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# Vibration analysis and experimentation of centrifugal pump impeller

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## ABSTRACT

***The impeller is a rotating component of a Centrifugal Pump. In the Pump application, excessive vibrations encountered would pose a damaging effect on the impeller. Most of the dynamic machinery problems result from the interaction between the exciting forces and associated structural frequencies. When frequency generated by exciting force becomes equal to natural frequency, the amplitude of vibration becomes maximum causing resonance Hence the main objective is to carry out static vibration analysis and conduct experimentation performance on the Impeller of two material- MS and Nylon and record the running pump parameters – Pressure head (H) and flow rate (Q) and deserve when the pump is running smoothly without any noise. The smooth run, without noise, indicates that the vibration level is normal. To find out the natural frequency of an impeller modal analysis was carried out. Cad model generation was done in CATIA V5, meshing in HYPER MESH and ANSYS is for post-processing. The experimentation carried out using different material (MS and Nylon) should not only smooth run of the Pump but also improves the Pump efficiency resulting in sufficient power saving of the pump.***

***Keywords****— Efficiency, Impeller, Duty point, Nylon*

## 1. INTRODUCTION

An impeller is a rotating component of a centrifugal pump, usually made of iron, steel, bronze, brass, aluminium or plastic, 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. The impeller made out of cast material in many cases may be called rotor. Also, it is cheaper to cast the radial impeller right in the support it is fitted on, which is put in motion by an electric motor, combustion engine or by steam driven turbine.

**Table 1: Specification of the Pump (Duty Point)**

| | |
|---|---|
| Discharge Capacity | 2.1 l/s |
| Number of revolution | 2900 rpm |
| Number of blades | 06 |
| Head | 11 m |
| Motor | 1 HP |
| Flow type | Radial flow |

**Table 2: Existing Radial Flow Impeller Dimension**

| Parameter | Size |
|---|---|
| Impeller outer diameter | 99 mm |
| Eye diameter | 20 mm |
| Blade number | 6 nos |
| Blade width at the inlet | 5 mm |
| Blade width at outlet | 2.5 mm |
| Inlet angle | 19.25° |
| Outlet angle | 23.76° |

 

### 1.1 Test on the impeller

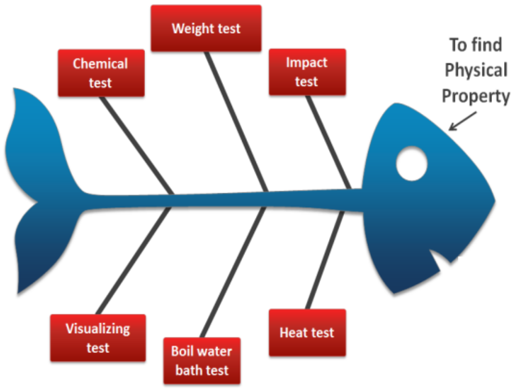


**Fig. 1: Test on the impeller**

#### 1.1.1 Test on Impeller Specifications: Material: Nylon (99 mm Dia)

**(a) Chemical Test**

Acid Test: $H_2So_4$ for 24 Hr.

Results: No any deformation, no fuming, no Burning, No fuming on Impeller material.

**(b) Impact Test**

Height of Drop down: 15 Ft. from Ground

Results: No any Damage and Crack on Nylon Impeller material.

**(c) Hot water Test**

Nylon Impeller was kept in hot (boiling) water for 1 Hr.

Result: I was taken out taken to examine visually found no damage and shrink.

**(d) Weight Test**

Wt. was compared with MS Impeller

Wt. of MS Impeller: 0.607 kg.

Wt. of Nylon Impeller: 0.091 kg.

So Nylon Impeller lighter in weight compared to MS Impeller (difference 0.516 kg.)This will help for less startup torque and hence motor of less cost.

**(e) Performance test and Impeller Visualization**

Impeller was assembled in casing and performance test (running at rotate speed for H, Q, and BHP) was conducted and after the test, the impeller was examined visually. It was found technically sound.

## 2. METHODOLOGY OF PROJECT

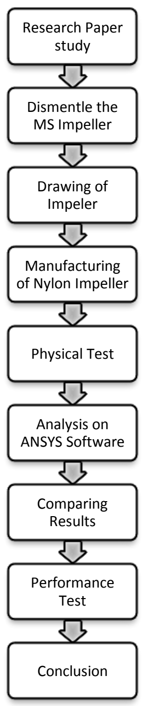


**Fig. 2: Methodology of project**

 

### 2.1 Mild steel
At present pump, the impeller is made of mild steel material. So, the first analysis is done using MS as a material. Steel is the traditional material for pump impeller. Steel is easy to get and it is also cheap. Steel is stiff but dense (heavy). Steel also resists fatigue failure well which is extremely useful - even if the assembly flexes under load, such flexing need not lead to a critical failure. The limitation with steel is its weight, or more accurately its density. With higher density or weight, the efficiency of a system decreases.

