การออกแบบระบบกวนเร็ว –กวนช้าแบบ *Impellers Mixer*

สำหรับน้ำประปาขนาด *5,000* ลูกบาศก์เมตรต่อวัน

โดย นายพรศักดิ์ สมรไกรสรกิจ

เกณฑ์การออกแบบ

1. เกณฑ์ในการออกแบบถังกวนเร็ว (Mechanical Mixing)

ข้อพิจารณา	เกณฑ์หรือค่าที่ใช้ออกแบบ	หน่วย	หมายเหตุ
1 เวลาที่น้ำอยู่ในถัง	10 - 40	วินาที	
2 ความเร็วรอบของใบพัด	100 - 120	รอบ/นาที	
3 ค่า G	500 - 1000	1/วินาที	

2. The Values of diesign parameters generally adopted in design of mechcanical mixers are as given below (Rapid Mixing) Water Treatment Process (Simple Option)

Item	Design Criteria	unit
1 Mixing Time	20 - 60	sec
2 Diameter of Mixing Tank (D)	1 - 3	m.
3 Diameter of impeller (D_a)	0.2D - 0.4D	m.
4 Speed of flat Blade turbine	10 - 150	rpm.
5 Speed of Propeller	150 - 1500	rpm.

3. Contact time and Velocity Gradient for Rapid Mixing

1. Rapid mixing time,s	20	30	40	>40
2. Velocity gradient(G), s^{-1}	1000	900	790	700

4. เกณฑ์ในการออกแบบถังรวมตะกอน (Mechnical Mixing)

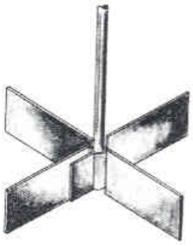
Impellers Mixer Design Criteria

ข้อพิจารณา	เกณฑ์หรือค่าที่ใช้ออกแบบ	หน่วย	หมายเหตุ
1. เวลาเก็บกักน้ำ	20 - 60	นาที	
2. ความเร็วรอบของใบพัด	1 - 15	รอบ/นาที	
3. ความเร็วตามแนวเส้นรอบวง	0.1 - 1	เมตร/วินาที	
4. ค่า G	10 - 75	วินาที$^{-1}$	
	5 - 100		
5. ค่า Gt	20,000 - 200,000		
6. ระยะห่างระหว่างก้นถังกับปลายใบพัดหรือระยะห่างระหว่างผนังด้านใน	0.15 - 0.3	เมตร	
7. ความลึกของถัง	1.5 - 2	เท่าของเส้นผ่าศูนย์กลางวงล้อ	
8. ความเร็วในแนวราบของน้ำ	0.15 - 0.25	เมตร/วินาที	
9. พื้นที่ของใบพัด, % ของพื้นที่ภาคตัดขวางของถ	10 - 25		

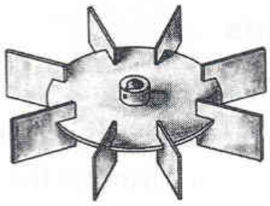
5. Kawamura

TABLE 3.2.4-2 General Design Criteria

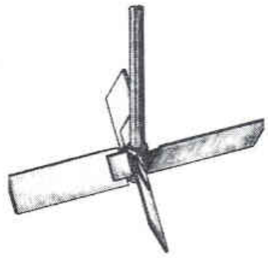
	Baffled Channel	Mechanical Flocculators: Horizontal Shaft with Paddles	Mechanical Flocculators: Vertical Shaft with Blades
G (s^{-1})	50–10 tapered	50–10 tapered	70–10 tapered
T (min)	30–45	30–40	20–40
Flocculation stages (number of channels or number of horizontal shafts)	6–10	3–6	2–4
Mix energy control	Flow passage variation	Variable mixing speed	Variable mixing speed
Maximum flow velocity or mixer tip speed (fps)	3	3	6–9
Blade area/tank area (%)	—	5–20	0.1–0.2
Blade: D/T	—	0.5–0.75	0.2–0.4
Shaft rpm	—	1–5	8–25
Major application	Conventional complete treatment	Conventional complete treatment	Direct filtration and conventional complete treatment



