Australian Journal of Basic and Applied Sciences, 9(36) December 2015, Pages: 583-591

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Effect Of V-Shaped Impellers In The Shaft Co-Axial And Eccentricity Position On Hydrodynamics Of Un Baffled Stirred Tank

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ARTICLE INFO

Article history:
Received 10 November 2015
Accepted 30 December 2015
Available online 18 January 2016

Keywords:
Fluid mechanics; hydrodynamics; mixing; simulation; co-axial and eccentricity agitation; un-baffled vessel

ABSTRACT

Background: The aim of this work is to investigate the effect of the shaft Co-Axial and eccentricity on the hydrodynamics of un-baffled stirred vessels with V -Shaped impeller. The difference between coaxial and eccentric agitation is studied using computational fluid dynamic software (gambit & fluent) and the result is to be compared with experiments setup. **Objective :**The comparison of the experimental and simulated mean flow fields has demonstrated that calculations based on the k–e model equations are suitable for obtaining accurate results. **Conclusion:** Depending on the position of the shaft, steady-state or transient calculations have to be chosen for predicting the correct flow patterns. Mixing performance of the stirrer vessel is based on turbulence intensity which is created by the impellers; V-Shaped impeller (eccentricity position included Angle 60 degree) is to create more turbulence intensity compared to Disc type impeller.

To Cite This Article: Sasikumar.R and Dr. KCK .Vijayakumar., Effect Of V-Shaped Impellers In The Shaft Co-Axial And Eccentricity Position On Hydrodynamics Of Un Baffled Stirred Tank. ***Aust. J. Basic & Appl. Sci.,*** *9(36): 583-591, 2015*

INTRODUCTION

Nowadays, computational fluid dynamics (CFD) simulations based on the solution of the *k*–e model equations are feasible tools for design and optimization of several apparatuses of chemical and process industry. In the past decade, many efforts have been devoted to the development of mathematical models for CFD and the capabilities of the models in predicting equipment fluid dynamics have often been assessed through the comparison with experimental data. Experimentation and has opened the way for the adoption of CFD for the selection and the design of stirred vessels. For the simulation of single-phase/multi-phase baffled stirred vessels, the more appropriate mathematical models and computational strategy to adopt when using the *k*–e model equations CFD codes is presently fairly well known. From a geometrical point of view, the un baffled vessels are simpler than the baffled ones. Therefore, it could be presumed that reliable forecasts of the fluid dynamics of such apparatuses are obtainable just by solving the same mathematical models that were proved to be suitable for baffled vessels, but without the need of resorting to particular simulation strategies, thus reducing the computational cost and complexity. A un-baffled stirred vessel provided with a coaxial impeller and obtained satisfactory results in terms of both laminar and turbulent characteristics of the flow. Generally un-baffled stirred vessels provided with coaxial mixers is available, although un baffled vessels are sometimes used in Eccentric configurations have been even less studied, but probably they have a wider practical interest, as the off-centre impeller positioning improves the mixing performance with respect to co axial. The effect of impeller eccentricity on mixing has to be investigated experimentally, in this work the hydrodynamics of an un-baffled vessel, stirred with a Disc type impeller located either coaxially or eccentrically are to be investigated. industrial practice,e.g.textile printing industries

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Fig. 1: fabricated -Disc impeller

Disc type impeller replaced by V-Shaped impeller included angle of 20,40,60,90 degrees. Each V-Shaped impeller blade co- axial and eccentricity is to be investigated and compared with Disc type impeller performance. The particular flow features of the eccentric configuration are further investigated by the *k*–e model equations CFD simulations. The comparison of the results with the experiments setup and to be find out simulations predict is correct, the laminar flow field in off-centre stirred vessels superior than co axial one.

