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Simulation Studies on Flow Enhancement in Mixed Flow Pump With Modified Impeller Design Using CFD Analysis

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***Abstract*--Stirred tank has been the research area for many decades due to its applicability in chemical, pharmaceuticals, polymers, food and paints industries for variety of operation. Most of the energy supplied by the impeller is dissipated in the impeller region which leads to no uniformities in the energy dissipation throughout the reactor. From the survey taken from industry, it is observed that most of the industries use disc impeller. The disc impeller having major drawback of lower mixing rate and high power consumption. To overcome this, V-shape impeller is designed with various blade angles. The turbulence of the respective angle with various speeds has been analyzed by using CFD software.**

***Key words* – Mixed flow pump, Design impeller, V-shape impeller, CFD.**

INTRODUCTION

The progress of Computer Fluid Dynamics (CFD) for the last 20 years has made it as important tool for process mixing in stirred tanks. Stirred tank reactor is commonly used in many industries such as chemical biotechnologies, chemical, food processing and many more [4]. Many design and specification have come out for stirred tanks and they were different according to its use [1]. Most of the study is to make the optimum stirred tank design configuration with good efficiencies of mixing process. Factors that manipulate the performance of mixing process are, mixing time, blade type; blade numbers, speed and blade diameter of the rotating blade and the use of baffle [4]. Wu and Patterson [2] studied the energy dissipation for Rushton turbine; authors finished that about 30% of the total energy was dissipated in the impeller region, and rest in the bulk of the tank. equally, Zhou and Kresta [3] studied the maximum energy dissipation in the stirred tank for different geometry and impellers. They found the bulk of the energy dissipated in the impeller region and the impeller discharge stream. In order to decrease the non-uniformity and to make the entire reactor hydro dynamically active in a related manner, here we recommend the use of Fractal Impeller (*FI*) for mixing and dispersion. Fractal impeller occupies less than 0.4% of the total volume of the reactor which is nearly equal to the conventional impellers. The impeller does not have any blades that sweep up the liquid with it but the arrangement of blades only allows cutting the fluid thereby lower the friction throughout the tank. Performance of the present impeller design in terms of power consumption, mixing time, solid-liquid delay and gas-liquid dispersion has been studied [5]. The power number (*NP*) was found 0.38 which is lower than the conventional impellers (Ruston turbine = 6, PBTD = 1.84). Mixing performance was also relatively better than the conventional impellers. Bubble size delivery in gas-liquid dispersion was very much narrow which helps proving the self similarity hypothesis.

COMPUTATIONAL MODELING:

In CFD model, three dimensional times averaged Reynolds transport equations were solved with the k-ε model for turbulence. The equations were solved using rotating frame of reference formulations. The transport equation for a generalized flow variable f are written as

$$\frac{\partial(u_j \emptyset)}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\tau \frac{\partial \emptyset}{\partial x_j}\right) + S_Q$$

Here f stands for uj, k, ε etc. The source terms for different flow variables (SQ) are different.

IMPELLER DESIGN CALCULATION

The values of the shaft such as torque, motor power, rotational speed, impeller thickness are calculated below.

Shaft design for strength

U.S. Eng.

$TQ\ (max) = 63\ 025(P/N)$

P is motor power {W},
TQ is torque {N · m}
N is rotational speed [rpm]

$= 63025(2/1200$

$TQ = 105.40$ {N • m}

Impeller blade thickness

U.S. Eng.

$t = 615\ (P/Nnb\ (fL\ (D/2) - DS/2)/\ (\sin\alpha\ [fL\ (D/2)]\ W\sigma b))\ ½$

$= 615(1.5/(1200*4))*(0.8(0.05)-0.025)/(\sin 45^{o}[0.8*0.05]*0.05*(80*106))$

$t = 0.04m$

MODELING DATA

The modeling impeller data listed below

- Impeller diameter-280mm
- Hub- 3inch=25.4mm
- Thickness- 4mm
- Material used-stainless steel 304
- Angle-20, 40, 60, 90
- Blade shape- V shape

SOLID WORKS MODEL

The v-shape impeller is designed in various angles of 20º, 40º, 60º, 90º by using

Solid works 2008. Those impellers are shown in the figures given below with various angles as mentioned above.

