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MODIFICATION OF AN AGITATOR TO MINIMIZE THE DEFECTS OF MIXING PROCESS OF DILUENT IN STIRRED TANK

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Abstract *—Beacon Diagnostics Pvt. Ltd is well equipped, independent manufacturing facility as per WHO guidelines & U.S.F.D.A regulations. Beacon is a Research & Development Oriented Company. Their R&D sections are doing continuous research in Diagnostic Products at Navsari, Gujarat, India. Beacon Diagnostics Pvt. Ltd has faced problems in dilute process of chemicals, the mixing of chemicals in dilute process does not result into the homogenous mixture. It also causes difference in pH values at various levels for same chemical mixture in tank. This dilute process is time consuming. This project intend to modify the agitator to make the mixture homogenous so that we can get equal pH value at all levels for same chemical mixture in Stirling tank. Homogeneous mixture and required pH value of mixture is achieved by modifying industrial agitator .In this project, we modified agitator by increasing Number of Impeller Blade, using of Agitator with different shapes of blades, changing position and orientation of agitator. Result shows that By changing position and orientation of agitator at bottom of stirred tank with 45^0 Angle homogeneous mixture with 7.1 pH value at upper side and bottom side of stirred tank is received. Time of dilute process is reduced to 30 minutes from 2 hour.*

Keywords- *Stirred tank, Dilute process, Agitator, Impeller blade , Homogeneous mixture, pH value*

I. INTRODUCTION

Beacon Diagnostics Pvt. Ltd is well equipped, independent manufacturing facility as per WHO guidelines & U.S.F.D.A regulations. Beacon is a Research & Development Oriented Company. Their R&D sections are doing continuous research in Diagnostic Products at Navsari, Gujarat, India. Beacon Diagnostics Pvt. Ltd has faced problems in dilute process of chemicals, the mixing of chemicals in dilute process does not result in the homogenous mixture. It also causes difference in pH values at various levels for same chemical mixture in tank. This dilute process is time consuming. We find that homogeneous mixture and required pH value of mixture is achieved by modifying industrial agitator .This project intend to modify the agitator to make the mixture homogenous so that we can get equal pH level at all levels for chemical mixture in Stirling tank. This modification should result in better mixing, less power and time consumed.

The stirred tank is widely used in many industries such as in chemical industry, mineral water processing, petroleum. The stirred tank is widely used to obtain the desired type of fluid mixing. In the context of mixing process, two different fluids and have a different properties will mix in a single equipment to produce another fluid with a new property. Figure 1 shows Stirred tank and its components. The stirred tank has following system:

- An agitator system : The function of the agitation system is to provide good mixing and thus increase mass transfer rates through the bulk liquid and bubble boundary layers and provide the appropriate shear conditions required for the breaking up of bubbles.
- An oxygen delivery system : The oxygen delivery system consists of a compressor, inlet air sterilization system, an air sparger exit air sterilization system. A compressor forces the air into the reactor. The compressor will need to generate sufficient pressure to force the air through the filter, sparger holes and into the liquid.
- A foam control system : Excessive foam formation can lead to blocked air exit filters and to pressure build up in the reactor. The latter can lead to a loss of medium, damage to the reactor and even injury to operating personnel. Foam is typically controlled with aid of antifoaming agents based on silicone or on vegetable oils. Excessive antifoam addition can however result in poor oxygen transfer rates. One probe is immersed in the fermentation liquid while the other placed above the liquid level. When the foam reaches the upper probe, a current is carried through the foam. The detection of a current by the foam controller results in the activation of a pump and the antifoam is then added until the foam subsides.
- A temperature control system : The temperature control system consists of temperature probes And transfer system. The heat transfer system will use a jacket to transfer heat in or out of the reactor. The jacket is a shell which surrounds part of the reactor. The liquid in the jacket does not come in direct contact with the fermentation fluid.

- A pH control system : The neutralizing agents used to control pH should be non-corrosive. They should also be non-toxic to cells when diluted in the medium.
- A cleaning and sterilization system : This system involves the complete cleaning of not only the stirred tank but also all lines linked to the internal components of the stirred tank. Steam, cleaning and sterilizing chemicals, spray balls and high pressure pumps are used in these processes. The process is usually automated to minimize the possibility of human error.

