Review on Design of Agitator to Optimize its Performance  
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Abstract— Mixing is very important operation in any process industry. All operations involving liquid phase reactions, homogenization, emulsion, dissolution, extraction, need mixing in one form or other. Mixing of powders, pastes, paints jellies and many other products is needed to be done in many industries for many applications. In this paper, we have mainly focused on different parameters used for design of agitator including design of shaft, impeller blade, coupling, bearings, Hub and Keys. The design of agitator affects on the mixing process as proper design can increase the agitation and uniform distributions of all additives, chemicals, raw material presents in given agitator. The review drives us to design an mistake prone model for agitator which will increase the mixing process; ultimately increase the growth of industry to get right place into market with price for product. This review gives the complete information about agitator and parameters to be considered for design to enhance its performance.  

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

I. INTRODUCTION  
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, a hydraulic motor or a steam turbine.  

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 stuffing box or seal is used for preventing leakage through this clearance.  

II. SHAFT DESIGN  
The shaft is attached to the agitator and may be located in horizontal, vertical or angular 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.  

\[ N_p = \frac{P}{gN^2D^4} \]  
And  

\[ N_{re} = \text{inertia force }/ \text{viscous force } = gNd^2/\mu \]  
Where, \( N_p \) – Power number, \( P \) – power, \( g \) – density of liquid, \( N \) – speed of agitator, \( D \) – agitator diameter, \( \mu \) - viscosity.  

In an unbaffled vessel the relation between function power number \( N_p \) and Reynolds number \( N_{re} \) is  

\[ N_p = \frac{P}{gN^2D^4} \text{ for } N_{re} < 300 \]  
\[ N_p = \big(\alpha - \log(N_{re})/N_{re}\big)/\beta \text{ for } N_{re} > 300 \]  
Where, \( N_{re} \) is known as the Froude number and is given by \( N_{re} = \text{inertia force }/ \text{gravity force } = N^2D^2/g \)  

Values of \( \alpha \) and \( \beta \) are given in table  

<table>
<thead>
<tr>
<th>Diameter (D) cm</th>
<th>D/D</th>
<th>( \alpha )</th>
<th>( \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.5</td>
<td>1.0</td>
<td>40.0</td>
</tr>
<tr>
<td>15</td>
<td>0.33</td>
<td>1.0</td>
<td>40.0</td>
</tr>
</tbody>
</table>

Table 1: Values of \( \alpha \) and \( \beta \)

B. Shaft Design:  
From these, it is possible to determine the continuous average rated torque on the agitator shaft.  

\[ T_c = \frac{P}{2\pi N} \]  
Where, \( N \text{ – rps, } \)  
Torque, \( T_c \text{ - N.m, } \)  
\( P \text{ – Watts. } \)  

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 1½ times the continuous average torque at low speed and 2½ times at high speeds. The shaft is therefore, designed for either of these maximum values. The maximum shear stress developed is given by  

\[ f_s = (1\frac{1}{2} \text{ or } 2\frac{1}{2}) \times \frac{T_c}{Z_{p} = T_m/Z_{p}} \]  
Where, \( T_m \text{ - maximum torque } \)  
\( f_s \text{ - Shear stress } \)  
\( Z_{p} \text{ - Polar modulus of the shaft cross-section } \)  

If the permissible stress value of \( f_s \) 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.  

\[ M_e = \frac{1}{2} \left[ M + \sqrt{M^2 + (T_m)^2} \right] \]  
Where, \( T_m \text{ – } (1.5 \text{ or } 2.5) T_c \)  
\( M \text{ – bending moment. } \)  

The bending moment \( M \) is determined as follows:  

The torque \( T_m \) is resisted by a force \( F_m \) acting at a radius of 0.75\( R_b \) from the axis of agitator shaft.  

\[ F_m = T_m/0.75R_b \]  
Where, \( R_b \text{ - radius of blade. } \)  

The maximum bending moment \( M \) occurs at a point near the bearing, from which the shaft overhangs  

\[ M = F_m \times l \]  
Where, \( l \text{ - } \) shaft length between agitator and bearing.  

The stress due to equivalent bending moment is given by
The shaft always has bearing support. The critical speed is then denoted by a factor $\beta$ given by

$$\beta = \frac{1}{(1+\alpha (I/b_0))^{0.5}}$$

Where $\alpha = b/l, I =$ moment of inertia.

### 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) = $T_{max}/R$

$$F = \frac{\pi \delta^2/4}{f_\text{t}} \cdot n = \frac{\delta f_\text{t}}{f_\text{c}} \cdot n$$

Where, $\delta =$ mean diameter of bolt

$t =$ thickness of flange

$f_\text{c} =$ shearing and crushing stresses

$n =$ number of bolts.

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

$$f_\text{c} (\text{hub}) = T_{max}/(\pi D^2 - d^4) \cdot 0.16$$

$$f_\text{c} (\text{flange}) = T_{max}/\pi D t D/2$$

#### 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.

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

Where, $\mu =$ coefficient of friction between sleeve and shaft

$d =$ diameter of shaft

$p =$ contact pressure

$l =$ length of sleeve

Force per bolt (p) = $p d \cdot 2/\pi n/2) = 2T_{max}/\mu \pi d(n/2)$

Where, $n =$ total number of bolts.

#### 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

$$P_b = \frac{T_{max}/R.n.l}/d_n b_0$$

Where, $T_{max} =$ maximum torque

R - radius at which the pins are located

$L =$ length of hub.

### 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 $p_b = P / l.d$
Review on Design of Agitator to Optimize its Performance
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Where, 
P – radial load,  
l – length of bearing,  
d – diameter of shaft

The heat generated due to friction between journal (shaft) and the bearing depends on coefficient of friction, load and speed.

\[ \frac{H}{\text{Min}} = \mu \cdot \frac{P_b \cdot d \cdot d \cdot l \cdot n}{d \cdot l \cdot d \cdot n} \]

Where, \( \mu \) - coefficient of friction,  
\( P_b \)– 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