# DESIGN CALCULATION OF THEORETICAL TORQUE AT SLURRY TANK AGITATOR GEAR BOX FOR SLURRY DENSITY OF 2.4 gm/cc: OR DESIGN CALCULATIONS FOR IRON ORE SLURRY AGITATORS IN STEEL INDUSTRY.

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**Abstract :***In many solids-suspension tasks, especially in the minerals-processing industries, abrasion can be a significant issue. In this case, lower velocities may be required to limit abrasion. An increased impeller size can compensate for the lower velocities. During power failures, sediments can quickly build up in suspension tanks. Impellers are often designed to withstand attempted restarts, while submerged in a densely settled slurry. In some instances, "restart in slurry" becomes the key design criterion.*

*Process experts as well as equipement manufactures have opined that the design of agitators for mixing Irone ore in Pellet Plant (Steel industry) is complicated and tricky issue. In this paper , We will discuss the subject with disription of invovled terminolgy , associted design parameters and methodolgy with sample motor rating and Gearbox torque sustaining capacity. Calculations for the slurry (iron ore and water) mixing agitator of a Pre –disilication tank of Pellet Plant in Steel Industry.*

**Key words :** Introduction, Design calculation of slurry tank agitator gear box for slurry density 2.4 gm/cc, Conclusion, Future Scope**.**

## 1.INTRODUCTION:

In Steel industry High-viscosity slurry processing Slurries that contain a high-solids concentration of small particles can exhibit non-Newtonian flow behavior. Such slurries are commonly en- countered in the mineral processing industry, where typical solids volume concentrations are 35 to 50%. In these applications, the settling velocities of the suspended solids are very low and the key mixing task becomes the blending of the highly-viscous, non- Newtonian mixture, rather than solids suspension. Tanks for such ore slurries can be up to 1000 $m^3$, and agitator powers can be correspondingly very large. It is not possible to accurately predict flow behavior in such a system by using theoretical correlations based on solids concentration and particle- size data. For high-viscosity slurries, tests with original product are indispensable to ensure good performance without overdesign.

### 1.1 Design Fundamentals:

In addition to agitator parameters and the slurry tank/vessel geometry, the properties of both the liquid and the solid particles influence the fluid-particle hydrodynamics and, thus, the suspension. The important physical properties for agitator design are: the liquid density, the density difference between solids and liquid, the liquid viscosity, the average particle size and the volumetric concentration of the solids. A single particle's free-settling velocity, $v_s$, is calculated by methods given in the relevant literature. The hindering effect on the settling process due to the presence of several particles is quantified by the following relation, where the exponent m is a function of the particle Reynolds number, and varies between 2.33 and 4.65

$v_{sh} = v_s (1- c_v)^m$ ……………………………………….. (1)

where $v_{sh}$ is the hindered settling velocity, $v_s$ is the free-settling velocity and $c_v$ is the volume fraction of solids.

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If it is assumed that all solid particles in the liquid are distributed uniformly, and all simultaneously begin to settle under the effect of gravity, they release a "settling power", which can be quantified by the relation:

$P_{settle} = v_{sh} \cdot c_v \cdot \Delta\rho . g . V$ ............................. (2)

Where,

Δρ is the difference in density between solid and liquid. In order to maintain a defined degree of uniformity in the suspension, the agitator must provide a power input to the liquid that counteracts this settling power. The agitator power always amounts to a multiple of the settling power. When one is using the above Equations (1) and (2), the choice of particle size that is used to calculate the free-settling velocity, $v_s$ , is very important. In powders or slurries, the individual particles vary in size and shape. Choosing the largest particle size can result in a much higher agitator power than is required. From experience, reliable results are obtained with a design particle size that corresponds to a value where between 80 and 90% pass through the mesh size.

## 2. PROBLEM DEFINITION:

ABC company problem facing regarding agitator gearbox breakdown problem. Gearbox having existing capacity 28300 Nm and output shaft speed 24 rpm. The agitator agitates Iron ore Slurry density in the range of 2.30 gm/cc to 2.40 gm/cc.