2.Literature Review:

Previous studies of the Rushton turbine have shown that the power number is sensitive to the details of impeller geometry, and in particular to the blade thickness, but is independent of the impeller diameter to tank diameter ratio. In this paper, a similar study is reported for the pitched blade impeller. The results show that the power number is independent of blade thickness, but dependent on the impeller to tank diameter ratio. This is exactly the opposite result to that observed for the Rushton turbine. Physical explanations are given for the differences in behaviour between the two impellers. For the Rushton turbine, power consumption is dominated by form drag, so details of the blade geometry and flow separation have a significant impact (30%) on the power number. For the pitched blade impeller, form drag is not as important, but the flow at the impeller interacts strongly with the proximity of the tank walls, so changes in the position of the impeller in the tank can have a significant impact on the power number (j. Aubin, p. Mavros(2001).

The hydrodynamics of the flow in stirred-tank reactors, i.e., velocity profiles, stress fields, turbulence characteristics and etc., are essential for the confident design of mixing tanks. fluctuation tangential and radial velocities were measured using a two-component laser doppler anemometry (LDA) system for a typical Rushton turbine impeller. The working fluids had different concentrations of polyacrylamide (PAA) with rheological properties typical of those found in polymer processes. It is shown that the correlations for fluctuating velocities in Newtonian fluids do not apply to the case of viscoelastic liquids. New correlations are given in the lower part of the transition region, i.e., $30 < Re < 2000$, for fluctuating tangential and radial velocity components values along the centre line of the impeller tip (Zied Driss 2008).

The aim of this work is to investigate the effect of the shaft eccentricity on the hydrodynamics of unbaffled stirred vessels. The difference between coaxial and eccentric agitation is studied using a combination of experiments carried out by particle image velocimetry, that provide an accurate representation of the time-averaged velocity, and computational fluid dynamics simulations, that offer a complete, transient volumetric representation of the three-dimensional flow field, once a proper modeling strategy is devised. The comparison of the experimental and simulated mean flow fields has demonstrated that calculations based on Reynolds-averaged Navier–Stokes equations are suitable for obtaining accurate results. Depending on the position of the shaft, steady-state or transient calculations have to be chosen for predicting the correct flow patterns. Care must be exerted in the choice of turbulence models, as for the unbaffled configurations the results obtained with the Reynolds stress model are superior to that of the k–ε model (Günther Hessel, 2008).

The laminar flow structure and mixing performance of T-shaped and double-T-shaped micro mixers with rectangular cross-section have been investigated using computational fluid dynamic (CFD) simulation. FLUENT software is used to evaluate the mixing efficiency. The numerical simulation results show that the presented double-T-micro mixer is highly efficient over T-shaped micromixer. The performance of double-T-micromixer with and without static mixing elements (SME) is also investigated. The enhancement in mixing performance is thought to be caused by the generation of eddies and lateral velocity component when the mixture flows through these elements. Mixing efficiency as higher as 97% is reached within a mixing length of 320 μm downstream from the first

T-junction with the enhancement of three SME (m. Cudak, 2007). Single phase turbulent flow in a tank stirred with two different axial impellers, a pitched blade turbine (PBT) and a Mixel TT (MTT) has been studied using Laser Doppler Velocimetry. The effect of the agitator configuration, i.e. up-pumping, down-pumping and reverse rotation, on the turbulent flow Field, as well as power, circulation and pumping numbers has been investigated. An agitation index for each configuration was also determined. In the down-pumping mode, the impellers induced one circulation loop and the upper part of the tank was poorly mixed. When up-pumping, two circulation loops are formed, the second in the upper vessel. The PBT pumping upwards was observed to have a lower flow number and to consume more power than down-pumping; however, the agitation index and circulation efficiencies were notably higher. The MTT has been shown to circulate liquid more efficiently in the up-pumping configuration than in the other two modes. Only small effects of the MTT configuration on the power number, flow number and pumping effectiveness have been observed (j. aubin, p. mavros(2001).