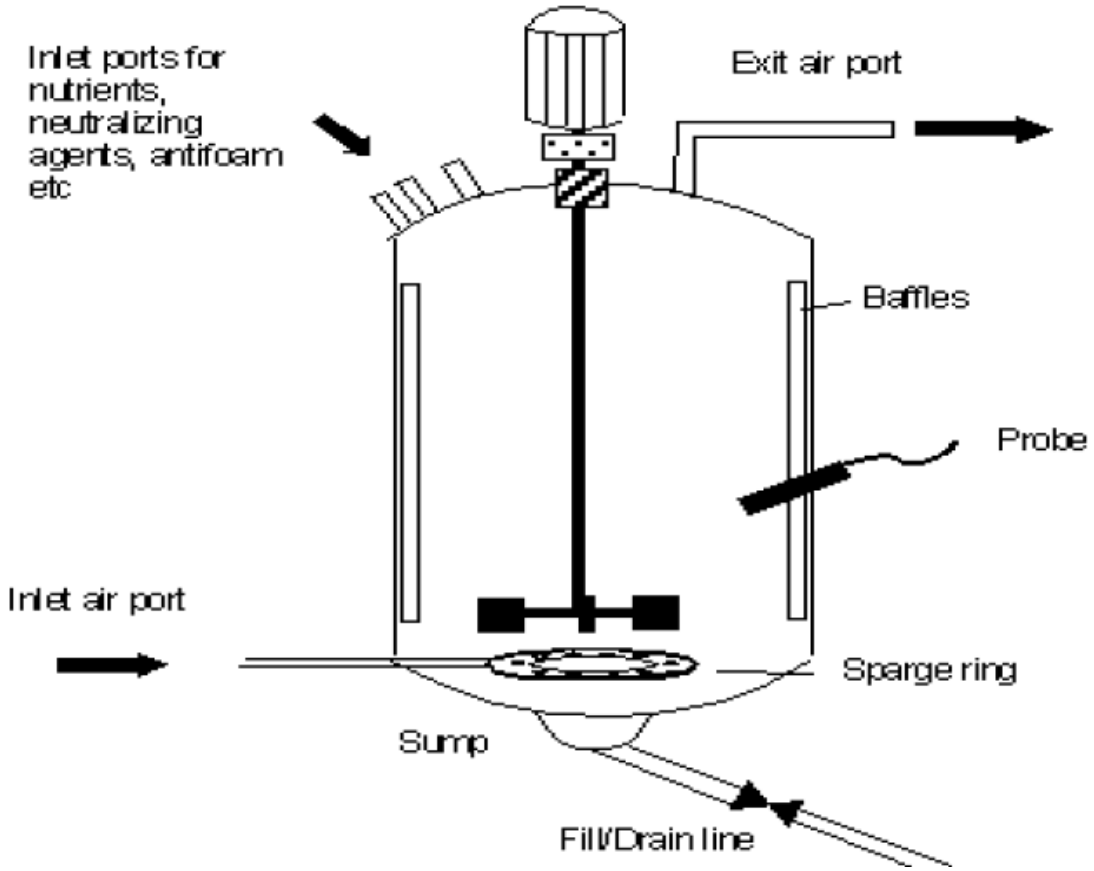

Figure 1. Stirred tank

In this project, we mainly focus on an agitation system. The agitation system consists of the agitator and the baffles. The baffles are used to break the liquid flow to increase turbulence and mixing efficiency. An agitator is composed of a drive device (motor, gear reducer, belts), a guiding system of the shaft (lantern fitted with bearings), a shaft and impellers. If the operating conditions are under high pressure or high temperature, the agitator must be equipped with a sealing system to keep tightened the inside of the tank when the shaft is crossing it. If the shaft is long (> 10m), it can be guided by a bearing located in the bottom of the tank (bottom bearing). Figure 2 depicts an agitator.

The agitation of liquid is made by one or several agitation impellers. Depending on its shape, the impeller can generate:

- the moving of the liquid which is characterized by its velocity and direction.
- Turbulence which is an erratic variation in space and time of local fluid velocity.
- Shearing given by a velocity gradient between two filets of fluids.