To overcome this problem we are going to redesign whole agitator gearbox assembly. Slurry density is major property to generate to high torque on agitator. Here we considering the tank is fill up full of tank having slurry density 2.40 gm/cc

## 3. ANALYTICAL DESIGN CALCULATION:

**Existing Slurry Tank agitator Drive specification:**

| | | |
|---|---|---|
| Motor rating | : | 75 kW |
| Motor RPM | : | 1500 RPM |
| Gear Box Ratio | : | 62.5 |
| Agitator Rotational Speed | : | 24 RPM |
| Design Torque Rating of Gear box | : | 28300 Nm |
| GB Supplier | : | SEW-EURODRIVE INDIA |

GB Type:MC 3 R V S F 09

size: (Based on shaft dia)
02...09
Gear unit mounting:
F = Foot mounted
T = Torque arm
Low speed shaft type (LSS):
S = Solid shaft
H = Hollow shaft (key or shrink disc connection)
Gear unit design:
L = Horizontal LSS
V = Vertical LSS
E = Upright mounting position
Gear unit type:
P = Helical gear unit
R = Bevel-helical gear unit
Number of gear stages:
2 = Two stages
3 = Three stages
Industrial gear unit series: MC

**Agitator rpm (N) :**

N =Drive motor / gear box reduction
=1500/62.5
=24 rpm

**Impeller Flow Number $(N)_q$ :**

$N_q = Q / N * D_i^3$

Where,
Q = Impeller primary flow (m³/sec)[Pumping capacity]
$D_i$ =Impeller diameter (m)

**Impeller Power number $(N_p)$ :**

$N_p = P / N^3 * D_i^5 * \rho$
Where,
P = Impeller power (w)
N= Impeller rotational speed (rpm)
$D_i$ =Impeller diameter (m)=3.85m
ρ = slurry density ($kg/m^3$) =2.400 $gm/cm^3$

**Impeller Reynolds Number (Re):**

$Re = D_i^2 * N * \rho / \mu$

Where,
N= Impeller rotational speed (rpm) = 24 rpm
$D_i$ =Impeller diameter (m) = 3.85 m
ρ = slurry density ($gm/cm^3$) =2.4 $gm/cm^3$
μ = Viscosity ($Ns/m^2$) =0.050 $Ns/m^2$ given)

$Re = 3.85^2 * 24 * 2.4 / 0.050$

Re = 11383.68
Assuming turbulent flow
Impeller Power number is determined based on Reynolds number from generic agitator curves.

**Pumping capacity (Q)($m^3$/sec)**

$Q= N_q*N* D_i^3$
Assume $N_q = 0.56$

$Q= 0.56*24*(3.85)^3$ ::$(1/min)*(m)^3$

$Q= 766.97544$ :: $(m)^3/min$

$Q= 766.97544/60$ :: $(m)^3/sec$

$Q= 12.782924$ :: $(m)^3/sec$

**Area of Tank :**

$A = (\pi*D_t^2) / 4$ [ where $D_t$ = Diameter tank]

$A = (\pi*10.2^2) / 4$

$A = 81.6714$ $m^2$

Slurry tank model :

