

**Fundamentals of Food Process Engineering**  
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**Lecture - 50**  
**Mixing and Agitation ( Contd. )**

Hello everyone welcome to the NPTEL online certification course on Fundamentals of Food Process Engineering. So, today is the last section of the Mixing and Agitation chapter that we will cover.

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**Content**

- ✓ Introduction
- ✓ Mechanism of Solid mixing
- ✓ Mixing index and mixing
- ✓ Mixers for dry powders
- ✓ Mixers for cohesive solids
- ✓ liquid mixing: flow patterns, Types of agitator
- ✓ Power requirement for liquid mixing

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So, in the previous classes of this particular topic we have discuss about the introduction of mixing and agitation process, mechanism of solid mixing that particular solid or powder mixing. And mixing index how we can define the uniformity in the mixing process then mixers for dry powders and cohesive solids and also the liquid mixing. In the liquid mixing different flow patterns how we can control them and what are the kind of agitator that are used, what is the power requirement for a liquid mixing, how we can control the vortex formation all such things we have discussed.

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**Power requirement for non Newtonian fluid**

- ✓ The power input to a non-Newtonian liquid may be estimated, based on an 'apparent' viscosity'

$$\tau = k \cdot \dot{\gamma}^n$$
$$= k \cdot (\dot{\gamma})^{n-1} \cdot \dot{\gamma}$$

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And today we will just continue for the power requirement section in a bit more. In the last class we have seen that for power requirement of Newtonian fluid and if this is rotated inside a tank of baffled or unbaffled condition so, what will be the power requirement and how the different power requirement can be you know related with the dimensionless parameters or dimensionless number; those are based on the geometry of the you know geometry of the tank and also on the fluid properties.

Now, this mixing or power requirement they depends on many factors. For example, that what will be the circulation inside a liquid and what will be the you know the velocity and what will be the viscosity of the fluid density of the fluid. All those will have an important effect on that right.

So, we will see today that power requirement for non Newtonian fluid. Now, the power input to a non Newtonian liquid may be estimated based on the apparent viscosity. We know that for the non Newtonian liquid we can express the shear stress and shear rate behaviour by this factor and again we can write them as  $K$  into  $\dot{\gamma}$  to the power  $n$  minus 1 into  $\dot{\gamma}$ . So, this is called the apparent viscosity.

So, based on this apparent viscosity because for the Newtonian fluid what we have done that we have calculated Reynolds number and Froude number also. So, this Reynolds number and some power factor co relation we did and those correlation empirically has

been defined for different kind of geometry of the impeller and that help us to calculate the power in a particular mixing phenomena.

Now, when we want to use this, so, instead of the viscosity term that we have use in the Reynolds number, now we need to use the apparent viscosity ok.

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**Power requirement for non Newtonian fluid**

- ✓ The power input to a non-Newtonian liquid may be estimated, based on an 'apparent' viscosity'
- ✓ In non Newtonian fluid apparent viscosity varies with shear rate.

$$\mu_a = \frac{\tau}{\dot{\gamma}} = K\dot{\gamma}_{avg}^{n-1}$$

- ✓ Metzner and Otto (1957) relationship:

$$N_{Re} = \frac{\rho_f N D_a^2}{\mu_a} = \frac{\rho_f D_a^2}{K \beta^{n-1} N^{n-2}}$$

- ✓ Where,  $\dot{\gamma}_{avg}$  is avg shear rate &  $\beta$  = a dimensionless shear rate constant
- ✓ Power no formula is similar to that of Newtonian fluid

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So, in non Newtonian fluid apparent viscosity varies with shear rate. So, then  $\mu_a$  that is the apparent viscosity is expressed as  $\tau$  by  $\dot{\gamma}$  that is equal to  $K$  into  $\dot{\gamma}_{avg}$  to the power  $n$  minus 1.

So, Metzner and Otto relationship has been developed on that is  $N_{Re}$  is equal to ideally  $\rho_f N D_a^2$  by  $\mu_a$ ;  $\mu_a$  is the apparent viscosity,  $D_a^2$  is the diameter of the agitator or impeller,  $\rho_f$  is the density of the fluid,  $N$  is the revolution part second of the impeller.

