REVIEW ON DESIGN OF AGITATOR

[1]AKASH J PATIL, [2]SACHIN B RAJUDE, [3]MAYUR S THOK, [4]AJIT R PAWAR

BE Student. Mechanical engineering
SNDCOE &RC,YEOLA

***Abstract*-This paper describes the mechanical design of agitator to mixing polyectrolyte having viscosity 1.5cp considering the fluid forces that are imposed on the impeller by the fluid. The analysis shows that the forces are a result of turbulent flow of fluid and static fluid forces. The loads are active and are transmitted from the impeller blades to the agitator shaft and then to the gear box. Agitator design is often though as the application of two engineering disciplines. The first step is process design from a chemical viewpoint and involves the specification of the impeller pattern, speed, temperature and blade angle etc. The next step in the design series is the mechanical design of the agitator component. The approach is straight forward design for the power (torque & speed) then shaft loads. The experiment is carried out for agitator 500 liter of capacity. Drawback of the old agitator is removed. The old agitator does not gives homogeneous mixing.**

Key words: Agitator, Power Number, Critical Speed, Moment of Inertia, Shear Stress.

I. INTRODUCTION

In this age, mixing is one of the most fundamental operations in industries like paper, food, cosmetic, and chemical, biochemical and process industry applications. In order to rotate the agitator at the required speed, it is attached to a shaft. The driving system usually consists of shaft, coupling, bearing, gearing, pulleys and belt. The power is supplied by an electric motor.

In case of toxic, flammable or volatile materials or liquid under pressure, special provision has to be made to prevent leakage, between the shaft and portion of vessel surrounding the shaft. To allow free rotation of shaft, a clearance must be maintained between these adjacent parts. A seal is used for preventing leakage through this clearance.

Agitation Phenomenon

Agitation is putting into motion by shaking or steering to achieve mixing. Certain processing operations, such as blending, dispersion gas absorption, crystallization etc., need agitation of liquids. In such operations agitator system has to be provided along with the basic equipment.

II. SHAFT DESIGN

The shaft is attached to the motor gear and may be located in vertical position.

A. Power Requirement for Agitation:

Power required to operate an agitator depends on several factors such as the properties of the liquid, agitator type and size, the tank or vessel size and speed of agitation. NP = imposed force/inertia force =P/ϱN3Da5 And

N_{Re} = inertia force /viscous force = ϱNDa2 /μ

Where,

NP – Power number,

P – Power,

ϱ – Density of liquid,

N – Speed of agitator,

D_a – agitator diameter,

μ - viscosity.

In an unbaffled vessel the relation between function power number NP and Reynolds number N_{Re} is

$NP = P/\varrho N_3 Da_5$ for $N_{Re}<300$

$NP = (\alpha - \log 10\ N_{Re}) / N_{Fr}\beta$ for$N_{Re}>300$

Where, N_{Fr} is known as the Froude number and is given by N_{Fr} = inertia force / gravity force $=N_2\ Da/g$

Values of α and β are given in table

Diameter (Da)cm	Da/D	α	β
10	0.3	1.0	40.0
15	0.33	1.0	40.0

Table 1: Values of A and B

B. Shaft Design:

The normal power required for the agitator and frictional losses are indicated under 'power requirement for agitation. Average rated torque on agitator shaft

$T_c = (P\times60\times1000)/2\pi N$

Where, N– rps,

Torque, Tc - N.m,
P –KWatt.

During a starting up, the shaft has to withstand much higher torque. During running, apart from the torque, various forces acting on the shaft have to be taken into account. These are transient unbalanced hydraulic forces due to turbulence in the liquid or asymmetrical construction of the agitator and baffles, acting laterally on the shaft in a cyclic manner. Centrifugal forces are also present while the shaft is rotating and agitator is out of balance.

During starting, the shaft must be capable of resisting 1½times the continuous average torque at low speed and 2 ½ times at high speeds. The shaft is therefore, designed for either of these maximum values. The maximum

Shear stress developed is given by

$f_s = (1½ \text{ or } 2 ½).\ T_c / Z_p = T_m / Z_p$

Where, T_m - maximum torque

f_s - Shear stress

Z_p - Polar modulus of the shaft cross- section

If the permissible stress value of fs is known, the shaft diameter can be determined. Another criterion of design is based on the fluctuating loads during running. Consider the agitator blade jammed at 75% of its length for a short period. In this case it is necessary to work out the equivalent bending moment which is the cumulative resultant of the bending moment and maximum torque.

