CFD Analysis of Agitated Vessels of Different Geometric Parameters: A Review

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Abstract - *Agitation or stirring is the process of making an object move in a certain way. Many processes of chemical Industries heavily rely on the effective mixing of Solid-Liquid or Liquid-Liquid phases. In many agitators the vortex is formed at the centre of fluid, this forces baffle plates into the agitating vessel.*
In this paper we studied the details of geometric parameters affecting the mixing performance of agitated vessel. It is observed that mixing performance is depends on rotations of impeller and Reynolds number that is, if speed of impeller and Reynolds number increased proper mixing occurred. Viscosity is also an important parameter that if viscosity increases ideal mixing occurred.

Key Words: Agitated Vessel, CFD, Mixing Performance, Reynolds Number, Dispersion

1. INTRODUCTION

Agitation or stirring is the process of making an object move in a certain way. Many processes of chemical Industries heavily rely on the effective mixing of Solid-Liquid or Liquid-Liquid. Although the Agitator is incredibly effective in the industry today but it still has many problems affecting the process of agitation. In many agitators the vortex is formed at the center of fluid, this forces to put baffle plates into the agitating vessel. In some agitators bubbles are formed. These bubbles cause the formation of Cavitations. Significant amounts of energy are retained in the form of pressure energy because of cavitations. So, efficiency of the agitation gets affected inversely. Agitation can be used for many purposes which are suspension of solid particles, preparation of blend of miscible liquids, formation of emulsion, enhancement of heat transfer between liquid and jackets or coil etc.

The efficiency of agitation is affected by various factors; some of these are related to the characteristics of the liquid such as density, viscosity, and some are related to the geometry of the Agitator such as diameter of container or vessel, length of impeller, speed of rotation and position of impeller from the bottom of vessel. In order to achieve great efficiency of the process, the optimization of design parameters must be done. In order to achieve maximum efficiency we are going to study the agitation and simulate the process of agitation.

2. LITERATURE REVIEW

Toshihiro Hanada Et.al. [1]improved a TDM axial mixer in order to attain the same axial mixer performance when operating against twice the duration, while reducing the pressure decrease by almost 40%. In addition, Z was less than the Z factor of the Kenics mixer. The TDM enhanced was less. Through changing pitch of branch paths, improved mixing performance has been achieved, while a changed element shape reduced the pressure drop and improved the mixing performance. The profiles of concentration and arrival timings in every branch path of the mixers were extracted further useful information.

Saeed Asiri Et.al.[2] simulated that fluid power and force transfer would be subject to the internal container form and thickness of the impeller blade. Experimental work and FEM have been conducted to calculate the optimum container form and optimum impeller blade thickness. Experimental work was done in order to articulate the inner container form in the efficiency of agitation. The intakes of the internal container (suck and unload) have been adjusted and the effect is expressed in pH. In all experial studies the complete absorption area was found to be the optimal shape configuration of the internal intake container (sucking and discharge) (sucking and discharge) by repeating the lap test with new types of internal intake container, given the high flow rate. The optimum impeller angle is 45 degrees because it provides high suction and discharge rates through the inner container for any experimental analysis with a new impeller angle and scale repeated the lap test. It is found that when the difference between the impeller tip and the internal container surface is minimum, the optimum dimensions of the impeller are.

A new self-agitator for enhancing thermal transfer is developed and computational and experimental analysis is demonstrated by **Zheng Li Et.al.[3]**. The results in numbers allow the auto-agitator to increase heat transfer by 42% with the same speed and 27% with the same pump energy, while the number of Nusselt can be increased by 52% with the same number of Reynolds, in comparison to clean channels. In order to research the critical relationship of convective heat transfer improvement to vorticity fields, modal analysis is carried out in numerical transient vorticity and temperature areas.

Idris A. Kayode Et.al.[4] designed new KIA impeller using ANSYS CFX V15, and the following comparison study is carried out using three traditional style impellers (Rushton, Anchor and Pitched Blade). The results indicate that, KIA impeller increases efficiency of the Rushton impeller of six blades, with greater than before impeller speeds and enhanced heat distribution in terms of mixing capacities, reduced in dead areas. Among the impellers tested, the anchor and pitched blade impellers are improving overall because of use of the single phase model method in simulating the fluid. The homogenising vessel is fitted with a baffle for KIA, Pitched Blade and Rushton pushers. The anchor impeller offers greater homogeneity of the fluid and heat dissipation (carrot – orange soup) in the homogenizer but a significantly higher energy usage than other impellers.

