Performance Analysis of Pitched Blade Impellers for Homogenizing Low Viscosity Fluids

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Abstract : ***Impellers play an important role for homogenizing the liquids. This work is aimed at achieving the axial motion created by the pitched blade impeller which ensures proper blending of the fluids and also axial flow ensures development of single loop during mixing, hence results in better coalition. In this work, a pitched blade impellers are designed to ensure proper homogenizing for all low viscosity fluids. To facilitate proper blend of liquids, the pitched blade impellers is designed on a station with certain degrees of freedom like longitudinal/axial motion of mixer for loading and unloading, facility to adjust the impeller location from the bottom, etc. In this dissertation, different components required for the impeller for mixing such as shaft, motor mount and frame were modeled using CAD software (Solid works). Stress analysis and CFD analysis of the Impellers was carried out using FEA software package (ANSYS Structural Simulation) and CFD software package (Solid works Simulation) respectively.***

Keywords: Flow, CAD Design, Pitched Blade Impellers, Low Viscosity, FEA, CFD.

I. INTRODUCTION

Various impeller designs and configurations are used, depending on the batch viscosity and processing requirements for components within the batch. Unfortunately, despite all the technologies currently available, most companies—regardless of how big or small—do not properly apply the different types of dispersion. More than 90% of people within the industry believe that a proper tip speed for a disperser is 5000 FPM. While this speed is required for particle size reduction and deagglomeration, it is by no means necessary or efficient when used in blending applications, or in applications that contain shear-sensitive components.

Fig 1. Two Blade Impeller Design

II. DESIGN AND ANALYSIS

CALCULATION

Selection of fluid

Viscosity is the property of a fluid which opposes the relative motion between two surfaces of the fluid that are moving at different velocities. In simple terms, viscosity means friction between the molecules of fluid. When the fluid is forced through a tube, the particles which compose the fluid generally move more quickly near the tube's axis and more slowly near its walls; therefore some stress (such as a pressure difference between the two ends of the tube) is needed to overcome the friction between particle layers to keep the fluid moving.

Viscosity plays an important role in the design of mixer. It determines the power required for proper mixing of the fluid. Reynolds's (Re) number is given as

$$Re = \frac{\rho V D}{\mu}$$

Where ρ = Density of fluid, V = Velocity of tip, D = Diameter of impeller

μ = Kinematic viscosity

If Re is < 2000 the flow is laminar

If 2000< Re < 40000 the flow is transitional

whereas if Re > 4000 the flow is turbulent.

Hence it is necessary to ensure that the flow is turbulent.

Higher the viscosity lower is the Reynolds's number and hence flow becomes laminar which does not ensure proper mixing and the speed and diameter needs to be increased in order to compensate for the reduced Re number.

In this step, in order to keep the solution feasible and economical we have chosen low viscosity fluids which can be mixed easily. After a preliminary study we found that fluids having viscosity in the range of 1-3 cP can be mixed using a low power motor making the solution feasible and economic.

Density of the fluid also plays an important role in motor selection and influences the fluid forces acting on the shaft design. In order to keep fluid forces within safe range and to use low power motor fluids having density approximately around water.

Following are some of the fluids with their properties:

Fluid	Viscosity [cP]	Density [kg/m3]
Acetone	0.306	784
Benzene	0.6	876
Water	0.894	997
Milk	1.54	1026
Ethanol	1.74	789
Methanol	0.544	792
Nitrobenzene	1.863	1200
propanol	1.945	803

Impeller Design

The most important factors governing the selection of the impeller type include the power number and Reynolds number. The power number gives the amount of the consumed by the blade whereas the Reynolds number suggests the type of flow.

The power number is one of the most widely used design specifications in the mixing operation and has proven to be a reliable predictor of a number of process results. The power number can be calculated from the formula:

$$Np = \frac{P}{\rho N3\, d5}$$

Where Np is the power number, P = Power consumed, ρ = Density of fluid

d = Diameter of the impeller, N = Speed of impeller

Flow number is also an important parameter to be taken into consideration while selecting an impeller.