$M_e = ½ [M+\sqrt{M_2} +(T_m)2]$

Where, T_m – (1.5 or 2.5) T_c

M – Bending moment.

The bending moment M is determined as follows:

The torque Tm is resisted by a force F_m acting at a radius of $0.75R_b$ from the axis of agitator shaft.

$F_m = T_m /0.75R_b$

Where, R_b - radius of blade.

The maximum bending moment M occurs at appoint near the bearing, from which the shaft overhangs

M = Fm .l

Where, l- shaft length between agitator and bearing.

The stress due to equivalent bending moment is given by

f= Me /Z

Where, Z – modulus of section of shaft cross section.

The stress f should not exceed the yield stress of the material or 0.2% proof stress.

The load on the blade is assume to act as 75% of the agitator radius. This will create a bending moment, which will be maximum at the point where the blade is attached to hub.

Max. BM = F $(0.75R_b – R_h)$

Where F – force on each blade R_b – radius of blade R_h – radius of hub.

If the blade is flat, the stress in the blade will be given by

f= Max BM/ Z = $F(0.75R_b – R_h)$ / (bt.bw2/6)

Where, b_w -blade width

b_t - blade thickness.

C. Design based on Critical Speed:

It is difficult to assess the unbalance hydraulic forces due to asymmetric construction of agitator, As the shaft rotates, centrifugal forces are created. If the speed of the shaft varies, it is not possible to balance dynamic forces completely. Only the partial balance may be possible this forces change direction as the shaft rotates and cause vibration. The speed at which the shaft vibrates violently is known as the critical speed. It is recommended that the range of speed between 70% and 130% of the critical speed should be avoided. Low speed agitator such as paddles and turbine normally operate between 50% and 65% of their critical speed. If dynamic balancing is done, one can operate even at 70% of critical speed. High speed impeller such as propellers and discs, normally operate above the critical speed. Determination of critical speeds for shaft is done as follows:

If a horizontal shaft, supported at two bearings A and B at distance b. The loads w1, w2 are acting perpendicular to the shaft. The deflection due to each load acting independently is given by

$\delta = Wl_3 /3EI$

Where, l – appropriate length

W – Concentrated load

w – Uniformly distributed load per unit length

E – Modulus of elasticity

I – moment of inertia of the cross section of shaft. The critical speed can be determined as follows:

N_c= 946 /[$^{\delta}$1+$^{\delta}$2+$^{\delta}$s/1.25]1/2

Where, $^{\delta}$1 , $^{\delta}$2 ,$^{\delta}$s are the deflections in mm due to each load and N_c expressed in rpm.

As an approximation, we can use above formula for a vertical shaft also. The critical speed Nc given in equation is for static conditions only. However. We then calculate deflection, due to this force and impeller with hub acting at the end of shaft via above equation and further assuming shaft to be cantilever with uniformly distributed load. The shaft always has bearing support. The critical speed is then denoted by a factor β given by

$\beta = \{1/ (1+\alpha\ (Il/Ib)\}0.5$

Where $\alpha = b/l$,

I = moment of inertia.

The main parts of agitator are the hub and blades. Wooden agitator are useful only for relatively low speed. They are difficult to balance. the load on the blade is assume to act as 70% of the agitator radius. This will create bending moment, which will be maximum at the point where the blade is attached to the hub.

Max $BM=F(0.75R_b-R_h)$

Where, F- force on each blade

R_b – radius of blade,

R_h- radius of hub

If the blade is flat, the stress in the blade will be given by

$\sigma =6F(0.75R_b-R_h) \div (b_t\times bw_2)$

Where, b_w –blade width

b_t – bade thickness

III. DESIGN OF COUPLING

For connecting the agitator shaft to the driven shaft, three types of couplings are generally used. These are flange coupling, split coupling, and sleeve coupling.

A.Rigid Flange Coupling:

It consists of two flanges, one for each shaft fixed by keys. Certain dimensions are based on practical and safety consideration.

R=1.5 d;

D=2 d;

B=1.5 to 2d;

Number of bolts (n)=3+0.2d The bolts are under shearing and crushing stresses.