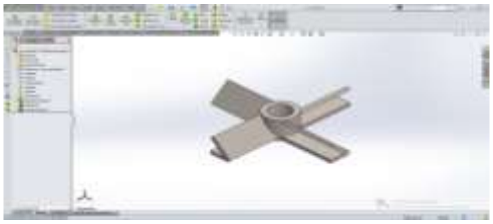

Fig 1.1 impeller angle -20°

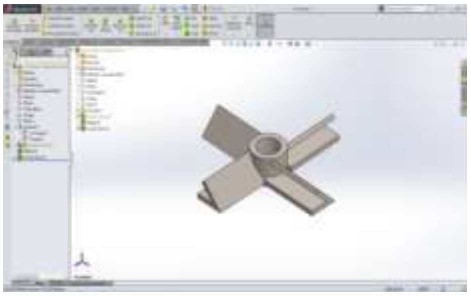

Fig 1.2 impeller angle -40°

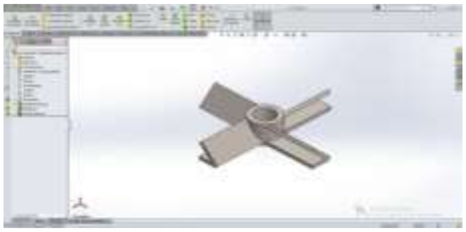

Fig 1.3 impeller angle -60°

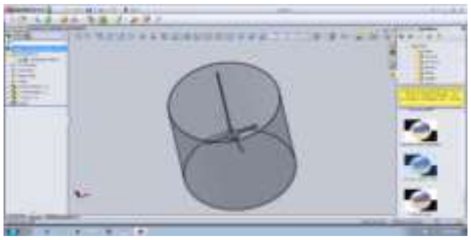

Fig 1.4 impeller angle -90°

RESULTS AND DISCUSSION

CFD simulations of the un-baffled stirrer vessel provided with the coaxial stirrer confirmed that the *k*–e turbulence model is an appropriate one, the *k–e* turbulence model equations is calculated mean flow field is characterized by an unphysical rigid body rotation.

CO -AXIAL RESULTS - TURBULENCE OF KINETIC ENERGY

The below images represents turbulence of kinetic energy k-e turbulence with various angle results from co-axial flow

Figure 2.1 Turbulence of kinetic energy - k– e turbulence – V20

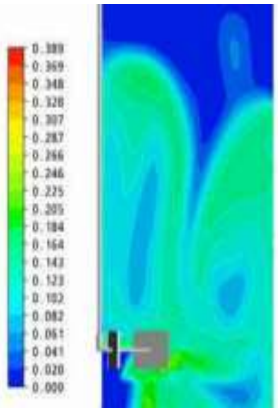

Figure 2.2 Turbulence of kinetic energy - *k*–e turbulence – V40

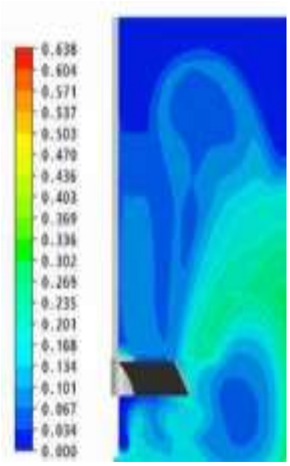

Figure 2.3 Turbulence of kinetic energy - *k*–e turbulence - V60

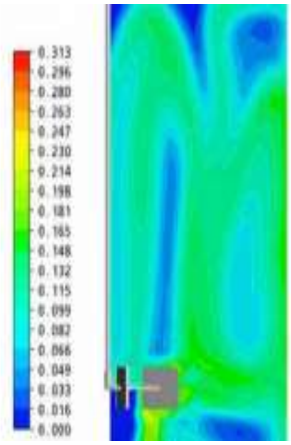

Figure 2.4 Turbulence of kinetic energy - *k*–e turbulence – V90

On comparing the above figures, the better turbulence of kinetic energy is achieved in v-20 (fig 2.1) and v-60 (fig 2.3). This is due to the presence of mixed fluid which reduces both turbulent kinetic energy and dispersion used k-Epsilon functions of equation drive a fluid attend v-shape action of the impeller

CO -AXIAL RESULTS - RADIAL VELOCITY

The below images represents turbulence of radial velocity– k-e turbulence with various angle results from co-axial flow

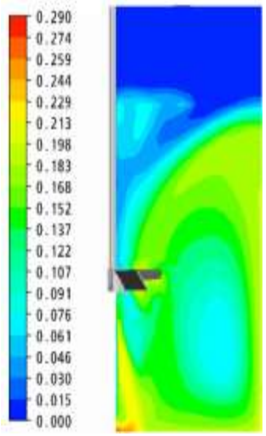

Figure 3.1 Radial velocity - *k*–e turbulence – V20

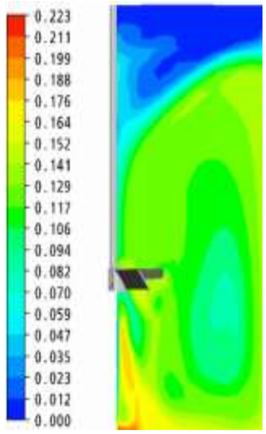

Figure 3.2 Radial velocity - *k*–e

turbulence – V40

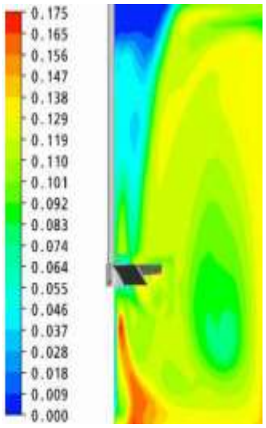

Figure 3.3 Radial velocity - k–e
Turbulence - V60

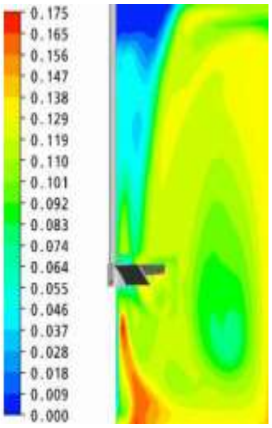

Figure 3.4 Radial velocity - k–e

turbulence – V90

On comparing the above figures, the better turbulence radial velocity is achieved in v-20 (fig 3.1) and v-90 (fig 3.4).