It is important to extend and to validate computational flow models to simulate continuous operation of stirred vessels and to capture possible interaction of feed inlet/outlet with the flow generated by impellers. In the present work, we have developed and used a computational model to understand the flow generated by an axial flow impeller in a batch and a continuously operated baffled vessel. A multiple reference frames approach was used to simulate flow generated by the Mixel TT impeller in stirred vessel. The predicted velocity results show reasonably good agreement (qualitative as well as quantitative) with the experimental data. Characteristics of flow around blades of Mixel TT were studied using the computational model. The computational model was extended to simulate flow and mixing in a Continuous operation. Simulations were carried out to understand the interaction of the jet emanating from the feed pipe and the flow generated by the impeller. Model predictions were compared with published experimental data, obtained by laser Doppler velocimetry. The differences and similarities between batch and continuous operation are highlighted. Mixing simulations were carried out to examine possible short-circuiting and non-ideal behaviour of the continuous operation of the stirred vessel. Influence of the impeller speed, feed rate and location of inlet/outlet on mixing and on the extent of non-ideality of flow was studied. The computational model and results discussed in this work will be useful for understanding the mixing process in continuous-flow stirred vessels (v. Buwa 2006). LDA measurements are reported on the turbulent velocity fields in vessels agitated by a Rushton turbine and containing Newtonian as well as non-Newtonian, shear-thinning fluids. Ten different liquids were investigated, with flow indices varying from 1.00 down to 0.56. Experiments were performed in three vessel sizes, viz. 28.6, 44.1, and 62.7cm in diameter, at various impeller speeds. The main issue of the paper is the question whether or not, and if so to what extent, turbulent flow of shear-thinning fluids differs from that of Newtonian liquids, or – in other words – whether and when turbulent flow of shear-thinning liquids exhibits Reynolds number similarity. The experimental data presented comprise profiles of the mean velocity components and the rms fluctuating velocity components as a function of the radial position in the tank at the height of the impeller disc as well as similar profiles in the impeller outflow near to the impeller tip. The effects – if any – of both Reynolds number and flow index on these profiles are assessed. Fit equations are presented for the various profiles in the various liquids. These fit equations are claimed to be valid throughout the ranges of Reynolds numbers and flow indices covered by the experiments presented. The idea is that these fit equations may be used to validate Computational Fluid Dynamics (CFD) simulations of the Reynolds Averaged Navier–Stokes (RANS) type for agitated shear-thinning liquids, even for liquids and conditions not investigated in this study as long as falling within the Reynolds number and flow index ranges investigated (r. khopkar (2005).

3.Research Methodology:

Methodologies of this study starts with the product selection and continue with problem identification it refers to the problem in mass flow rate inside the collector tube then collection of geometric data from an already existing Impeller systems and goes to creation of model using solid works software finally it ends with the Experimentally analyzed to optimize the mass flow rate is shown in figure 1.

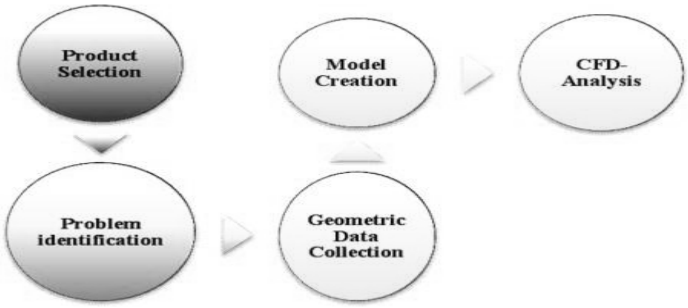

Fig. 1: Methodology of this study

4. Product Selection:

The investigation is to be carried out in a cylindrical tank (tank diameter, T =500mm, tank height, H =T), provided with a flat base. Agitation was provided with a Disc type impeller (DT) of diameter $D = T/3$ placed at the distance $C = T/3$ the vessel base is shown figure 2. For the eccentric configuration, the shaft was located at 125 mm ($E = T/4$) from the vessel axis. The vessel was contained inside filled with the working liquid either pigments or Sodium Silicate gel at room temperature; the impeller rotational speed 150&1400 rpm and time (15 minutes) to be fixed for laminar & turbulence flow.