Formula of flow number is given by:

$$Nq = \frac{Q}{Nd3}$$

Where Q is the radial discharge

Typical values of flow number for various impellers are shown in the table below:

Table no. 3 Impeller comparison

Impeller Type	Power number	Flow number
Narrow blade hydrofoil	0.3	0.52
Wide blade hydrofoil	0.7	0.66
Pitched Blade Turbine	1.50	0.80
Flat Blade Turbine	3.0	0.80
Rushton Turbine	5.00	0.65
HSD-Sawtooth	0.10	0.05

As observed from the table the least power number and the highest flow number is observed in the Pitched Blade Turbine. Hence we have selected Pitched Blade Turbine as our impeller. The exact value of power number is obtained from the fig that shows power curve for standard tank configuration given in [11] Joshi's Process Equipment Design (4th edition) on page no. 379. The procedure followed for impeller design is as follows:

First step in impeller design is to obtain the tank dimensions in which mixing is carried out which are as follows:

Tank Dimensions:

D = 590 mm, H = 950 mm

h = 767 mm (Fluid height), V = 200 liters

Now, following empirical relations are used to find the impeller specifications taken as from [5]"Handbook of Industrial Mixing Science and Practice"

Impeller Calculation:

d = (0.3 to 0.6) * D = 0.3 * 590 = 177 ....(For practical feasibility, d = 210 mm)

$w = \frac{d}{10} = 20$ mm

t = (8 to 10 mm) = 10 mm

h = 1.3 * D = 1.3 * 590 = 767 mm

n = 2 .... (Number of impeller)

$d_h = 2d_o$ (Shaft Outside Diameter)

$d_h = 2 * 48.3 = 96.6$ mm

Stresses in Blade

$R_b = d/2 = 177/2 = 88.5$ mm, $R_h = d_h/2 = 96.6/2 = 48.3$ mm

Stresses in the blade are given by the equation [11]

$$\sigma = \frac{Max\ B.M}{Z} = \frac{(0.75Rb - Rh)}{\frac{t*w^2}{6}}$$

$$= \frac{202.2727\ (0.75 * 88.5 - 48.3)}{\frac{10*20^2}{6}}$$

$= 5.4841\ N/mm^2$

$= 5.4841 * 10^6\ N/m^2$

$5.4841 * 10^6\ N/m^2 < 80 * 10^6\ N/m^2$............(Blade design stress)

Hence, blade design is safe.