#### 2.1.1 The advantages of using steel are:
- Best stiffness overall
- Air-hardened alloys make ultra-high strength affordable

#### 2.1.2 The limitations of steel are:
- Can be heavy
- Not the materials for big, light frames
- Rust-prone

### 2.2 Nylon-6
Composite materials are basically hybrid materials formed of multiple materials in order to utilize their individual structural advantages in a single structural material. Various scientific definitions for composite materials are; the word composite means made up of two or more parts. A composite material is one made of two other materials. The composite material then has the properties of the two materials that have been combined.

The word composite in the term composite material signifies that two or more materials are combined on a macroscopic scale to form a useful third material. Natural frequency for five modes of two different materials are as follows:

**Table 3: Frequency mode for two different materials**

| Frequency Mode For Three Different Materials in Hz. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nylon 6 | 0.075 | 63.617 | 137.92 | 256.11 | 907.48 | 0.075 | 63.617 | 137.92 | 256.11 |
| Cast Iron | 0.1834 | 174.71 | 264.37 | 709.61 | 2244.2 | 0.1834 | 174.71 | 264.37 | 709.61 |

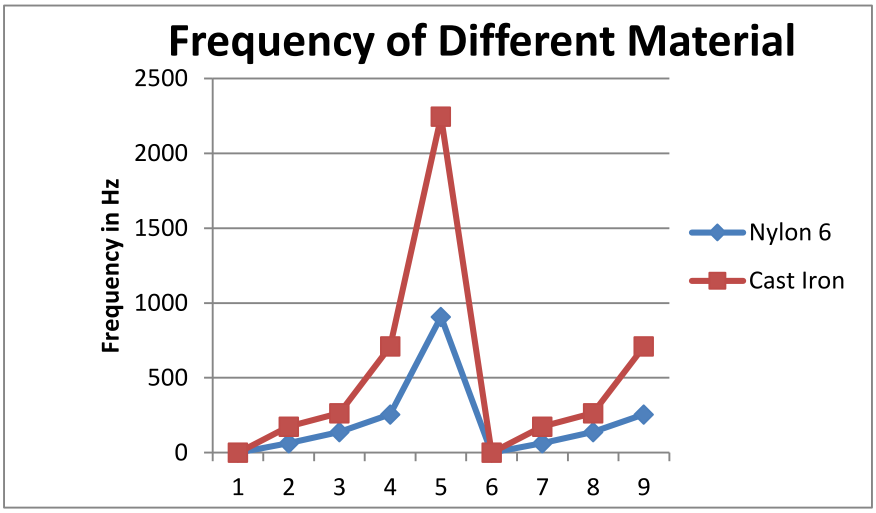


**Fig. 3: Frequency mode for two different materials**

From analysis results and comparison of properties of all the materials, it is found that Nylon-6 is the material which is having the low natural frequency, least density and stress values less than their respective permissible yield stress values so that the design is safe and it is easily available. Machining cost for Nylon-6 is less. Hence it is the best suited alternate material for pump impeller.

## 3. EXPERIMENTAL SETUP

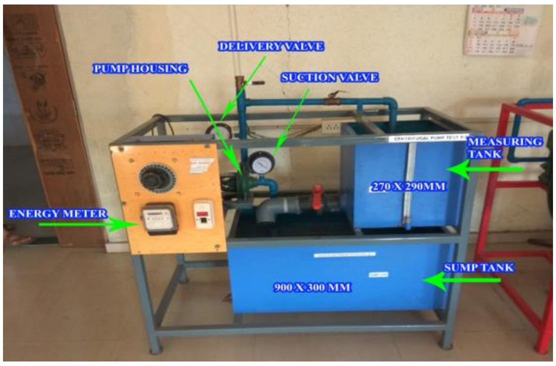


**Fig. 4: experimental setup**

 

The experiment was carried out on best suited alternate material for pump impeller that is Nylon-6. FFT analyzer is used to measure the vibration response of a system. In the experimental modal test, the structure is artificially excited by using impact hammer and performing a running test on actual working condition.