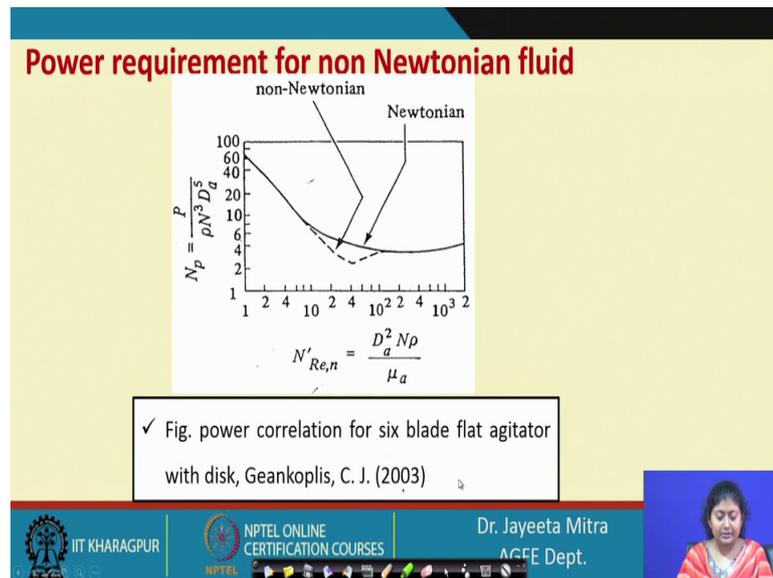
Now, how we can write this as  $\rho_f N D_a^2$  by  $K$  into  $\beta$  to the power  $n$  minus 1 and  $N$  to the power  $n$  minus 1 because here  $\mu_a$  is related to the apparent viscosity. This is related to the average shear rate  $\dot{\gamma}_{avg}$ ,  $\dot{\gamma}_{avg}$  is the average shear rate,  $\beta$  is a dimensionless shear rate constant ok.

So and  $N$  is the  $N$  to the power  $n$  minus 2. So, this  $N$  is the revolution. And small  $n$  is the flow behaviour index. So, if you put it that shear rate we are putting the value of shear rate and shear rate is expressed can be expressed as the velocity gradient ok, so, velocity

by the distance in that. So, using that we are now getting that this expression rho f into D a square by K into beta n minus 1 into N n minus 2 capital N to the power small n minus 2.

So, power number formula is similar to that of Newtonian fluid that we have developed only with some change some modification we have done here because of the non Newtonian fluid.

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So, here we can see that for power requirement of non Newtonian fluid, here we have Reynolds number with respect to the apparent viscosity and here we have power number P by rho into N cube into D a to the power 5.

So, if you see the difference between Newtonian and non Newtonian there is a in the viscous region there is not much effect, in the transition layer actually we have some effect and again in the when very high Reynolds number we can observe. So, there is the change is not much prominent ok. So, for the non Newtonian we are getting the lower power number in the transition region. This correlation has been developed for six blade flat agitator with disk.

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**Power requirement**

- ✓ **Correlations for the Density and Viscosity of Mixtures**
- ✓ Empirical relationships are available for both the density and the viscosity of binary mixtures  
$$\rho = \rho_c V_c + \rho_d V_d$$
- ✓ where  $v$  is the volume fraction and the subscripts  $c$  and  $d$  represent the continuous and dispersed phases, respectively
- ✓ For an un baffled vessel  
$$\mu = \mu_c^{V_c} \mu_d^{V_d}$$
- ✓ for a baffled vessel  
$$\mu = \frac{\mu_c}{V_c} \left( 1 + \left[ \frac{1.5 \mu_d V_d}{\mu_c + \mu_d} \right] \right)$$

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Now, correlations for density and viscosity of mixtures; so, empirical relationship are available for both the density and the viscosity of binary mixture. So, what are these correlations? These correlations are available for both density and viscosity of the binary mixtures.

So, now we have seen that when the fluid is there and the Newtonian and non Newtonian how the viscosity will be changing. Now for the mixture how this density and viscosity can evolve that we will see now.

So, if we see this equation that is density the combined density of a mixture  $\rho$  is equal to  $\rho_c$  into  $V_c$  plus  $\rho_d$  into  $V_d$ , where  $V$  is the volume fraction and the subscript  $c$  and  $d$  represent the continuous and dispersed phase respectively.