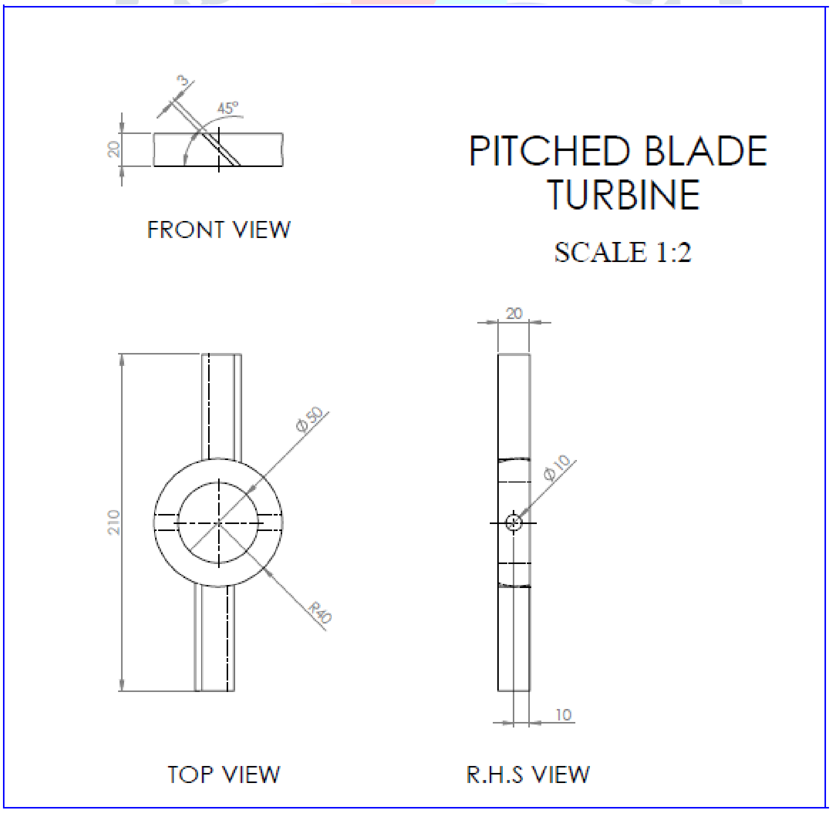


Fig 2. Impeller Blade Draft Design

Impeller Analysis:

Fig 3. Two blade Pitch blade impeller

Material Property:-

Properties Name: AISI 304	Model type: Linear Elastic Isotropic
Default failure criterion: Unknown	Yield strength: 2.06807e+008 N/m^2
Tensile strength: 5.17017e+008 N/m^2	Elastic modulus: 1.9e+011 N/m^2
Poisson's ratio: 0.29	Mass density: 8000 kg/m^3
Shear modulus: 7.5e+010 N/m^2	Thermal expansion coefficient: 1.8e-005 /Kelvin

Loads and Fixtures:

Fig 4. Fixture Image

Fixture Details:-

Entities:	1 face(s)
Type:	Fixed Geometry

Load Name: Gravity-1:

Fig 5. Gravity (load image)

Load Details:-

Reference:	Face< 1 >
Values:	0 0 -9.81
Units:	m/s^2

Load Name: Torque-1:

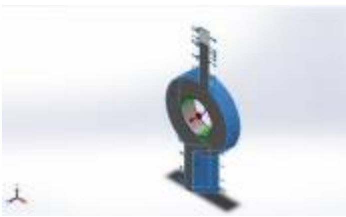


Fig 6. Torque-1(load image)

Load Details:-

Entities:	6 face(s)
Type:	Apply torque
Value:	13.35 N.m

Solid Mesh:

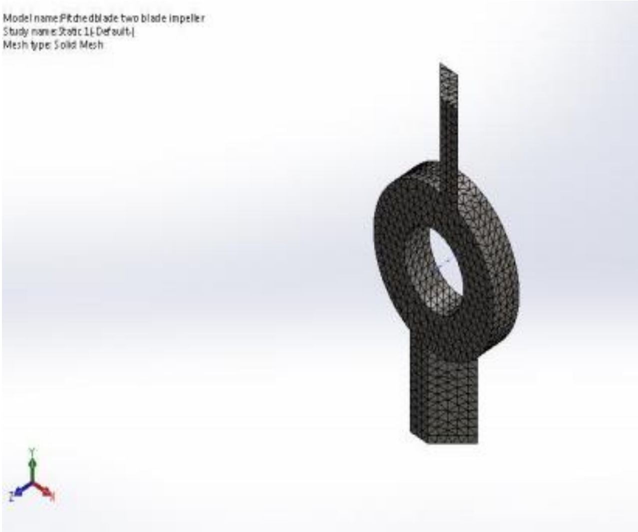


Fig 7. Pitch blade Solid Mesh

Mesh information:-

Mesh type:	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	5.21404 mm
Tolerance	0.260702 mm
Mesh Quality Plot	High

III. STUDY RESULT

Name	**Type**	**Min**	**Max**
Stress1	VON: von Mises Stress	4.876e+003N/m^2 Node: 5412	2.348e+006N/m^2 Node: 10727