Impellers give an inlet and outlet which are on axial direction, preferably downward, they are characterized by a nice pumping flow, low energy consumption and low shear magnitude as well as low turbulence. With radial flow mixing, the liquid flow from the impeller is initially directed towards the wall of the reactor; ie. along the radius of the tank.

The agitation is achieved by generating movement of the liquid phase, thanks to the impeller. This is due, on mechanical agitators, to the rotation of an impeller. The bulk can be composed of different substances and the aim of the operation is to blend it or to improve the efficiency of a reaction by a better contact between reactive product. Or the bulk is already blended and the aim of agitation is to increase a heat transfer or to maintain particles in suspension to avoid any deposit.

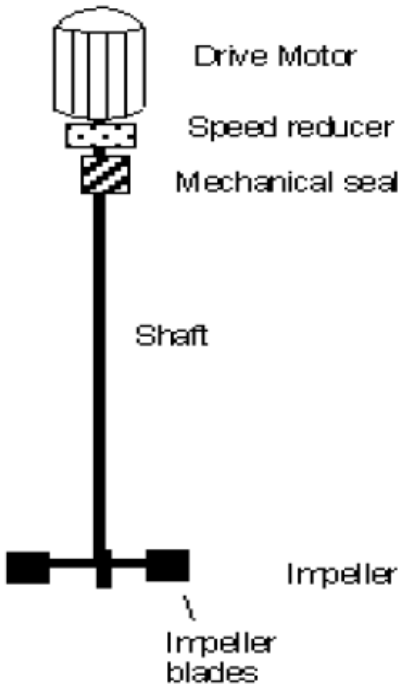

Figure 2. Agitator

In Stirred tank, the impeller shaft can enter from the bottom of the tank or from the top. A top entry impeller (overhung shaft) is more expensive to install as the motor and the shaft will need to be structurally supported. Figure 3 shows agitator system with top entry impellers in Stirred tank.

Bottom entry agitators tend to require more maintenance than top entry impellers due to the formation of crystals and other solids in the seals. Figure 4 shows agitator system with top entry impellers.