The results obtained in this work for the coaxial configuration in the Table 1. The simulation accuracy has been performed is to be compared with the experimental setup vs CFD. The velocity at three direction and turbulence intensity are important for stirrer operation.

Table 1 Co-Axial Readings for Different Parameters

DESCRIPTION	CO - AXIAL				
	V 20	V 40	V 60	V 90	DISC
Velocity magnitude m/s)	1.31	1.28	1.28	1.28	1.26
Axial velocity (m/s)	0.055	0.084	0.075	0.099	0.016
Radial velocity (m/s)	0.290	0.223	0.175	0.297	0.058
Turbulence kinetic energy (m^2/s^2)	0.579	0.359	0.638	0.313	0.037
Turbulence intensity (%)	57.9	35.9	63.8	61.3	15.8

The above table values are showing various impeller angles to be analyzed for using CFD software. The turbulence intensity is higher than V-60 (63.8) impeller blade compared to other blades. The disc impeller turbulence intensity is very lower than V-shape impeller. The turbulence kinetic energy is higher than V-60 impeller compared to other impeller. Impeller is replaced by V-shaped impeller the turbulence intensity is 31.3 to 35.9% greater than disc type impeller in Co-axial position.

The economical stirrer operation with low power consumption and maximum flow field generation is vital role so that Power number and flow number were calculated for each impeller. The power number and flow number v-shaped impeller in co-axial position only. The power number is related with power consumption of the stirrer vessel motor, the main parameter which is going to affect power number is shear stress, diameter of the impeller, RPM of the impeller.

The flow number is related with flow field generation, the maximum flow field is related with axial flow direction.

Formula

1) Flow Number (FN) = $Q/(ND^3)$
2) Flow (Q) = $\int \pi R^2 V$ (axial)

CO-AXIAL		
IMPELLER MODEL	POWER NUMBER	FLOW NUMBER
DISC	0.008567	0.03297
V-20	0.06082	0.108134
V-40	0.046927	0.16485
V-60	0.040907	0.147188
V-90	0.036276	0.194288

Table 2 Co-Axial Readings for Power Number and Flow Number

The value of power number and flow number are tabulated for co-axial Table 2 V20, V40, V60, V90 impellers. The power number (0.036276) and flow number (0.194288) is higher than blade angle of V-90 is compared to others impeller

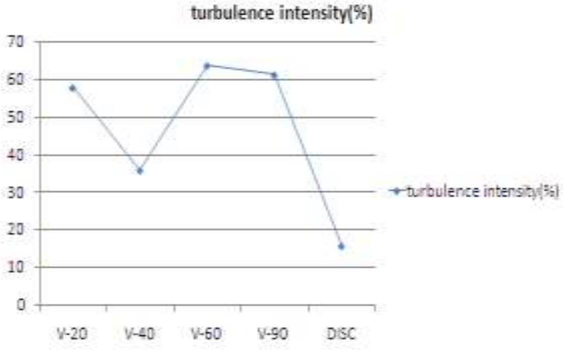

Figure 4.1 Turbulence intensity for Co-Axial

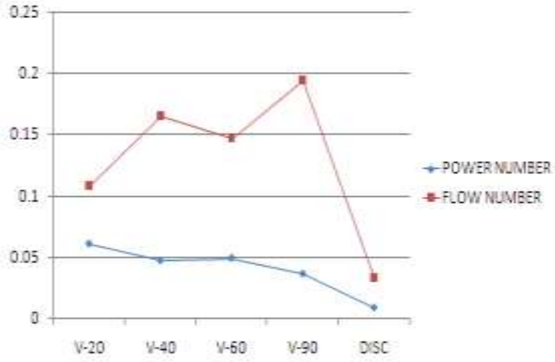

Figure 4.2 Power & Flow number for Co-Axial

Figure 4.1 shows that maximum intensity in impeller V-60 is 63.8%. But the power number also high when compared to other impellers, it will be suitable for high viscous fluids. Impeller V-60 turbulence intensity is 63.8% higher than V-90 but power number is maximum and flow number is minimum. In Figure 4.2 Impeller V-90 the flow field generation is higher than other four impellers and the power consumption is also less when compared to other type of blades.

Conclusion

In this project, an attempt has been made to improve the mixing ratio, turbulent kinetic energy and optimum of blade angles in a mixed flow pump.

From this study the following conclusions are drawn:

- Mixed flow pump with various impeller angles is analyzed using CFD software, the result showed that turbulence intensity of (63.8%) and Turbulence kinetic energy of ($0.638 m^2/s^2$) which is higher than V-60-shape impeller when compared to others
- At the same time the V-90 impeller has given higher flow number and power consumption which is lesser than V-60 impeller
- So we are choosing the V-90 impeller to got more mixing rate, flow number and reduced power consumption when compared to other impellers

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