Coupling make/type/size	SM 30-P*100-180
15	Spacer distance	180 mm
16	Motor rpm	1500
17	Motor shaft diameter	60 mm
18	Motor shaft keyway	18*4 mm
19	Motor	55 KW

Table 2 Specifications of impeller

S.No	Name of equipment	C.O. Feed
1	Impeller maximum	1500 rpm
2	Impeller minimum	1440 rpm
3	Fluid flow touch	Full
4	Impeller external temperature	82-850°C
5	Impeller internal temperature	900°C
6	Impeller total heat flux	900°C

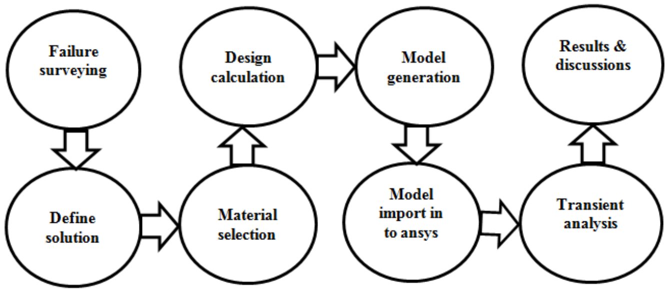

Figure 1 Methodology

5. Material selection

The following materials are selected for this study.

a) Inconel alloy 740
b) Inconel alloy 783

Variuos chemical compositions, Mechanical, Thermal and Physical properties of Inconel alloy 740 & 783 materials material are shown in table.4, 5, & 6 respectively.

6. Design

The following parameters are taken into account to design the impeller. Various parameters which is used to design the impeller is shown in table.3.

Table 3Design parameters

Diameter of suction flange	10in
Velocity in suction flange	10.22 ft/s
Shaft diameter	21/8 in
Impeller hub diameter	2 ½ in
Impeller eye diameter	75/16 in
Velocity through impeller eye	11 ft/s
Diameter of inlet vane edge	7 5/16 in
Velocity at inlet vane edge	12 ft/s
Passage width at inlet	1.75 in per
Tangential velocity of inlet vane edge	56.2 ft/s
Vane angle at inlet	13^0
Impeller outlet diameter	13 ½ in
Radial component of outlet velocity	11 ft/s
Vane angle at outlet	20^0
Total passage width at outlet	1.98 in
Tangential velocity of outlet vane	103.7 ft/s
Absolute velocity leaving impeller	52.5 ft/s
Tangential component of absolute	51.5 ft/s
Angle of water leaving impeller	13^0
Number of impeller vanes	*6*

Table 4Chemical compositions of Inconel alloy 740 & 783 materials

Material/ Compositions	C	Si	Mn	P	S	Cr	Mo	Al	Ti	Co	Cu	Fe	Nb	Ta
Inconel alloy 740	0.03	0.50	0.30	-	-	25.0	0.50	0.90	1.80	20.0	-	0.70	2.0	2.0
Inconel alloy 783	0.03	0.50	0.50	0.015	0.005	2.5-3.5	-	5-6	3.5	-	0.5	24-27	-	-

Table 5 Mechanical properties of Inconel alloy 740 & 783 materials

Material	Density (*1000 kg/m^3)	Poisson's ratio	Elastic Modulus (GPa)	Tensile strength (MPa)	Yield strength (MPa)	Elongation (%)	Reduction in area (%)	Hardness (HB)
Inconel alloy 740	7.7-8.03	0.27-0.30	190-210	1158	1034	15	53	335
Inconel alloy 783	7.7-8.03	0.27-0.30	190-210	1158	1034	15	53	335

Table 6 Thermal properties of Inconel alloy 740 & 783 materials

Material	Thermal expansion (e^{-6}/k)	Thermal conductivity (w/m-k)	Specific heat (J/kg-k)	Melting Temperature (°C)	Service Temperature (°C)	Density (kg/m^3)	Resistivity (ohm.mm^2/m)
Inconel alloy 740	16-17	16	500	1370-1400	0-500	8000	0.7
Inconel alloy 783	16-17	16	500	1370-1400	0-500	8000	0.7

There are most software packages are available for creating the 3D model of the slurry pump impeller. Fig 2 shows the geometric model of the impeller which is created by using SOLID WORKS software.