## 4. SETUP CALCULATION

Performance of single stage Centrifugal Pump (99mm Impeller Dia),
MS/CI Material Kirloskar make the pump
(Data: Measuring Tank C. S. Area: 27X29cm, Water Volume =8410 cm3,

$$(po)\ output\ \ Power = \ \rho xgxhtxQ \div 1000(kw)$$

$$Pi\ (Input\ Power = \frac{3600}{3200} X \frac{10}{t1},$$

$$\eta\,(Efficiency) = \frac{Po}{Pi} x100)$$

**Table 4: Performance of single stage Centrifugal Pump (99mm Impeller Dia), MS/CI Material Impeller**

| S no./ Units | Delivery Pressure | Suction Pressure | Time for 10 Pulse of Energy meter (t1) | Time for 10 cm water column rise in delivery Tank (t2) | Total Pressure (ht) | Output Power (Po) | Input Power (Pi) | Water Flow Rate | Pump Efficiency (η) |
|---|---|---|---|---|---|---|---|---|---|
| Units | Kg/cm2 | Cmhg | Sec | Sec | cmwc | kw | kw | Cm3/s | %age |
| **S no.** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | 0.25 | 25.610 | 14.57 | 2.14 | 598 | 0.193 | 0.772 | 3930 | 25.00 |
| 2 | 0.50 | 22.059 | 8.52 | 2.50 | 800 | 0.264 | 0.709 | 3367 | 37.25 |
| 3 | 0.75 | 25.735 | 24.33 | 4.00 | 1100 | 0.227 | 0.462 | 2100 | 49.13 |
| 4 | 1.00 | 14.706 | 52.82 | 10.96 | 1150 | 0.073 | 0.165 | 667 | 45.50 |
| 5 | 1.10 | 7.353 | 68.08 | 12.61 | 1200 | 0.075 | 0.165 | 767 | 45.45 |

Sample calculations.
Calculation for S no (3) where delivery pressure of 0.75 kg/cm2)

$$Total\ Pressure\ Head\ = \ ht\ = (0.75x1000) + (\frac{257.35}{10} x13.6x1100) = 7.5 + 349.99$$

= 750+1099.99

=1100cmwc

$$Water\ flow\ rate\ = Q = \frac{29x\ 29x10}{4} = 2.1025x103 = 2.1x103cm3/s$$

$$Po = \ Power\ Output = \ \frac{\rho}{1000}\ x\ g\ x\ ht\ x\ Q\ (kw)\ = \frac{1000}{1000}\ x\ 9.81\ x\ 11\ x2.1x10^{-3}$$

0.2266 ≅ 0.227 kw

$$Pi\ = \ Power\ Input\ = \frac{3600}{3200}\ x\ \frac{10}{t1}\ = \ \frac{360}{32}\ x\ \frac{1}{24.33}\ = \ 0.462\ kw$$

$$\therefore \eta p\ = \ Pump\ efficiency\ = \frac{Po}{Pi} = \frac{0.227}{0.462} = 0.4913\ or\ 49.13\ \%$$

Performance of single stage Centrifugal Pump (99mmImpeller Dia)
, Nylon Material with Kirloskar casing
(Data: Measuring Tank C. S. Area: 270X290 mm, Water Volume =8410 cm3,

$$(po)\ output\ \ Power = \ \rho xgxhtxQ \div 1000(kw);$$

$$Pi(\ Input\ Power = \frac{3600}{3200} X \frac{10}{t1},$$

$$\eta\,(efficiency) = \frac{Po}{Pi} x100)$$

**Table 5: Performance of single stage centrifugal pump (99mm Impeller Dia), Nylon impeller**

| S no./ Units | Delivery Pressure | Suction Pressure | Time for 10 Pulse of Energy meter (t1) | Time for 10 cm water column rise in delivery Tank (t2) | Total Pressure (ht) | Output Power (Po) | Input Power (Pi) | Water Flow Rate | Pump Efficiency (η) |
|---|---|---|---|---|---|---|---|---|---|
| Units | Kg/cm2 | cmhg | Sec | Sec | cmwc | kw | kw | cm3/s | %age |
| **S no.** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | 0.25 | 26.471 | 17.00 | 3.00 | 610 | 0.168 | 0.662 | 2800 | 25.38 |
| 2 | 0.50 | 24.265 | 20.34 | 3.30 | 830 | 0.200 | 0.553 | 2550 | 37.63 |
| 3 | 0.75 | 26.010 | 23.44 | 3.82 | 1104 | 0.238 | 0.4800 | 2200 | 49.68 |
| 4 | 1.00 | 14.81 | 57.69 | 11.00 | 1201 | 0.089 | 0.195 | 760 | 45.64 |
| 5 | 1.10 | 14.00 | 55.69 | 11.50 | 1201 | 0.092 | 0.202 | 730 | 45.54 |