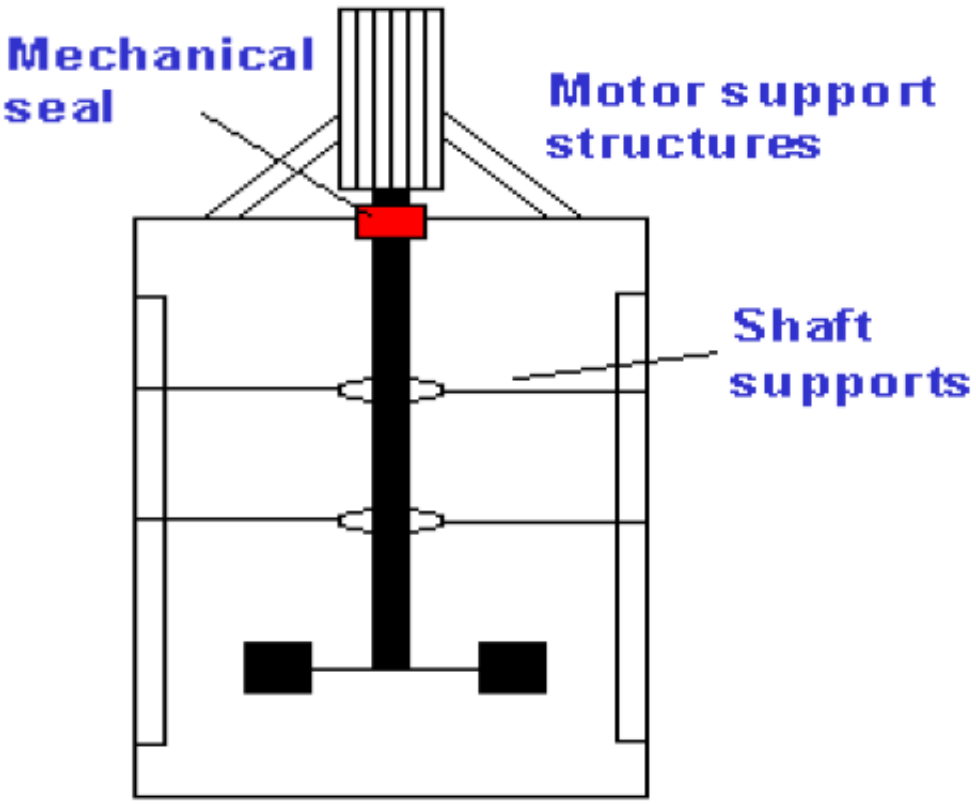

Figure 3. Agitator system with top entry impellers in stirred tank

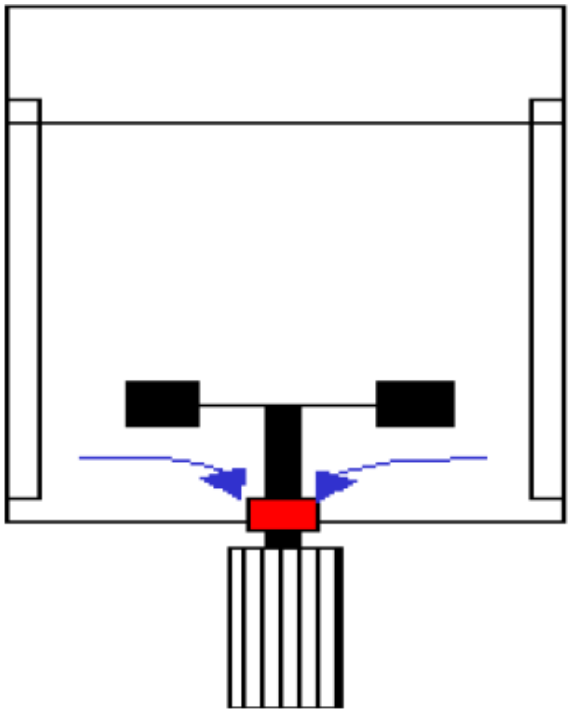

Figure 4. Agitator system with bottom entry impellers in stirred tank

II. EXPERIMENTAL SETUP

Stirred tank is used for mixing liquids together, promote the reactions of chemical substances, keeping homogeneous liquid bulk during storage. Figure 5 depicts Stirred tank installed at Beacon Diagnostics Pvt. Ltd.

Figure 5. Stirred tank installed at Beacon Diagnostics Pvt. Ltd, Navsari

A. Components of Stirred tank

Stirred tank has major four components.

- ***Stainless steel tank:*** To provide a directly scalable operation for stirred-tank cell culture, a stainless steel tank will use established geometry in which working volume height is about 1.5 times the diameter. A tank

with 30% volume for headspace and with sample points and probe installation points located at 20% of working volume allows the system to operate at 5:1 turndown volumes and accommodate efficient strategies for head sweep action and foam management. The tank will be insulated for efficient heat transfer.

- ***Agitator:*** Agitator is a device used for purpose of mixing. It mainly consist impeller blades, speed reducer, mechanical seal, motor and shaft. Agitator is mounted at the top of tank. Agitator has one impeller blade.
- ***pH and dissolved oxygen control:*** Dissolved oxygen and pH probes must be inserted into the sterile envelope of the bioreactor bag. The ability to insert more than one probe for redundancy, profiling, or collect in additional data is a significant consideration. Tank hardware should be designed to accommodate and support probe installation. Standard electromechanical probes can be used for pH and O_2 measurements. They are then integrated into a control system for gas-flow and pump control to ensure that a process value tracks set point.
- ***Baffles:*** Baffles are needed to stop the swirl in a mixing tank. Almost all impellers rotate in the clockwise or counter-clockwise direction. Without baffles, the tangential velocities coming from any impeller(s) causes the entire fluid mass to spin. It may look good from the surface seeing that vortex all the way down to the impeller, but this is the worst kind of mixing. There is very little shear and the particles go around and around like in a Merry-Go-Round. This is more like a centrifuge than a mixer.

B. Mechanism

Commonly different liquid are mixed by using the stirred tank. In this, agitator and baffles are used for increasing efficiency of the mixing. Agitator is located at the top of the tank and mounted in vertical direction and rigidly fixed. Agitator cannot be oscillated. Agitator is consisting of the impeller blade, motor, shaft. Impeller rotates inside the tank then imparting centrifugal force on the fluid. Impeller may be rotating in clockwise or counter clockwise direction. Speed reducer is provided with the agitator for achieving lower speed as compared to rated speed. The particles of liquid are only rotate in the circular motion. All the particles have same direction so that they are not completely mixed with each other, for increasing the efficiency of mixing the baffles are provided. Baffles oppose the motion of rotating particle at the walls.