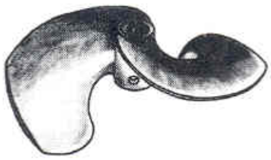
(a)



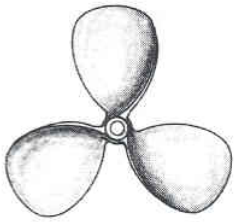
(b)



(c)



(d)



(e)

1. Rapid Mixing by Radial and Axial Impellers

Theory $$G = \sqrt{\frac{P}{\mu V}}$$

Where :

G = Velocity gradient, sec^{-1} (G = 700 to 1000 sec^{-1})

P = Power Imparted to the water, N-m/s or Watt or $kg.m^2/s^3$

V = Volume of the basin, m^3

μ = absolute viscosity of the fluid, $N\text{-}s/m^2$

The motor power of the mixer is the power to drive the speed reduction gears. The powe imparted to the water by a mixer is calculated from

Theory $$P = 2\pi nT$$

Where :

n = Impeller speed, revolutions per second (rps)

T = Impeller shaft torque, N-m.

Other expression for the power imparted to the water are given by :

Theory $P = N_p \mu n^2 d^3$ is used for the Laminar-flow range (Reynolds number $N_R < 10$)

$P = N_P \rho n^3 d^5$ is used for the Turbulent-flow range (Reynolds number NR > 10,000)

Where :

N_P = Power number of the impeller (power numbers for different types of impellers are give in table 8 - 5

d = impeller diameter, m

ρ = mass density of fluid, kg/m^3

μ = absolute viscosity of water, N-s/m^2

The Reynolds number for Rapid mixers is given by :

Theory $$N_R = \frac{d^2 n \rho}{\mu}$$

The velocity gradient for a mixing basin utilizing flow - induced turbulence can be calculated from

$$G = \frac{g\rho\sqrt{h_L}}{t\mu}$$

Where :

h_L = total head loss through the mixer,m

t = detention time, s

Detention time in Rapid-Mix Basin

Theory $$t = \frac{V}{Q}$$

Where :

t = average detention time, min

Q = flow rate, m^3/min

V = volume of the tank, m^3

Check Mixer Tip Speed

Theory

$$Tip\ Speed = \pi D n \qquad \text{m/s}$$

Where :

D = Diameter of Impeller (m.)

n = Impeller speed, revolutions per second (rps)

Rapid Mix

Tip Speed > 1 m/s

Slow Mix

1.Baffle Channel < 0.9 m/s

2.Mechanical Flocculators

- Horozontal Shaft with Paddle < 0.9 m/s
- Vertical Shaft with Blade < 1.8 m/s to 2.7 m/s

1. Power Number for Impeller

Table 8-5 Power Numbers of Various Rapid-Mix Impellers

	Power Number, N_p
Radial flow	
Straight blade turbine	
4 blade ($w/d = 0.15$)[a]	2.6
4 blade ($w/d = 0.2$)	3.3
Disc turbine	
4 blade ($w/d = 0.25$)	5.1
6 blade ($w/d = 0.25$)	6.2
Axial flow	
Propeller 1:1 pitch	0.3
Propeller 1.5:1 pitch	0.7
45° Pitched blade	
4 blade ($w/d = 0.15$)	1.36
4 blade ($w/d = 0.2$)	1.94

a w/d = blade width-to-diameter ratio.
Source: Adapted in part from References 2, 5, 27, and 28.

2. Coefficient of Drag for Paddle

Table 8-6 Coefficient of Drag (C_D) for Paddle-Wheel Flocculator, Based on Length-to-Width Ratio of the Paddle

Length-to-Width Ratio (L/W)	C_D
5	1.20
20	1.50
∞	1.90

RAPID MIXING TANK

Give

1 Flow rates

$Q_{aveage\ flow\ rate\text{-}day}$	=	5000	m^3/d
$Q_{maximum\ flow\ rate}$ $(1.5Q_{average\ flow\ rate\text{-}day})$	=	7500	m^3/d
	=	313	m^3/hr
Velocity in Raw water pipe	=	2	m/s

Theory $Q = Av$

Pipe Diameter (D) $= \sqrt{\dfrac{4Q}{\pi v}}$

Diameter of Raw water pipe	=	0.24	m.
Use Mixing Tank	=	2	Tank
∴ Flow rate per tank	=	156	cu.m/hr
Give Detention Time	=	40	sec