So, the continuous phase density and volume plus the dispersed phase density multiplied with the volume fraction.

So, volume fraction of both the case multiplied with the respective density of the continuous phase and disperse phase will gave the total density of the mixture.

Now, for an un baffled vessel n for baffled vessel what will be the case? For un baffled vessel  $\mu$  that will be the combined viscosity will be viscosity of the continues part to the power volume fraction into the viscosity of the disperse phase to the power the volume fraction. And for a baffled vessel the relation has been developed as viscosity

will equal to viscosity of the continuous phase  $\mu_c$  by  $V_c$  into  $1 + 1.5 \mu_d$  that is the viscosity of the disperse phase into  $V_d$  volume fraction divided by  $\mu_c$  plus  $\mu_d$ .

So, these two equations are for the un baffled and baffled in case of the mixture.

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✓ A pseudo plastic mixture is prepared by mixing two liquids in the volumetric ratio 60:39.9 along with 0.1% emulsion. A 4 baffled agitation tank (1.2m dia) with 6 blade turbine (0.8m dia) rotating at 200rpm is used for agitation. A draft tube is installed to facilitate high shear rate. Consequently power requirement increase 20% due to installment of draft tube. Calculate the total power requirement. Use empirical relation for non newtonian, 6 blade turbine:  $N_p = 0.4486 (N_{Re})^{0.4587}$

Liquid	Phase	K (Pa.s <sup>n</sup> )	n	P (kg/m <sup>3</sup> )	Avg shear rate
A	Continuous phase	8	0.65	959	$\dot{\gamma} = 10N$
B	Dispersed phase	6	1.3	1050	$\dot{\gamma} = 38N(D_a/D_t)^{0.5}$

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Now, we have a problem again. So, that is a pseudo plastic mixture; pseudo plastic mixture if you remember in our geology class we have seen that non Newtonian can be straight away differentiated into pseudo plastic and dilatants. So, if this is Newtonian this is pseudo plastic where  $n$  is less than 1.

So, flow behaviour index is less than 1. So, pseudo plastic mixture is prepared by mixing two liquids in the volumetric ratio of 60 is to 39.9 along with 0.1 percent emulsion.

Now, a 4 baffled agitation tank having 1.2 meter diameter with 6 blade turbine that is 0.8 meter dia rotating at 200 rpm, revolution per minute is used for agitation. A draft tube is installed to facilitate high shear rate ok.

So, we have seen this that how the draft tube will be helping to mix it properly. Consequently power requirement increases 20 percent due to installment of draft tube. Calculate the total power requirement and use empirical relation for non Newtonian, 6 blade turbine that is power number related with this equation that is  $0.4486 N_{Re}$  to the power 0.4587 ok.

So, for empirical relation for non Newtonian empirical relation for non Newtonian 6 blade turbine this is given this is the power number. So, no power correlation earlier we have taking from the chart here directly the relation has been given we will use this one now.

So, liquid A and liquid B because we are doing with the mixture which is the pseudo plastic mixture. So, liquid A and B now continues phase is A and dispersed phase is B.

So, this is given that is 8 is the value of K and 6 is the value of K in case of the dispersed phase, N is 0.63 and 1.3 is 0.65 and 1.3. Density is for the continues phase 959 kg per meter cube. And for the dispersed phase 1050 kg per meter cube. And also gamma shear rate average shear rate gamma value or gamma dot that is equal to 10 into N, where N is the revolution; N is actually we calculated revolution part second here it is given in rpm so, we will change it. And then for the disperse phase the average shear rate is 38 N D a by D t to the power 0.5.