 

Sample calculations.
Calculation for Sr No (3)
Where delivery pressure of 0.75 kg/cm2)

$$Total\ Pressure\ Head\ =\ ht\ =(0.75x1000)+(\frac{257.35}{10}x13.6x100)=750+354.99$$

= 750+354

=1104mwc

$$Water\ flow\ rate\ =Q=\frac{0.29x\ 0.29x10}{3.82}=2.20x103m3/s$$

$$Po\ =\ Power\ Output\ =\ \frac{\rho}{1000}\ x\ g\ x\ ht\ x\ Q\ (kw)\ =\ \frac{1000}{1000}\ x\ 9.81\ x\ 11.04\ \ x\ 2.20\ x10-3$$

= 0.238

$$Pi\ =\ Power\ Input\ =\frac{3600}{3200}\ x\ \frac{10}{t1}\ =\ \frac{36}{32}\ x\ \frac{10}{23.44}\ =\ 0.4820\ kw$$

$$\therefore \eta p\ =\ Pump\ efficiency\ =\frac{Po}{Pi}=\frac{0.238}{0.482}=0.4958\ or\ 49.58\ \%$$

**Table 6: Comparison of Nylon and CI/MS Impeller efficiency**

| **S no./ Units** | **Delivery Pressure** | **Pump Efficiency (η) of CI/MS** | **Pump Efficiency (η) of Nylon** |
|---|---|---|---|
| Units | Kg/cm2 | %age | %age |
| **S no.** | 1 | 2 | 3 |
| 1 | 0.25 | 25.00 | 25.38 |
| 2 | 0.50 | 37.25 | 37.63 |
| 3 | 0.75 | 49.13 | 49.68 |
| 4 | 1.00 | 45.50 | 45.64 |
| 5 | 1.10 | 45.45 | 45.54 |

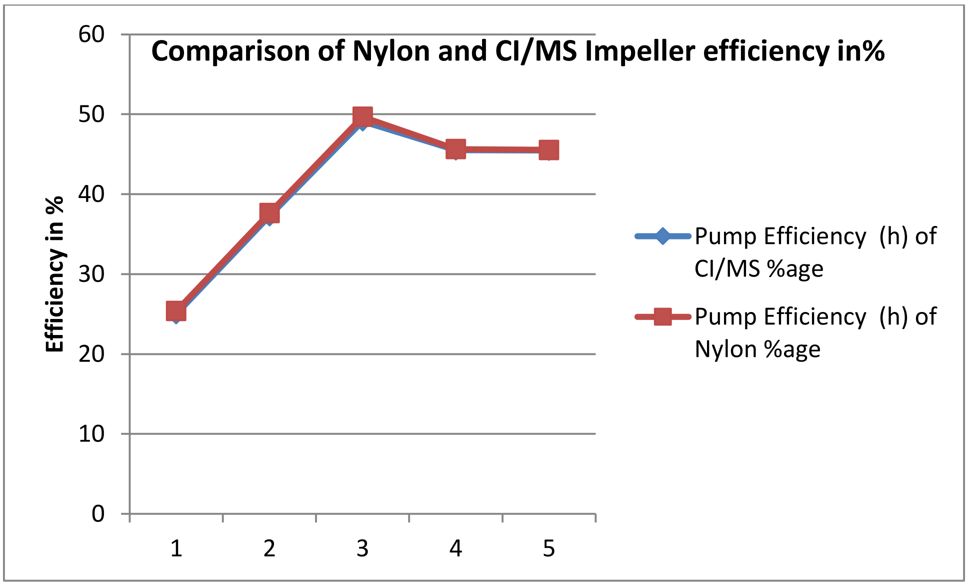


**Fig. 5: Graphical Representation of Nylon and CI/MS Impeller efficiency**

**Additional Merits of Nylon Impeller Pump**

(a) Corrosion is Avoided
(b) Starting torque less hence saving in power and Electricity Bill.
(c) Sample calculation for saving in input power and electricity Bill.