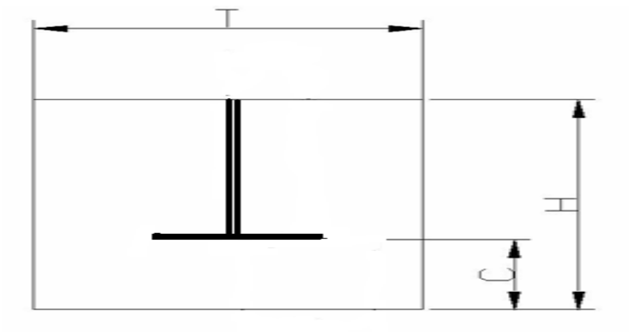

Fig. 2: co-axial

The Liquid density is to be measured with aid of hydrometer. The different types of V – shaped impeller (blade included angle 20,40,60,90 degrees) to be replaced and the investigation is to be carried out for Co - axial and eccentricity. The result is to be compared with disc type impeller.

5.Model Generation:

5.1design Consideration Of Disc Impeller:

Among all the problems encountered in designing Impeller blades, the most crucial one concerns with the end- effectors. Basic features for a Impeller depend strongly of the rotating mechanism. Thus, factors can be considered before choosing a grasping mechanism as following:

1. Characteristics of the Impeller, which include maximum payload, dimensions, orientations, number of the composed links.
2. Characteristics of the objects, which include weight, body rigidity, nature of material, geometry, dimensions, condition, position and orientation, contact surfaces, forces acting on the object and environmental conditions.
3. Impeller technology, for the construction of components (mechanism links and finger parts) with proper manufacturing and materials.
4. Flexibility of the Impeller, whether it allows rapid replacement, or easy adjusts and external modification, or adaptation to a family of objects that are contained within a range of specifications.
5. Cost for design, production and application to complex operation and maintenance. In fact, those characteristics are fundamental from a practical viewpoint for the grasping purpose, since they may describe the range of exerting force on the object by the fingers, the size range of the objects which may be grasped and a particular manipulation type. Thus, a dimensional
6. Design of Impeller mechanisms may have great influence on the maximum dimensions of the grasped object by a Impeller, and on the grasping force, since the mechanism size may affect the grasp configuration and transmission characteristics.

These peculiarities can be considered well known when it is taken into account the great variety of mechanisms which have been used.

5.2 Factors Focusing:

1.Impactive
2. Ingressive

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3.Astrictive
4.Contigutive
5. Force and torque considerations

5.3 Conceptual Design Of The Disc Impeller:

1. It should be able to grasp irregular objects of different shape and size.
2. It should be able to take different loads (of course with upper limit)
3. There should be stability during manipulations.
4. It should be independent of friction coefficient between object and Impeller.
5. Synchronization in rotating motion.
6. Employment of minimum number of actuators.
7. It should not slip, so there should be provision of interlocking.
8. It should simulate the human hand.
9. It should be precisely control (through computer or manually).

5.4 Generative 3Dimentional Modeling:

It is well known that minimum three points are required to hold any object. In my project work, a four motorized Impeller each with two limbs have been designed to hold slurry fluids as this can be used for both force and form closure purpose is figure 3,4,5,6.