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✓  $N = 200/60 = 3.33 \text{ rps}$   
 ✓ For liquid A:  $\dot{\gamma} = 10N = 33.3 \text{ s}^{-1}$   
 $\mu_c = K\dot{\gamma}_{\text{avg}}^{n-1} = 8(33.3)^{0.65-1} = 2.35 \text{ Pa}\cdot\text{s}$   
 ✓ For liquid B:  $\dot{\gamma} = 38N(D_a/D_t)^{0.5} = 38 \times 3.33 (0.8/1.2)^{0.5} = 103.31 \text{ s}^{-1}$   
 $\mu_d = K\dot{\gamma}_{\text{avg}}^{n-1} = 6(103.3)^{1.3-1} = 24.12 \text{ Pa}\cdot\text{s}$   
 ✓ Then for mixture:  $\mu = \frac{\mu_c}{V_c} \left( 1 + \frac{1.5\mu_d V_d}{\mu_c + \mu_d} \right) = \frac{2.35}{0.6} \left( 1 + \frac{1.5 \times 24.12 \times 0.6}{2.35 + 24.12} \right) = 6.05 \text{ Pa}\cdot\text{s}$   
 $\rho = \rho_c V_c + \rho_d V_d = 0.6 \times 959 + 0.399 \times 1050 = 994.4 \text{ kg/m}^3$   
 ✓ Reynolds no:  $N_{\text{Re}} = \frac{\rho_f N D_a^2}{\mu} = \frac{994.4 \times 3.33 \times 0.8^2}{6.05} = 350.3$

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So, first we have converted the revolution per minute to second that is 3.33 rps. Then for liquid A since shear rate we need to calculate average share rate 10 N that is 33.3, 10 into 3.33; so, 33.3 per second.

So, then for liquid A we need to calculate mu c that is the apparent viscosity. So, the formula was K into average shear rate to the power n minus 1. So, 8 into average shear

rate 33.3 into 0.65 minus 1. So, 2.35 Pascal second that is the apparent viscosity of continuous phase.

Similarly, for liquid B the shear rate is 38 into revolution per second into  $D_a$  by  $D_t$  to the power 0.5. So, N value is 3.33 and  $D_a$  impeller 2 time dia, the ratio is 0.8 by 1.2 to the power 0.5.

So, finally, average shear rate is coming as 103.31 per second. Then the mixture apparent viscosity of the mixture we need to calculate. So, shear rate from the liquid B will give you the value of apparent viscosity of the disperse material. So,  $K$  into gamma average n minus to the power n minus 1. So, this is coming 24.12 Pascal second.

For the mixture the formula is this  $\mu$  equal to  $\mu_c$  by  $V_c$  into 1 plus 1.5 disperse phase viscosity into volume fraction of disperse phase divided by the viscosity of the continuous as well as the disperse phase these are apparent viscosity remember this.

So, putting all the value 2.35 by 0.6 1 plus 1.5 into 24.12 into this volume fraction 0.6 by 2.35 plus 24.12.

So, we are getting 6.05 Pascal second. Volume fraction this was also given, volume fraction was given. So, we are getting 6.05 Pascal second. And density is again we have to put in the formula.

So,  $\rho_c V_c$  plus  $\rho_d V_d$  that is equal to 0.6 into 9 into 0.6 into 959 plus 0.399  $\rho_d$  into 1050; so, 994.4 kg per meter cube.

Then our aim is to find the Reynolds number ok. So, putting this  $\rho$  and  $\mu$  and N we know 2.33 revolution per second into  $D_a$  square. So, we are getting the Reynolds number it is coming only 350.3.

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**Power requirement**

- ✓ empirical relation for non newtonian, 6 blade turbine:  
$$N_p = 0.4486 (N_{Re})^{0.4587}$$
- ✓  $N_p = 0.4486(350.3)^{0.4587} = 6.59$
- ✓ Power requirement:  
$$P = N_p \rho N^3 D_a^5$$
  
$$P = 6.59 \times 994.4 \times 3.33^3 \times 0.8^5 = 79.29 \text{ kW}$$
- ✓ Including draft tube:  
$$P_{\text{total}} = 1.2P = 95.15 \text{ kW}$$

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So, empirical relation for non Newtonian 6 blade turbine; relation has been given this as  $N_p$  equal to  $0.4486 N_{Re}$  to the power  $0.4587$ .

So, putting the value of  $N_{Re}$  now because this we have calculated we will calculate what is  $N_p$  that is the power requirement;  $N_p$  is the power number. So, from the power number we will calculate the power requirement because the formula is power requirement  $P$  equal to  $N_p$  into density of the combined of the mixture into  $N$  cube into  $D_a$  to the power 5.

So, this is coming  $N_p$  is 6.59 into 994.4 into 3.33 cube into 0.8 to the power 5. So, finally, we are getting 79.29 kilowatt.