Figure 2Geometric model of impeller

7. Analysis

Entire analysis of the impeller is done by using ANSYS 12.0 software. Fig 3 shows the imported model of the impulse impeller model.Fig 4 shows the imported model of the impulse impeller model for transient thermal analysis. Imported impeller model is meshed with the following conditions. Fig 5 shows the mesh model of impeller.

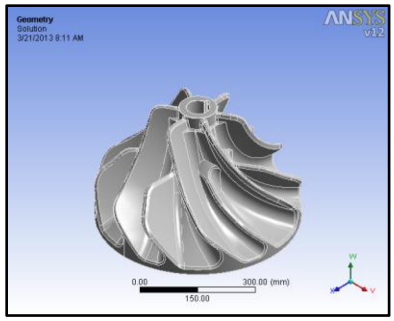

Figure 3Imported model of impeller

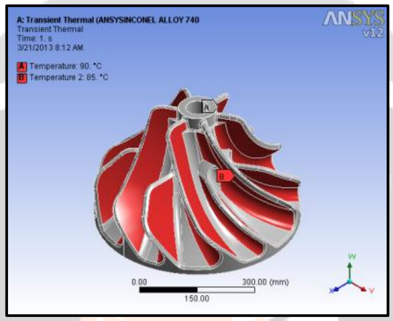

Figure 4Imported model of impeller for transient thermal analysis

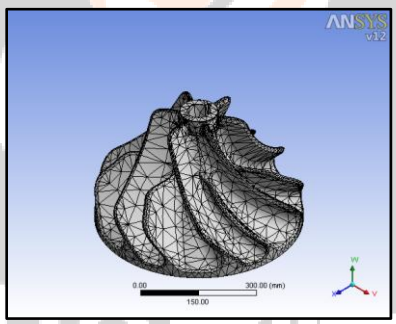

Figure 5Mesh model of impeller

The following meshing parameters are taken into account to make a mesh model of impeller.

a) Type of mesh : global
b) Element size : 0.5
c) Mode of mesh : volume
d) Key points : all

8. Results

8.1 Stress and thermal distributions

8.1.1 Inconel 740 alloy

Total heat flux distributions in impeller for Inconel alloy 740 material is shown in Fig.6.Following details provided to do the transient analysis in impeller for inconel 740 materials.

- Type of analysis : Transient
- Time taken : 60 seconds

- Minimum temperature :1.12x10-9 W/mm^2
- Maximum temperature :1.8 w/mm^2

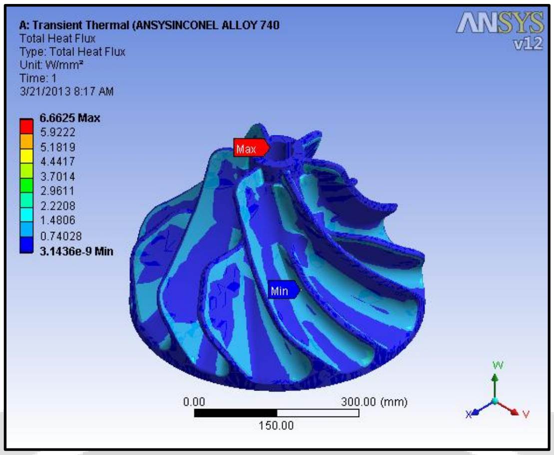

Figure 6Temperature Distributions in inconel alloy 740

8.1.2 Inconel 783 alloy

Fig.7 shows the total heat flux distributions in impeller for Inconel alloy 783 material. Following details provided to do the transient analysis in impeller for inconel alloy 783 materials.