CI/MS Impeller: Pi αρ.g.ht.Q

Efficiency = ηci = 49.13 %

Above 49.13 % is for Q = 2100 cm3; ht = 1100 cmwc
Input Power =Pi= 0.462 KW

ht = 1100 cmwc whereas Efficiency 49.68% is for Nylon impeller Q= 2200 cm3/s andht=1104 cmwc since ,Q and ht are different in these cases and for comparison these values are to be brought to same(Q) and (ht) i.e.0.462 KW to be update to Q = 2200 and ht = 1104 or $\frac{0.462\ x\ 2200\ x1104}{2100x1100}$ = 0.48576

Nylon Impeller:

Efficiency = ηnyl = 49.68% (Refer: Table No (9.2)

$$\therefore Difference = (0.48576 - 0.462) \times \frac{49.68}{49.13} = 0.0246\ KW$$

∴Per day per pump energy saving Considering 24 Hr. operation /day for industrial use and tariff of Rs 8.5/KWH = 0.024x 24x 8.5= Rs 4.896

Rs 4.896 Saving of Input Power = 0.0238 KW x 24 x8

= 4.08/Day /Pump/ Rs/Kwh

Assuming (3) Pumps such in operation and for one Year (365 –60) = 305 Day (considering 2 Month for maintenance)

∴ Per Year Power saving for 3 pump=4.896 x 3 x 305= Rs 4479.84

For 15 Years life period of the pump the saving is =4479.84x 15
67197.6/-≅ Rs.67198 /-

## 5. CONCLUSION

Vibration analysis and experiment were carried out on two different materials to reduce the vibration and to improve the performance of pump impeller to find out suitable alternative materials. From that, it was found that the maximum deformation and low natural frequency is possible for Nylon-6 as compared to CI/Mild Steel. Also, Nylon-6 has the least density so that weight reduction is possible. Due to low weight and low natural frequency of Nylon-6impeller, it is the best suitable alternative material for pump impeller, offering better efficiency.

## 6. REFERENCES


[1] Osama Hamomd, Xiang Tian, Abdul Rahman Albraik, Fengshou Gu, Andrew Ball, “A new method of vibration analysis for the diagnosis of the impeller in a centrifugal pump” Centre for Efficiency and Performance Engineering, University of Huddersfield, UK

[2] Atia E. Khalifa, “Effect of Blade Exit Shape on Performance and Vibration of a Double Volute Centrifugal Pump”, International Journal of Materials, Mechanics and Manufacturing, Vol. 2, No. 4, November 2014

[3] Waleed Abdulkarem, Rajakannu Amuthakkannan, and Khalid F. Al-Raheem, “Centrifugal Pump Impeller Crack Detection Using Vibration Analysis”, International Conference on Research in Science, Engineering and Technology (ICRSET’2014), March 21-22, 2014 Dubai (UAE).

[4] James David Kesler, “Centrifugal Fans Using Vibration Analysis To Detect Problems”, Copyright 2014 Technical Associates of Charlotte, P.C.

[5] Kristoffer K. McKee, Gareth Forbes, Ilyas Mazhar, Rodney Entwistle and Ian Howard Curtin University, Western Australia, ”A review of major centrifugal pump failure modes with application to the water supply and sewerage industries”, CurtinUniversity, Australia

[6] Sanjay Taneja, “Effect Of Unbalance On Performance Of Centrifugal Pump”, International Journal Of Scientific and Technology Research Volume 2, Issue 8, August 2013

[7] G. Suresh Babu*, Dr V. Chittaranjan Das, “Condition monitoring and vibration analysis of boiler feed pump”, International Journal of Scientific and Research Publications, Volume 3, Issue 6, June 2013 ISSN 2250-3153

[8] Ravindra Birajdar, Rajashri Patil, Kedar Khanzode, “Vibration And Noise In Centrifugal Pumps - Sources And Diagnosis Methods”, 3rd International Conference on Integrity, Reliability and Failure, Porto/Portugal, 20-24 July 2009

[9] Robert A. Shannon, PE, “Vibration Measurement Systems and Guidelines for Centrifugal Fans – A Field Perspective”, AMCA International Engineering Conference Las Vegas, NV, USA 2 – 4 March 2008.

[10] Nikhil K. Kar, Yinghui Hu,”Failure analysis of a polymer centrifugal impeller”, published by Elsevier Ltd, 11 March 2015.

[11] Dr P.N. Modi, Dr S.N. Seth, “Hydraulic and Fluid Mechanics Including Hydraulic Machines” 19th Edition, Standard Book House, Rajsons Publications Pvt. Ltd, pp. 1177-1214.


 