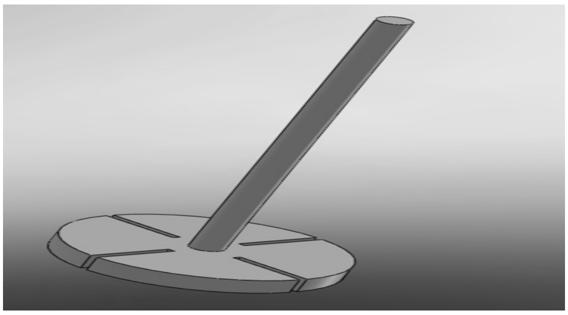


Fig. 3: (a) Disc type impeller,

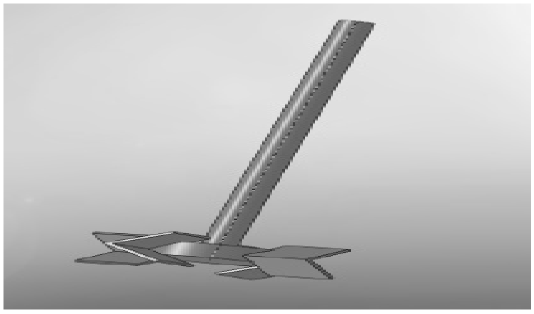
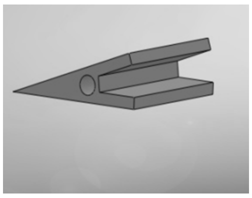
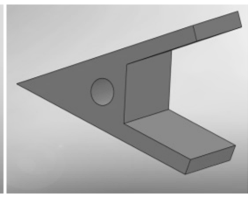
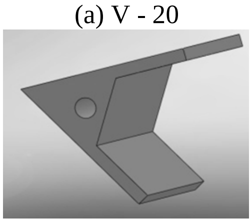


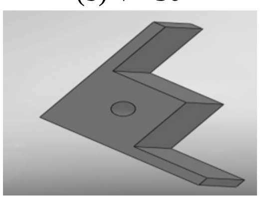
Fig. 4: (b) Modified as V- Shaped impeller





(a) V - 20 (b) V - 30





(c) V – 60 (d) V – 90

Fig. 5: Different impeller blade angles [a,b,c,d]- Modeling

In comparison to Impeller with single limb where it may fail if the friction force is not sufficient, here the presence of the second limb will augment the friction force and will help in firmly the object. The Impeller consists of a base, four fingers with two limbs each and two motors placed centrally. In order to control the two limbs of each finger, two independent actuators are required.

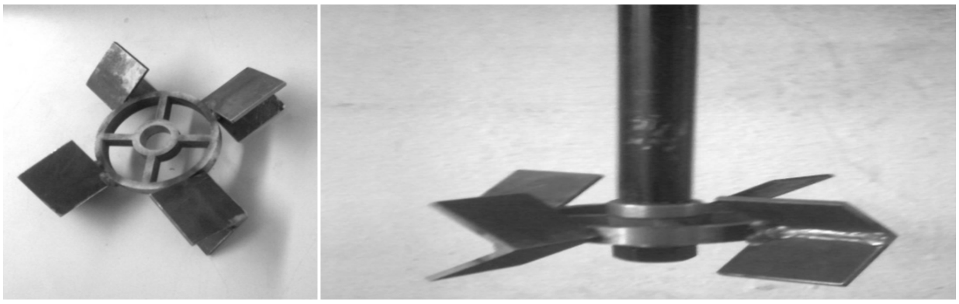


Fig. 6: fabricated parts and assembly of Different impeller blade angles

RESULTS AND DISCUSSION

Experimentally simulated of the un-baffled stirrer vessel provided with the coaxial and eccentricity 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. The results obtained in this work for the coaxial and eccentricity configuration in the Table I and Table II. The simulation accuracy has been performed is to be compared with the experimental setup. The Velocity at three direction and turbulence intensity are important for stirrer operation.

The economical stirrer operation (low power consumption and maximum flow field generation) is vital roles, so that Power number and flow number were calculated for each impeller. The power number and flow number V-shaped impeller were compared with disc type impeller in co-axial and eccentricity position. 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. (Formula 1, 2, 3)

Power number:

$$p_o = \frac{p}{\rho N^3 D^5} \quad \text{---------->} \qquad (1)$$

Power (P) = (2πN/60)*T ------------> (2)

Torque:

$$T = \frac{\pi}{16}\tau D^3 \quad \text{------------->} (3)$$

Table I: Different Positions for Disc Impellers.