- Type of analysis : Transient
- Time taken : 60 seconds
- Minimum temperature :1.12x10-9 w/mm^2
- Maximum temperature :1.8 w/mm^2

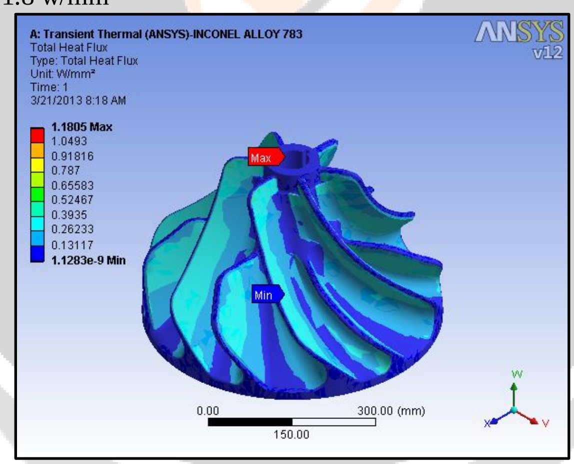

Figure 7Temperature Distributions in inconel alloy 783

9. Discussions

Heat flow rates inside the impeller for three different materials are shown in the table.7. From the following tabulation the following graphs are drawn and the comparison is carried out for different materials. The comparison is carried out for, factor of safety and heat transfer rate.

Table 7Comparison of heat flow rates

Material	Stainless steel 2324	Inconel alloy 740	Inconel alloy 783
Heat flow rate (Watts)	$1.3x10^{-9}$	$6.6x10^{-9}$	$1.18x10^{-9}$

These show satisfactory order of results in approximating the nominal stresses in the blade due to the axial and tangential loading cases. Thus, having confirmed the range of stresses we would expect from ansys calculations, we can be confident in the finite element results. From the results of the finite element analysis it is clear that a sizeable factor of safety is available with respect to this design stress, even when the correction factor is taken into account. Generally, the dominant force in this stress analysis is the tangential force, but at the lower deformation, the most important force is in fact the axial load. All things being equal, one would generally expect the axial load on an impulse impeller to be small, since the impeller at its design point does not experience an appreciable pressure drop across the rotor (in fact a slightly negative degree of reaction might not be unexpected). But the max equivalent stress is induced in the stainless steel blade material is less when compared to the other materials. But maximum stress is induced in the plastic reinforced carbon material.

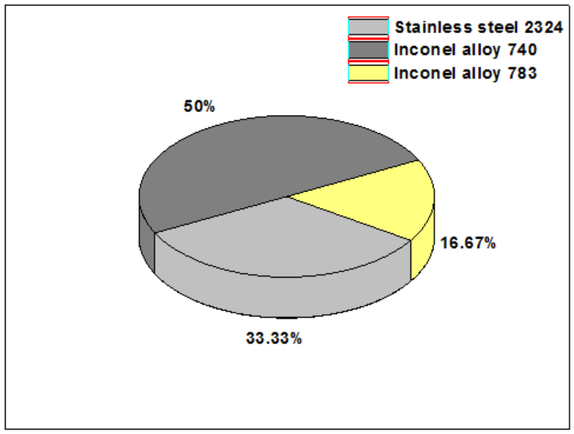

Figure 8 Heat flow distribution

So that the life of the impeller blade may decreased. When concentrating on the deformation graph comparison, the materials austenitic alloy and titanium alloy will produce the same deformation as compared to the stainless steel. But the inconel alloy783 will produce the more deflection under tangential and axial load temperature. As a consequence of the significant amount of time spent away from the design point, the result of negligible pressure drop across the rotor is no longer valid and an appreciable axial force is present. Finite element stress analysis results must also be evaluated, but the fact that stress analysis is so much more. It may be noted that, considering the thermal analysis carried out on the different materials which shows the heat losses due to transfer must be less so that total heat is fully converted to mechanical energy; this may cause the increase in percentage of output power. In this analysis, Titanium alloy blade material provides the less heat losses compared to other materials. But in this case of inconel alloy 740 materials is considerably very high due to its high thermal conductivity. From the analysis the materials like inconel alloy740 and inconel alloy 783 produces the better structural and thermal behavior than the existing material.

10. Summary

The following conclusions have been made based on the numerical analysis of the centrifugal caustic slurry pump. Two different materials like inconel 740 & 783 alloys have been chosen to evaluate the heat flow rates inside the pump casing. Numerical results show that inconel alloy740 produces the better thermal behavior compared to existing material (stainless steel).