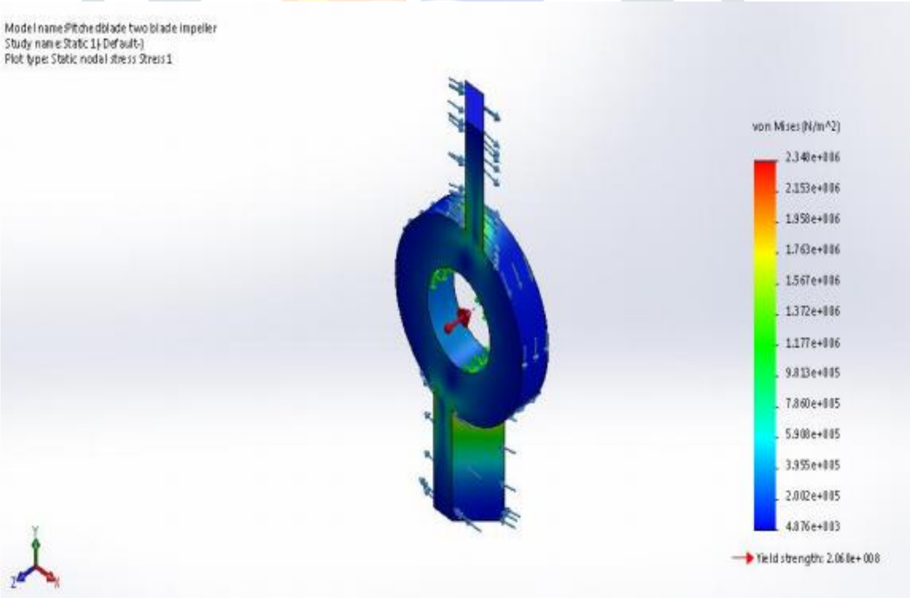


Fig 8. Pitch blade static nodal stress

Name	**Type**	**Min**	**Max**
Displacement1	URES: Resultant Displacement	0.000e+000mm Node: 1	2.310e-003mm Node: 404

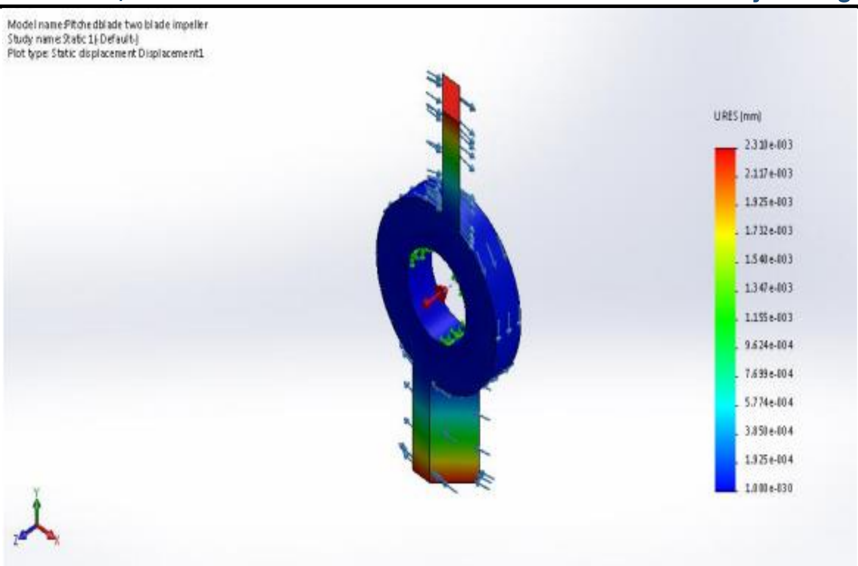


Fig 9. Pitch blade Static displacement

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	4.339e-008 Element: 3536	8.122e-006 Element: 2290