DESCRIPTION	Co - Axial				
	DISC	V 20	V 40	V 60	V 90
Velocity magnitude m/s)	1.26	1.31	1.28	1.28	1.28
Axial velocity (m/s)	0.016	0.055	0.084	0.075	0.099
Radial velocity (m/s)	0.058	0.206	0.184	0.187	0.139
Tangential velocity (m/s)	1.26	0.18	0.151	0.114	0.12
Turbulence kinetic energy (m2/s2)	0.037	0.415	0.323	0.293	0.294
Turbulence intensity (%)	15.8	52.6	46.4	44.2	44.3
Turbulent dissipation rate(m2/s3)	0.16	15.3	5.3	4.4	6.98

The value of power number and flow number are tabulated for co-axial (table III) and eccentricity position (table IV) for Disc, V20, V40, V60, V90 impellers.

While analyzing with CFD Flow field characterized the disc type impeller in co-axial position radial flow is 70% greater than axial flow, the flow field maximum at radial direction, at the same time turbulence intensity is 15.8 % only, while agitation more time required for mixing the fluids. Disc type impeller is replaced by V-shaped impeller the turbulence intensity is 28.5 to 36.8% greater than disc type impeller in Co-axial position.

The flow number is related with flow field generation, the maximum flow field is related with axial flow direction. (Formula 5, 6)

Flow Number (FL) = Q/ND^3 ---------------> (4)

Flow (Q) =πR^2 V (axial) ------------ > (5)

Maximum intensity in impeller V-20 is 52%. (Fig.7.) but the power number also high compare to other impellers, it will be suitable for high viscous fluids. Impeller V-20 turbulence intensity is 15.77% higher than V-90 but power number is maximum and flow number is minimum (Fig.8). Impeller V-90 the flow field generation is higher than other four impellers, Compare to disc type impeller turbulence intensity is 64% more and flow number is 83% greater, so it is suitable for low viscosity fluids in co-axial position.

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Table 2: Different Positions for Disc Impellers -Eccentricity.

DESCRIPTION	ECCENTRICITY				
	DISC	V 20	V 40	V 60	V 90
Velocity magnitude (m/s)	3.22	3.23	3.22	3.22	3.92
Axial velocity (m/s)	0.122	0.126	0.125	0.154	0.186
Radial velocity (m/s)	0.842	0.394	0.32	0.301	0.168
Tangential velocity (m/s)	3.22	0.398	0.387	0.407	0.23
Turbulence kinetic energy (m2/s2)	0.252	0.637	0.731	0.814	0.799
Turbulence intensity (%)	41	65.2	69.8	73.7	73
Turbulent dissipation rate (m2/s3)	5.72	467	66.1	47.6	62.5

Table 3: Different Positions -Co-axial Vs Power Number with Flow Number.

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 4: Different Positions -Eccentricity Vs Power Number with Flow Number.

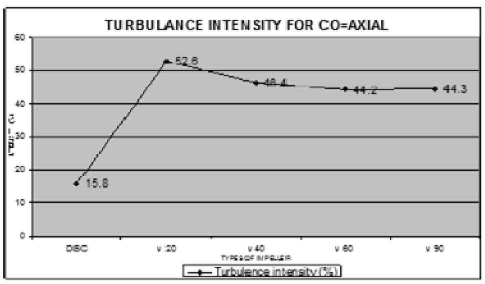
ECCENTRICITY		
IMPELLER MODEL	POWER NUMBER	FLOW NUMBER
DISC	0.118089	0.239425
V-20	0.553398	0.247275
V-40	0.249299	0.245313
V-60	0.208393	0.302225
V-90	0.275541	0.365025

Table 5: Different Positions Vs Eccentricity

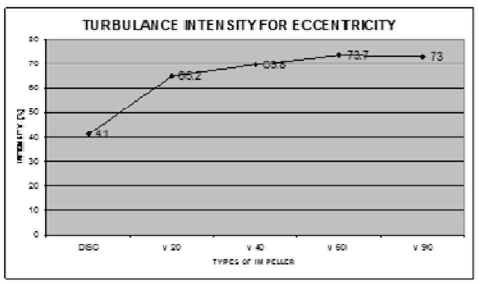
DISC	0.493219
V-20	2.237986
V-40	1.016251
V-60	0.689529
V-90	0.754855