Tomas Jirout Et.al.[5] discussed that, the hydraulic operation of mixing suspension is extremely significant. It also happens when dispersions are prepared. Mass transfer among solid and liquid particles and homogenization is carried out with chemical or biochemical reaction. The heterogeneous system, i.e. particulate solid phase-liquid, is estimated to account for approximately sixty percent of the compound. However, the revision of guidelines for the construction of suspension mixing machines focused on measurements of only two volumetric particle concentrations of 2,5% and 10%. It follows from its conclusion that in such situations axial flow pattern impellers are commonly understood to be the most appropriate agitators. His paper builds on impeller design guidelines for particle suspension in a wide variety of concentrations and particle diameters with many axial flow impeller forms. The designer's decision is based on the speed and power consumption needed for the off-bottom suspension of solid particles. So, designer is therefore responsible to choose between alternative impeller.

Gaikwad Prasanna P. Et. al.[6] discussed in his article that, The best option for tank and impeller geometry will differ widely depending on the purpose of operation performed in a mixer. In order to achieve the desired product quality, different materials need various types of impellers and tank geometries. Also in a single vessel, the flow field and mixing phase are very difficult. The fluid around the rotating impellers interacts with the fixed baffle plates and creates a dynamic, 3-dimensional turbulent flow. The other parameters such as rotor length from the bottom of the tank, the closeness of the vessel walls and the length of baffle plates would also affect the flow generated. It is also difficult to optimise the existence of too many design parameters. Thus the computer is built and manufactured and these components are assembled with standard parts available. The setup of the system is then tested to ensure its effectiveness. During the test, the machine will operate with defined rpm and enough turbulence is generated inside the mixing chamber. There are slightly less movements during service. All of this contributes to homogeneous mixing of the mixing chamber materials, our key purposes. The problem is that the system can function with a specific range of viscosity, and it can control its previously built restricted power. The efficiency of the computer is adequate for certain conditions. In the future, the idea of disruption, sensors and square vessel concept are also proposed for large capacity tanks.

Akash J Patil Et.al.[7] in his review article found that, Various agitator styles are available. The chemical mixing method is not consistent and proper in the various industries. Various stresses such as bending stress and deformation stress are caused by the agitator. The study can provide an idea of an optimal design that can increase the mixture percentage. Due to various joining methods used to combine arms and hub, the weight of the agitator is also heavy. The weight of the agitator can be lowered so that the energy consumption of the agitator can be reduced and its performance and mixing improves by decreasing its weight.

Sumit R.Desai et.al.[8] concluded that, By selecting various materials for agitators, we can increase strength, ductility and corrosion resistance. Impeller no rise increases the time of the mixing. It provides equilibrium and decreases deformation. We can provide for baffling plates in the ship with the assembly of the agitator shaft in the centre. The supply of blankets gives a structured blend. In a dual impeller shaft, the equivalent stress produced is about the same as in a single impel. Double shaft deflection is less than the single shaft impeller deflection. The distortion and the stress equivalent are within the permitted limit.

Praveen Patel et.al [9] Discussed that, Various reactors have been modelled to better understand mixing and hydrostatic dynamics in the stirred tank with different impeller configurations. The system has been tested in the speed profile and homogeneity. The structures of the reactor were flat, bottom and ellipsoid tanks with various types of impellers: revolving disc, four-wheel impellers and pitched blade impellers. At different revolution speeds like 10, 20, 50 and 100 RPM, each reactor configuration was simulated.

According to **Ian Torotwa [10]**, the technique proposed was applicable to the turbulent flow characteristics. In experiments and CFD analysis, the flow patterns of the various impeller designs used in his work were satisfactorily represented. The findings from CFD simulations have been verified to be compatible with experimental values. The design of the impeller blade was shown to affect the efficiency of a mechanically stirred mixer substantially. The best mixing designs improve mixing efficiency and have a reasonable level of homogeneity, depending on the design. His study would be helpful in choosing the correct type of impellers that will ensure optimal performance and the cost-effective use of costly chemicals and other mixing agents. It will also provide a framework on which, using minimum costs, time and space, large mixing systems can be built and operated.