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**Scale up of agitator system**

- ✓ **Geometric similarity:** Geometric similarity means that a single ratio between small scale and large scale applies to every length dimension.
- ✓ **Kinematic similarity:** two geometrically similar unit have constant ratio of velocity at corresponding point along with similar flow pattern.
- ✓ **Dynamic similarity:** all corresponding forces at counter part location in two geometrical similar units bears a constant ratio.

The slide includes a diagram of a circular impeller with a central shaft and six blades. Red arrows indicate the flow direction and velocity vectors at various points on the impeller.

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Now, the next thing is scale up of agitator system. Now since we have seen suppose in a laboratory scale or small liquid mixture or agitator when we are designing. So, once we have got all the shear factor and the parameters fluid parameters done power requirement calculation is being done then if you want to scale up this process for an industrial scale, so, what we should look for first is we need to go by Geometric similarity.

So, Geometric similarity means that a single ratio between small scale and large scale applies to every length dimension. I mean what scale we are increasing one dimension we will increase in the similar scale or similar factor increase for all other dimension. The next is that kinematic similarity in that two geometrically similar unit have constant ratio of velocity at corresponding point along with similar flow pattern.

So, when the similar flow pattern is existing for example, the actual flow or radial flow these are same and to geometrically similar that means, let us say both are round bottom tank having the same kind of same let us say 6 blade flat disk impeller is attached to both of them and with the constant ratio of the of the velocity.

So, kinematic similarity we can maintain to upscale it. Third is the dynamic similarity that is all corresponding forces at counter part location in two geometrical similar units bear a constant ratio. All corresponding forces at counterpart location in the two geometric similar units bear's a constant ratio.

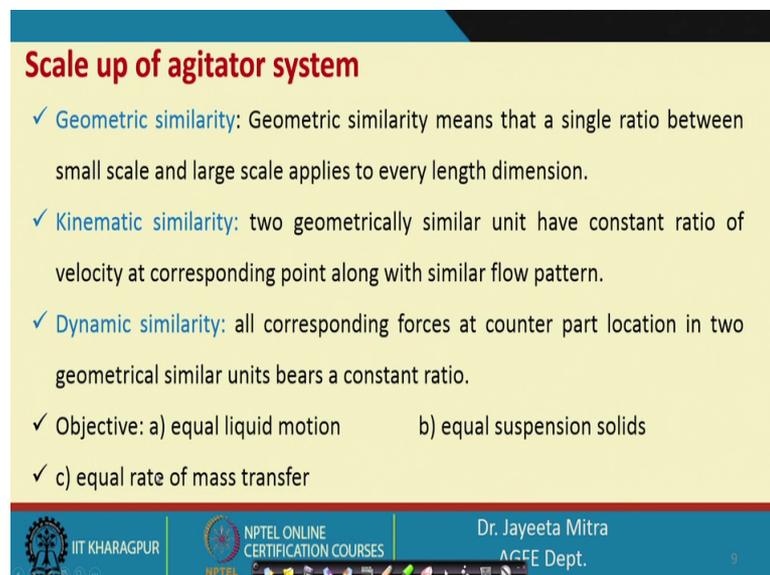
So, putting that the dynamic similarity can be access for the two systems, so that means, basically the corresponding forces we can see those are equal in the different cases.

So, for example, in at the end of the impeller tip you have measure the velocity impeller velocity you know. So, what will be the fluid velocity at the tip that you have analysed, for example, this will be your large scale you know large scale impeller dia.

So, from this point if what will be your velocity of the impeller and it has the you know radial and tangential direction.

So, if we consider the velocity of the fluid if you consider the velocity of the fluid, so, that also you need to calculate that this should be similar when we have the large scale system. So, at this point if you want to analyse what will be the force. So, this will be same for the other upscale version. Or else if you for example, any places you consider that other impeller tip or what is the in the draft tube section, so, all corresponding forces at the counter part location in the two geometrical similar units bears a constant ratio. So, maintaining these cases we can upscale the systems.