Eccentricity agitation the turbulence intensity is greater than co-axial, the turbulence intensity is 73.6% in V-60 impeller and minimum in V-20 impeller (65.2%), the maximum flow number in V-90 impeller but the power number also very high, compare to disc type impeller. V-60 is 44% greater intensity as well as power number is very low and flow number is reasonable greater.

The impeller power number Vs flow number will show the type of impeller if the value is greater than 2.5 then it is a shear type impeller otherwise flow type impeller table V shows the details, all the impeller is a flow type but the V20 in eccentricity position the value is 2.23 it is near to shear type, power number & flow number also high compare to other type impellers.



(a)



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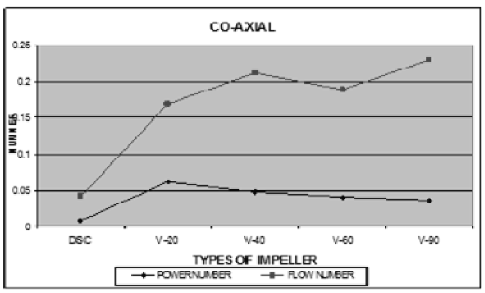
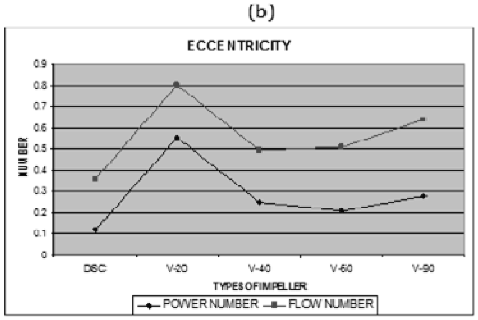
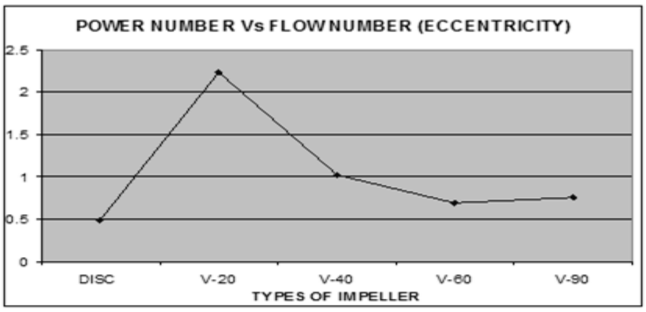


(c)



(d)



(d)

Summery:

In Experimental analyzed the effect of V-shaped impeller in the shaft position on the hydrodynamics of un-baffled stirred tanks has been investigated. Compare to disc type impeller V-shaped impeller characteristic is better and it gives good performance, while rotating it will do up and down pumping simultaneously, because of this the flow field generation is much better than disc type impeller.

The eccentricity result is superior to co-axial position. Even through V-90 impeller gives the maximum flow but the power is very much greater compare to V-60 impeller in the eccentricity position. 17.2 % of flow can be achieved by losing 24.36 % of power. Economical point of view V-90 performance is not good. V-60 impeller turbulence intensity is greater than V-90 impeller and appropriate flow can be achieved with minimum power consumption. To end this CFD result V-60 impeller in eccentricity position is giving very good performance.

Nomenclature:

Po – Power number
FL – Flow Number
P – Power (W)
ρ – Density of water (998 Kg/m^3)
D - Diameter of the impeller (m)
T – Torque of the impeller (N-m)
Q – Radial discharge (m^3/s)
V (axial) – Axial velocity of the impeller (m/s)
T – Tank diameter (m)
E – Eccentricity of the shaft (125mm)
H – Height of the tank

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