Force on bolt (F) = Tmax /R

The flange is usually made of cast iron, the stress in the hub and the portion of the flange can be checked by

f_s (hub) = Tmax / π(D4 - d4) 16 D

f_c (flange) = Tmax / πDt.D/2

B.Split-Muff Coupling:

It consist of a sleeve generally made of cast iron split into two halves, which are composed over the shaft by bolts. This coupling is more suitable for vertical shaft, and is easy to dismantle.

$T_{max}=\mu\pi d_p\ l/2.d/2$

Where, μ= coefficient of friction between shaft and sleeve

d = diameter of shaft

p= contact pressure

l= length of sleeve

d = nominal dia. Of bolt

C.Flexible Coupling:

Design of this coupling is somewhat similar to that of rigid flange coupling. The bearing pressure on the rubber brush is given by P_b=max/R.n.l/ $d_n t_b$

Where, T_{max} - maximum torque

R- Radius at which the pins are located

L = length of hub.

D. Clamp Coupling:

The coupling used for agitator is clamp coupling.

Force per bolt is given by,

$P = 2\times T_m/[\pi\times\mu\times d\times(n/2)]$

The coefficient of friction is assumed to be 0.35

IV. BEARINGS

A bearing is a machine component, which acts as a support for r moving part having rotary, oscillating or sliding motion. A bearing which supports a load normal to the longitudinal axis is known as radial bearing or journal bearing. If load on the bearing acts in axial direction, the bearing is known as thrust bearing. In deep tanks with long agitator shafts, excessive vibrations can be reduced by using a steady bearing at bottom of shaft.

A. Radial Bearing Or Journal Bearing:

Bearing pressure pb = P / l.d

Where, μ - coefficient of friction, Pb– bearing pressure l– length of bearing d- diameter of shaft n- rpm of shaft the heat generated due to friction between journal (shaft) and the bearing depends on coefficient of friction, load and speed. H/Min = μ.pd.d.l.π.d.n
Where, μ - coefficient of friction,
Pb– bearing pressure
l– length of bearing
d- diameter of shaft n- rpm of shaft.

V. CONCLUSIONS

The review finds that, there are different types of agitator are available. In the different industry mixing process of chemical is not uniform and proper. Different stresses are produced in the agitator like bending stress, deformation stress. The study can give idea about optimum design which can increase the mixing percentage. Also weight of agitator is high due to different joining methods present to join arms and hub together. We can reduce the weight of agitator so power consumption of agitator can decrease and efficiency and mixing percentage increases with reducing of its weight.

REFERENCES

[1] V.V. Mahajani, S.B. Umarji, “Process Equipment Design”, MACMILLAN, 4th Edition.
[2] Kazuhiko Nishi1, Naoki Enya2, etc “Potential of an asymmetrical agitation in industrial mixing” in Internat. J. Sci. Eng., Vol. 5(2)2013:73-80, October 2013.
[3] E.Rajasekaran1, B.Kumar2 “Agitator and Wiper Design Modification for Milk Khoa Machine” International Journal of Innovative Research in Science, Engineering and Technology An ISO 3297: 2007 Certified Organization, Volume 3, Special Issue 1, February 2014.
[4] Parker autoclave engineers _catalogue agitator/ mixture product.
[5] G. Hughmark,” Power requirements and interfiacial area in gas-liquid turbine agitated systems”, Ind. Eng. Chem. Process Des. Dev. 19:638-641. (1980)
[6] B. Junker “Scale-up methodologies for Escherichia coli and yeast fermentation processes”, J. Biosci. Bioeng, 97(6):347-364 (2004).
[7] B. J. Michael and S. A. Miller “Power requirements of gas-liquid agitated systems” AIChE J. 8 (2):262266(1962).
[8] Y. Oyamma and K. Endoh “Power characteristics of gas- liquid contacting mixers”, Chem. Eng. Japan 19:28(1955).
[9] K. Van’tRiet “Review of measuring methods and results in nonviscous gas-liquid mass transfer in stirred vessels”, Ind. Eng. Chem. Process Des. Dev. 18(3):357364 (1979).
[10] H. Yagi and F. Yoshida “Gas absorption by Newtonian and non-Newtonian fluids in sparged agitated vessels”, Ind. Eng. Chem. Process Des. Dev. 14(4):488493(1975).
[11] Saeed Asiri “Design and Implementation of Differential Agitators to Maximize Agitating Performance” in International Journal of Mechanics and Applications 2012,2(6):98112DOI:10.5923/j.mechanics.2012/02/06.