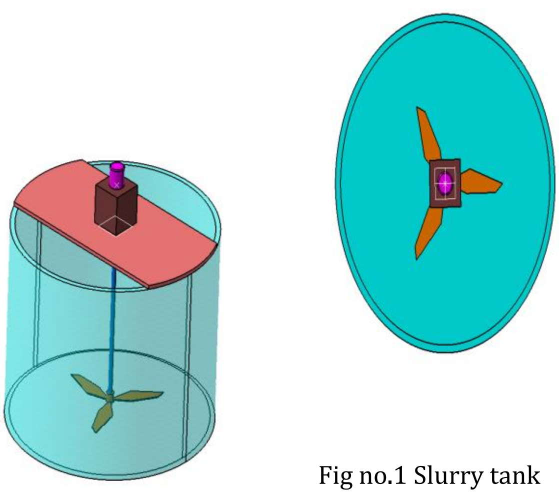

Fig no.1 Slurry tank

**Bulk fluid Velocity :**

Bulk fluid Velocity = Pumping capacity/ Area of Tank

Bulk fluid Velocity = 766.97544/ 81.6714 :: $\{m^3/min\}\{1/m^2\}$

Bulk fluid Velocity = 9.39099 m/min

But 1 m = 3.2799 ft

Bulk fluid Velocity = 9.39099 *3.2799 ft/min

Bulk fluid Velocity = 30.80192 ft/min

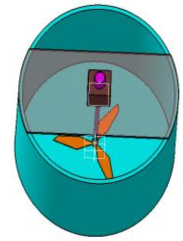

Fig no.2 Slurry tank

**Degree of Agitation** :

Degree of agitation is the guide line for optimizing the rate of suspension of solids which ranges from 1 to 10. For vigorous agitation in any vessel/tank the calculated degree of agitation may work out to more than 10 but it is considered as equal to 10 only.

Degree of agitation = Bulk fluid Velocity/6

{ For 6 ft/min ; Degree of agitation = 1
Degree of agitation varies from 0 to 10 }

Degree of agitation = 30.80192 / 6

Degree of agitation = 5.1336 ~ 5

**Annular Area :**

Annular Area = $[\pi*(D_t^2 – D_i^2) / 4]$

Annular Area = $[\pi*(10.2^2 – 3.85^2) / 4]$

Annular Area = 70.03573 $m^2$

**Rising velocity of particles :**

Rising velocity of particles = = Pumping capacity/ Annular Area

**Slurry tank top view**

Rising velocity of particles = 766.97544/ 70.03537 :: $\{m^3/min\}\{1/m^2\}$

Rising velocity of particles = 10.9512 m/min

Rising velocity of particles = 10.9512/60 m/sec

Rising velocity of particles = 0.182530 m/sec

**Tank capacity :**

Tank capacity = volume of slurry in tank (we consider max.)

Tank capacity= $(\pi * D_t^2 * H) / 4$ {Where H= slurry tank level(max.)}

Tank capacity= $(\pi * 10.2^2 * 9.2) / 4$ :: ($m^2$* m)

Tank capacity = 751.3769 $m^3$

**Tank Turnover Rate :**

Tank turnover rate is the guideline figure to optimize the revolution rate of impeller. The settling velocity of particles of solids cannot be kept more than the upward velocity in order to avoid settlement and accumulation of solids in tanks.

Tank Turnover Rate = Pumping capacity/ Tank capacity

Tank Turnover Rate = 766.97544/ 751.3769 :: {$m^3$/min}{1/$m^3$}

Tank Turnover Rate = 1.02076 times/min

Calculation of Theoretical Torque Rating of Gear Box:

Agitator Shaft Power:

$P= N_p * \rho * (D_i)^5 * N^3/(16*10^4)$

$N_p$ = Power number (factor)= 0.44

$\rho$ = slurry density = 2.40 gm/$cm^3$

$D_i$ =Impeller diameter= 3.85 m

N = Agitator rpm
=Drive motor / gear box reduction
=1500/62.5
=24 rpm

$P= 0.44*2.4*(3.85)^5*24^3/(16*10^4)$

P= 77.17583 hp

CONSIDERING FACTOR OF SAFETY OF 1.5:

Gearbox efficiency = 80%
Factor safety = 1.5

Drive motor rating:
= FOS * P/ (0.80)
= 1.5 * 77.17583/ (0.80*0.95)
= 144.7047 hp
= 144.7047* 746
= 107.9497 Kw

Thus the drive motor of about 110 kW shall be adequate (considering FOS of 1.5) for agitation of slurry of 2.4 gm/cc density in our slurry tanks.

Torque produced at output shaft of gearbox:

$P = 2 \pi * N * T / 60$

110000 = 2 *3.14* 24 *T / 60

T = 43789.8089 N-m

## 4.CONCLUSION:

As per the design calculation
Existing Agitator GB is designed for max. torque of 28300 Nm
Hence, we need to install gearbox with design torque = 43789.81 Nm with considering FOS =1.5 and gearbox output rpm = 24 rpm (Agitator rpm) to agitate slurry of density 2.4 gm/cc

## 5.FUTURE SCOPE:

After redesigning whole agitator gearbox assembly for slurry density 2.4 gm/cc. This assembly is used for high viscous iron ore slurry applications having torque requirement more than 283000 N-m. also higher slurry tank volume capacity and high slurry density applications.

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