3. STUDY OUTCOMES

The Agitated Vessel has vast flexibility with flow conditions; hence it is widely used in chemical industries. The maximum diameter of the tank is limited to the 4.6 m ($D \leq 4.6$ m). Therefore, increase in the height of the vessel H is only possible solution to increase the volume of liquid. This results in inconsistencies such as the need for a larger stirrer and an increase in duration of residence. H/D Aspect ratio ≈ 1 is preferred in most of the operations.

In the case where the viscosity of liquids is low and the rotation speed of the stirrer is very high, the vortex can reach the head of stirrer. This can result in entrains of gas in liquid. This may consequently result in the failure of stirrer. Even if the formation of Vortex does not results in the entrainment of gas, in case of two phase system with unequal densities, undesirable rotation of liquid is generated, due to the centrifugal force which counteracts. In cylindrical tanks the baffle plates can be installed in order to prevent the rotation of liquid. In complete baffling four baffle plates are used having width is equal to D/10. D indicates internal diameter of vessel. Baffle plates are placed along the wall of vessel. By using the baffle plates with width of D/12, placing them with clearance of D/50 from the wall of vessel, the dead zones behind it, in the direction of flow, can be avoided. Welded brackets are used to attach the baffle plates to the wall of vessel. If the cross section of the vessel container is rectangular; or the stirrer is laterally mounted inside the vessel, then there is no need of baffle plates. There are various types of stirrers which are used according to the requirement.

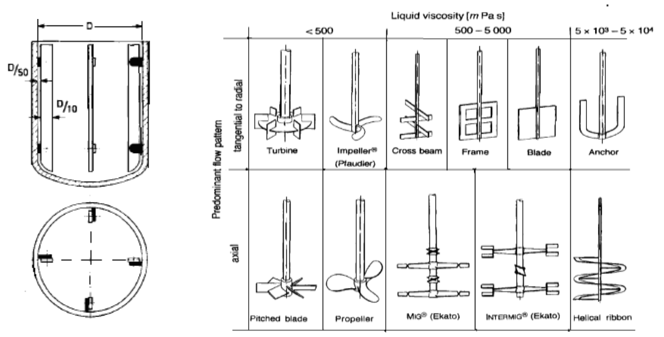

Fig - 1 Standard Design of Baffle and Types of stirrers **[11]**

Figure 1 describes the standard design for baffle plates and various types of stirrers. These standard stirrers are used is approximate 90% of agitated vessel. The speed of Turbine type impeller is highest all amongst above. If the viscosity of liquid is low then stirrers are used induces radial motion in liquid and in case of high viscosity; tangential motion. The turbine impeller is generally used for liquids with low viscosity and tank having baffled plates. The ratio of diameter of tank to diameter of impeller blade, D/d ranges from 3 to 5. Turbine impeller is very appropriate for dispersion process since it produces high shear levels.

Another type of stirrer is paddler impeller. Its stirring arms are rounded. It is used in tanks which are coated with enamel. It can be used with baffles and without baffles too. The ratio of diameter of tank to diameter of paddler impeller, D/d is generally 1.5 and it can be used with least bottom clearance.

Blade impellers, grid impellers and cross beam impeller has very slow speed of stirring. The ratio of diameter of tank to that of impeller, D/d in this case ranges from 1.5 to 2. These stirrers are suitable to use with baffle plates and without baffle plates if the viscosity of liquid is higher. These stirrers can be applied in process of homogenization.

The anchor type stirrer is slow speed stirrer. The ratio of diameter of tank to diameter of anchor impeller stirrer, D/d is less than 1.05 in order to increase the rate of heat transfer in case of liquids with higher viscosity.

Impeller type; propeller and Pitched blade has speed of stirring very high. They are designed in such a way that they can push the liquid in axial direction. These stirrers are used in case of liquids having lower viscosity. Since, the speed of rotation is very high the baffle plates are installed in tank. These stirrers are used for process of homogenization as well as process of solid suspension.

The helical ribbon stirrer has speed of stirring very low. The ratio of diameter of tank to diameter of helical ribbon stirrer, D/d is approximately equal to 1.05. It works such that is transports the liquid at wall of tank towards the bottom of tank. In case of homogenization of liquids with high viscosity, helical ribbon type stirrers are installed.

4. CONCLUSION

It is concluded that, the process of agitation can be influenced by internal parts such as baffle plates, stirrers, thermometer, feed and drain pipes. But mixing performance mainly depends on rotations of impeller and Reynolds number that is, if speed of impeller and Reynolds number increased proper mixing occurred. Viscosity is also an important parameter..

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