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**Scale up of agitator system**

- ✓ **Geometric similarity:** Geometric similarity means that a single ratio between small scale and large scale applies to every length dimension.
- ✓ **Kinematic similarity:** two geometrically similar unit have constant ratio of velocity at corresponding point along with similar flow pattern.
- ✓ **Dynamic similarity:** all corresponding forces at counter part location in two geometrical similar units bears a constant ratio.

✓ Objective: a) equal liquid motion      b) equal suspension solids  
✓ c) equal rate of mass transfer

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So, in that equal liquid motion we can maintain or equal suspension of the solid that we can maintain. So, third is that equal rate of mass transfer. So, we can see that for making this you know dynamic similarity. We can go for this kind of systems like liquid motion we maintain or we maintain the suspension concentration of solids that we are

suspending and we want mixing them properly that we can maintain or equal rate of mass transfer that also we can see or we can maintain by this dynamic similarities. So, these are the think given in mind when we want to upscale this systems.

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**Scale up of agitator**

- ✓ Scale up ratio:  $S_R = (V_2/V_1)^{1/3}$
- ✓ Also  $H=D$ ,  $\frac{V_2}{V_1} = \frac{\pi D_2^2 H_2}{\pi D_1^2 H_1} = \frac{D_2}{D_1}$
- ✓ Where,  $D$ = vessel diameter
- ✓ Using this  $S_R$  all new dimensions are calculated.  $S_R D_{a1} = D_{a2}$ ,  $S_R J_1 = J_2$  etc
- ✓ To determine agitator speed:  $N_2 = N_1 (1/S_R)^n = N_1 (D_1/D_2)^n$
- ✓ Where,  $n=1$  for equal liquid motion i.e  $\pi D_1 N_1 = \pi D_2 N_2$
- ✓  $n=3/4$  for equal suspension solids
- ✓  $n=2/3$  for equal rates of mass transfer i.e  $P_1/V_1 = P_2/V_2$

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So, scale up ratio if you follow scale up ratio  $S_R$  that is equal to  $V_2$  by  $V_1$  to the power  $1$  by  $3$ ;  $H$  equal to  $D$ . If we know the liquid level height inside a tank and  $D$  is the vessel diameter. And using this  $S_R$  all new dimensions are calculated.  $S_R$  if this factor we are maintaining, so, in this factor only we will we will upscale or downscale this. So,  $S_R$  into  $D_{a1}$  that will be  $D_{a2}$ ,  $S_R$  into  $J_1$  that will be  $J_2$  etcetera.

So, thus we can maintain the similarity between them and to determine the agitator speed  $N_2$  will be  $N_1$  into  $1$  by  $S_R$  to the power  $n$  as the ratio of  $N$  changes with the power of  $n$  power of small  $n$ .

So, here we can also write  $N_1$  into  $1$  by  $S_R$  is nothing but  $D_1$  by  $D_2$  to the power  $n$  where  $n$  equal to  $1$  for liquid where equal liquid motion  $n$  will be  $1$  that is  $\pi D_1 N_1$  equal to  $\pi D_2 N_2$ ;  $n$  will be  $3$  by  $4$  for equal suspension solid. This  $n$  the factor  $n$  will be  $3$  by  $4$  for equal suspension solid. And  $n$  will be equal to  $2$  by  $3$  for equal rates of mass transfer that is  $P_1/V_1$  equal to  $P_2/V_2$ ; sorry this will be  $\rho$  this will be actually  $\rho$  then only we can ok.

So, these three are the cases, how we can do the scale up for an agitator. So, in this case, while doing scaling up  $S_R$  is  $V_2$  by  $V_1$ ; so that means, only the ratio of the volume in the second one divided by the first one.

So, that is eventually the ratio of  $D_2$  by  $D_1$ . So, therefore, we have to use this  $V_2$  by  $V_1$  nothing but  $D_2$  by  $D_1$ . So,  $S_R$  will be  $D_2$  by  $D_1$  to the power  $1/3$  and with that we can upscale this case based on these three parameters where  $n$  equal to 1 for equal liquid motion,  $n$  equal to  $3/4$  for equal suspension of the solid and  $n$  equal to  $2/3$  for equal rate of mass transfer.