Table 1 shows Specification of the Stirred tank.

Table 1. Specification of the stirred tank

SR NO.	PARAMETER	SPECIFIED QUANTITY/MATERIAL
1	Capacity	2500 litres
2	Material	Stainless steel
3	Design pressure	0.1 kg/cm^2
4	Hydro test pressure	0.1 kg/cm^2
5	Wall thickness	3 mm
6	Height	3070 mm
7	Approx. diameter	1364 mm
8	Motor	2.238 Kw
9	Power Consumption	5 Kwh
10	Operation time	2 Hour

III. METHODOLOGY

Our main objective is to modify the agitator to make the mixture homogenous at all level of mixture in stirred tank. So that we can get equal pH value nearly 7 at all levels of chemical mixture in Stirling tank. This modification should result in better mixing, less power and time consumed with cost effectiveness. To achieve objective, we have done three types of modifications on agitator as under.

1. Increase Number of Impeller Blade
2. Use of different shapes of blades of Agitator
3. Change position and orientation of Agitator

IV. RESULT AND DISCUSSION

A. Use of Two Impeller Blade:

In the existing stirred tank situated Beacon Diagnostics Pvt. Ltd has agitator with one impeller blade is replaced with agitator having two impeller blade. Figure 6 depicts the agitator system with two impeller blades in stirred tank. We find that there was proper mixing of chemical but mixture has pH value above 7. The power consumption by agitators with two Impeller blades are more compared to one impeller blade agitator. The mixing time of chemical is nearly one hour. During this experiment, we find that vibrations problems are there as it is with existing agitator. Due to more Vibration, Maintenance cost is increased.

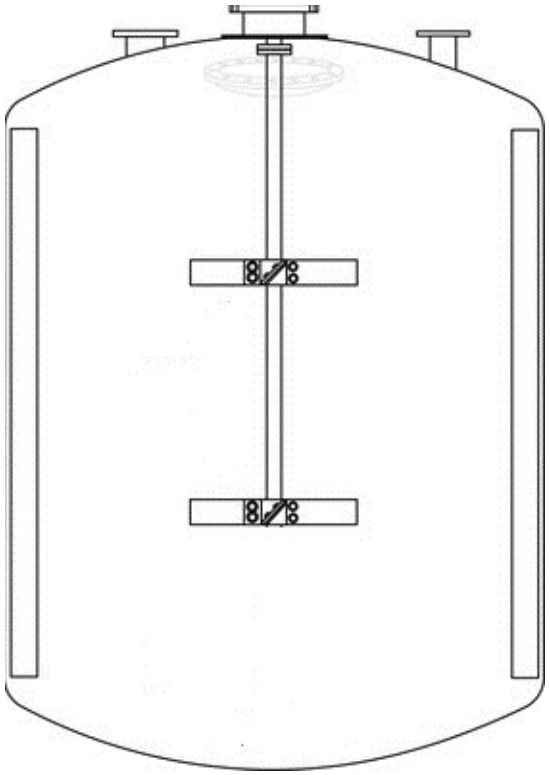

Figure 6. Arrangment of agitator with two mpeller blades in stirred tank

B. Use of agitator with different shapes of blades :

We have used agitator with different shapes of blades as shown in figure 7 in existing tank instead of one impeller blade. We find that there is proper mixing of chemical but mixture has pH value above 7. The power

Figure 7. Agitator with different shapes of impeller blades

consumption by agitators with two Impeller blades are more compared to one impeller blade agitator. The mixing time of chemical is nearly two hours which was more than with agitator having two impeller blades . During this experiment, we find that vibrations problems are there as it is with existing agitator. Maintenance cost is further increased due to vibration.

C. Use of Horizontal industrial Agitator:

We have used horizontal industrial Agitator as shown in figure 8 instead of Vertical industrial agitator. Due to horizontal axes agitator, Chemicals are not properly mixed in large tank. Power consumption and mixing time are more compared to one impeller blade agitator. Lesser vibrations are produced during the mixing process.