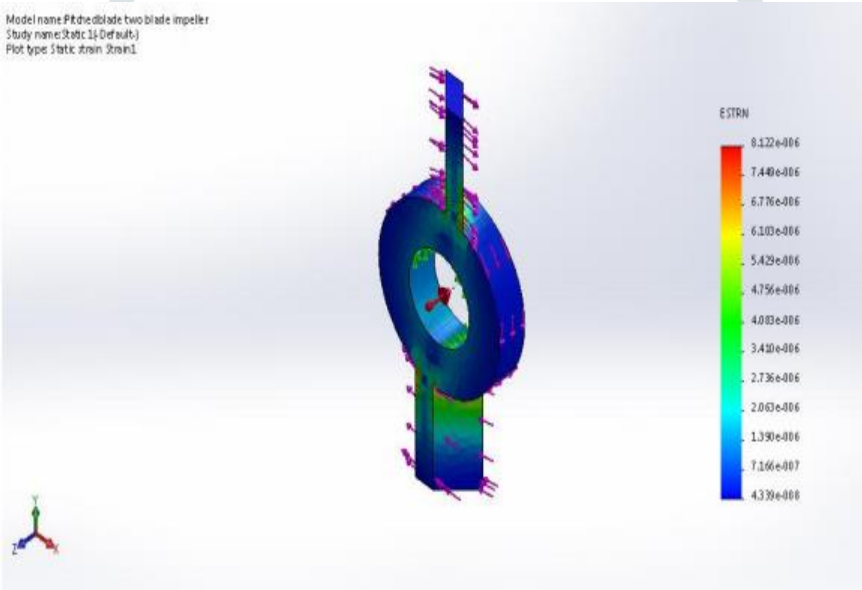
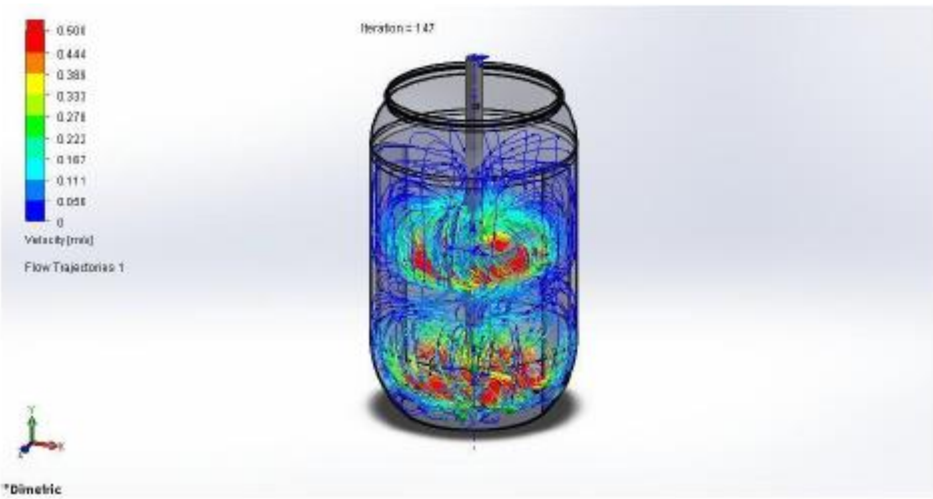


Fig 10. Pitch blade Static strain

Solidworks Flow Simulation was used to ensure proper axial flow was setup by using the shaft and impeller sub assembly and the used dimensions of tank using two baffles at 180$_0$ angle. The results of the study are demonstrated using velocity vectors plot as shown in figure below.



IV. CONCLUSION

The conclusion of the project was to design and develop a pitched blade impeller for a range fluid viscosity (1-3cp). In this project, studied the different configuration, pitched blade impellers and mixture layouts and have come to select the best possible outcome based on safety, availability and feasibility of manufacturing.

The Pitched Blade Impellers in the set up was designed and analyzed using computerized software packages such as Solidworks Flow Simulations and ANSYS Workbench for safety requirements. In the future work was to study different material for impeller design and also analysis force, stress, etc. with the help of ANSYS and Solidworks software's.

V. REFERENCES

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