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**Scale up of agitator**

- ✓ Condition of existing agitation system is as follows.  $D_t=1.83\text{m}$ ,  $D_a=0.61\text{m}$ ,  $J_1=0.15\text{m}$ ,  $N_1=1.5\text{rev/s}$ ,  $\rho=929\text{kg/m}^3$  &  $\mu=0.01\text{Pa.s}$ . scale up the agitation system for volume 3 times the existing one for following objective.
- a) where equal liquid motion is needed
- ✓ Solution:  $D_t=H$ ,  $V_1=3.142(1.83)^3/4=4.813\text{ m}^3$
- ✓  $V_2=3\times 4.813=14.44\text{ m}^3$
- ✓  $S_R=(V_2/V_1)^{1/3}=1.442$
- ✓  $D_{a2}=S_R D_{a1}=0.88\text{m}$  &  $J_2=S_R J_1=0.216\text{m}$

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Now, condition of an existing agitation system is as follows. So, the condition given as 10 dia  $D_t$  is 1.83 meter, agitator dia  $D_a$  that is equal to 0.61 meter,  $J_1$  which is the width of baffle that is 0.15 meter,  $N_1$  that is equal to 1.5 revolution per second, density 929 kg per meter cube, viscosity 0.01 Pascal second, scale up the agitation system for volume 3 times the existing one for the following objective.

So, this you can see it will be very beneficial for those who want to work this in an industrial scale system you want to upscale this. So, how we can solve this? This is the problem of a scalar based on equal liquid motion.

So, first we will consider this case  $D_t$  equal to height of the liquid level. So,  $D_t$  equal to  $H$   $V_1$  that is equal to 3.142 into 1.83 which is the dia of the tank cube divided by 4. So,

4.813 meter cube. Then V 2 we need 3 times the existing volume. So, we have calculated that.

Finally S R will be V 2 by V 1 power of 1 by 3. So, 1.442 this will be the value of S R scale up ratio we can consider this. So, D a 2 D a 1 is known to us. So, with this factor we will change. So, D a 2 will be S R into D a 1 that is equal to 0.88 meter, J 2 will be equal to S R into J 1 that is equal to 0.216 meter ok.

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### Scale up of agitator

- ✓  $N_2 = N_1(1/S_R)^n$
- ✓ For equal liquid motion:  $n=1$
- ✓  $N_2 = N_1(1/S_R) = 1.5/1.442 = 1.04 \text{ rev/s}$
- ✓ Reynolds no:

$$N_{Re} = \frac{\rho_f N D_a^2}{\mu} = \frac{929 \times 1.04 \times 0.88^2}{0.01} = 74819$$

- ✓ From graph:  $N_p = 5$
- ✓ Power requirement:

$$P = 5 \times 929 \times 1.04^3 \times 0.88^5 = 2.757 \text{ kW}$$

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So, then N2 will be N1 into 1 by S R to the power n. For equal liquid motion we know n equal to 1 small n equal to there are three cases; equal liquid motion, equal mass transfer and equal suspension. So, for all that this small n is defined then N 2 will be N 1 into 1 by S R. So, 1.5 divided by 1.442. So, 1.04 revolution per second, Reynolds number that will be rho F into N D a square by mu. So, 929 into N is 1.04 into Da 0.8 to the power square 0.8 square. This will be 0.88 because it has come 0.88 square by 0.01 viscosity.

So, we are getting very high Reynolds number. So, it shows the turbulent region. Now, from the graph we look for the value of N P. So, this is the correlation for this power number with respect to N R e.

So, we are getting very high range somewhere here corresponding to the value of Reynolds number, we are getting a very high range and that for this particular flat blade turbine which is showing by curve 1. We will straight away see that what is the value of

this number is coming. So, this number has been taken as 5 N p. So, 5 into 929 into 1.04 cube that is value of revolution and into 0.88 to the power 5; so, 2.757 kiloWatt.

So, this is how we can calculate the power requirement. And we can scale up also the process. So, here we end the discussion related to the mixing. We have once again we can remember that we have covered the importance of mixing. And what is the case for a solid mixing, cohesive powder mixing, mixing index determination then liquid mixing different flow pattern. And the power requirement in liquid mixing for baffled and un baffled tank, for Newtonian and non Newtonian fluid also for the different mix kind of and also for the scale up of a system ok.

So, we will stop here and we will continue with another chapter in the next class.

Thank you.