Figure 8. Horizontal industrial Agitator

D. Change position and orientation of industrial Agitator:

At Beacon Diagnostics Pvt. Ltd., Existing Agitator is mounted at the top of Stirred tank which does not provide proper mixing of chemicals, so We have changed the orientation of Agitator. Agitator is mounted at bottom of tank with 45^0 Angle as shown in figure 9 and figure 10.

Figure 9. Stirred tank with Agitator having one impeller blade and oriented at bottom of vessel at 45^0 angle

Figure 10. Agitator having one impeller blade mounted at bottom of tank at 45^0 angle

We find that there is proper mixing of chemical and mixture has pH value 7.1. The power consumption by modified agitator is nearly equal compared to existing one impeller blade agitator. The mixing time of chemical is reduced from one hour to thirty minutes. The major problem is found from this modification is there was leakage of chemical from the bottom of tank. This problem is solved using SILIOCONE seal.

New Setup has following data:

- Motor Specification :
  C=5HP
  C=5 * 0.746 Kw
  C=3.73 Kw

- Operation time required
  T= 30 minutes

- Power Consumption
  $Q_0 = C * T$
  $Q_0 = 3.73 * 0.5$
  $Q_0 = 4.976$
  $Q_0 = 1.865$Kw.Hr
  $Q_0 = 2$ units

- % of power consumption saved $= (Q_0 - Q_m) * 100/Q_0$
  $= (5-2) * 100/5$
  $= 60\ \%$

We concluded that 60% Energy is saved by modified bottom entry agitator.

Figure 11 shows graph % of homogeneous mixture versus arrangement of agitator at various experimental modifications. Graph shows that stirred tank with agitator having two impeller blades gives 80% homogeneous mixture, whereas agitator with different shapes of impeller blades and horizontal agitator gives 67% and 62% homogeneous mixture respectively. By changing the position and orientation of agitator at bottom of stirred tank and at 45^0 Angle gives 100% homogeneous mixture.

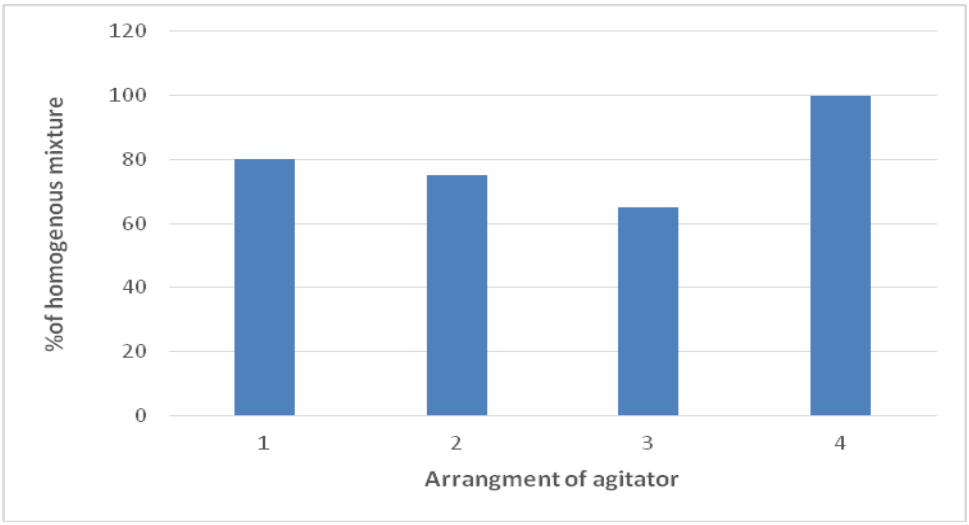

Figure 11. % of homogeneous mixture v/s arrangement of agitator

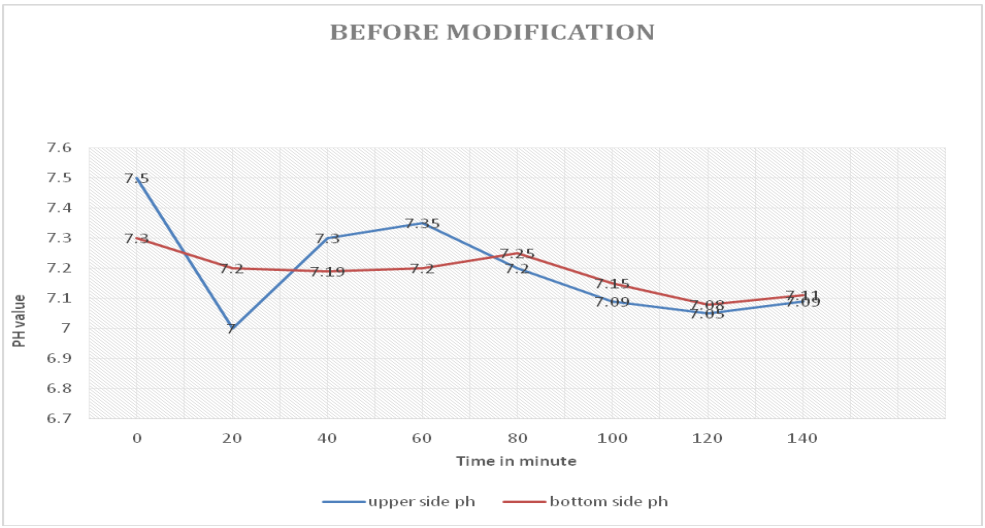

Figure 12. pH value at upper side and bottom side of stirred tank before modification

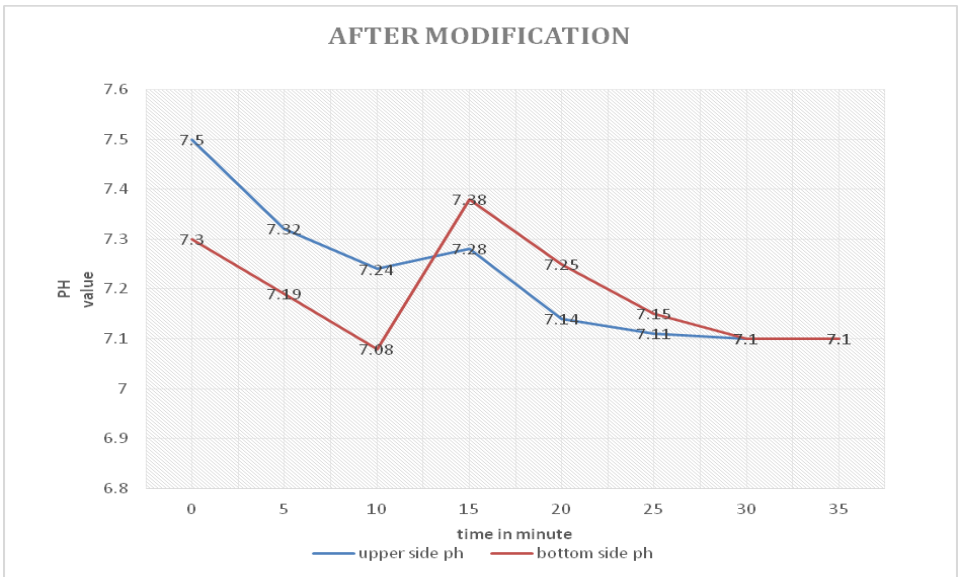

Figure 13. pH value at upper side and bottom side of stirred tank after modification

Figure 12 shows graph pH value at upper side and bottom side of stirred tank before modification. Figure 13 shows graph pH value at upper side and bottom side of stirred tank before modification. By comparing both graphs, it is found that after modification the ph value is achieved 7.1 in only 30 minutes. We also find homogeneous mixture with 7.1 pH value at upper side and bottom side of stirred tank. As the time of dilute process is reduced to 30 minutes from 2 hour, the production capability is increased by four times.

V. CONCLUSION

After analysing all the modifications made with agitator used in stirred tank, Conclusions are made as under.

- Among all modification, changing position and orientation of agitator at bottom of stirred tank with 45^0 Angle gives best result.
- By changing position and orientation of agitator at bottom of stirred tank with 45^0 Angle homogeneous mixture with 7.1 pH value at upper side and bottom side of stirred tank is received.
- Time of dilute process is reduced to 30 minutes from 2 hour.
- Almost four times higher production rate is achieved.
- Power consumption is reduced. 60% Energy is saved by modified bottom entry agitator.

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