Theory $Q = \dfrac{V}{t}$

2 **Volume of the Tank required** = 1.736 m^3

Geometry of Rapid-Mix Basin utilizing mechanical mixers are usually **square** and have a depth to width ratio of approximately 1.5 yields excellent performance with turbine mixers

∴ Volume of the Tank $= W \ x \ L \ x \ Depth$

$= W \ x \ W \ x \ 1.5W$

$= 1.5W^3$

Solve for W

$$W = \left(\frac{Volume\ of\ the\ Tank}{1.5}\right)^{1/3}$$

W = 1.050 m.

∴ Width of Rapid Mixing Tank	=	1.050	m.
Length of Rapid Mixing Tank	=	1.050	m.
Depth of Rapid Mixing Tank	=	2.100	m.

Impellers Mixer

Rapid Mixing

The sustained temperature of raw water is excepted to be in the range from5^o to 28^o.

The lowest temperature will present the critical condition in the mixer design

μ = = 0.000895 Kg/m.s at 25^{o}C

ρ = = 997.1 Kg/m^3 at 25^{o}C

Theory $G = \sqrt{\dfrac{P}{\mu V}}$

Where :

G = Velocity gradient, sec^{-1} (G = 700 to 1000 sec^{-1})

P = Power Imparted to the water, N-m/s or Watt or kg.m^2/s^3

V = Volume of the basin, m^3

μ = absolute viscosity of the fluid, N-s/m^2

Give Velocity Gradient (G) = 950 s^{-1}

3 **Power Imparted to the water,** P = 1402.3 N-m/s or Watt or kg.m^2/s^3

= 1.4023 kWatt

P is the power imparted to the water. The power of the driver(P') is calculated by diving P by the efficiency of the gearbox, which is typically arounc 90 percent

∴ Power Imparted to the water, P' = 1.5581 kWatt

1 HP = 0.7457 kWatt

∴ **Power Imparted to the water,** **P** = 2.0895 HP

∴ Use Standard motor of P' = HP, rpm =

and efficiency = 90 percent

4 **Impeller Design**

Calculate impeller size and rotational speed. The rapid-mix basin will be an "up flow" type.Experience

shown that radial-flow mixers perform batter than axial-flow mixers in a vertical-flow basir

Use axial flow 45oPitched blade 4 blade mixer

Blade width-to-Diameter ratio = 0.2

N_P = 1.94

Theory $P = N_P \rho n^3 d^5$

$$n = \left(\frac{P}{\rho N_P d^5} \right)^{1/3}$$

Diameter of mixing tank (D) = 1.050 m = Width of Rapid Mixing Tank

Diameter of impeller (d) = 0.2 to 0.4D use 0.3D

∴ Diameter of impeller (d) = 0.315 m

∴ n = 6.380911208 rps

= 382.8546725 rpm

∴ use gear box to convert rpm(standard motor) to 382.8547 rpm

5 Check Reynolds number for turbulent flow

Theory $$N_R = \frac{d^2 n \rho}{\mu}$$

∴ N_R = 705285.6756 > 10,000 OK

Therefore this equation is Valid

6 Dimentions of impeller are as follow

- Diameter of impeller (d) = 31.5 cm.
- Width of impeller (W) = 6.3 cm.

7 Check Impeller shaft torque

Theory $P = 2\pi n T$

∴ T = 34.99495323 N-m

∴ choose motor gear = 382.8546725 rpm.

Shaft torque = 34.99495323 N-m

Use Standard motor of P' = 2.0895 HP

8 Head loss through the mixer

Theory

$$G = \frac{g\rho\sqrt{h_L}}{t\mu}$$

$\therefore$ h_L = 1.208921E-05 m.

Flocculator Compartment 1

Give

1 Flow rates

$Q_{aveage\ flow\ rate\text{-}day}$	=	5000	m^3/d
$Q_{maximum\ flow\ rate}$ $(1.5Q_{average\ flow\ rate\text{-}day})$	=	7500	m^3/d
	=	313	m^3/hr
Use Mixing Tank	=	2	Tank
∴ Flow rate per tank	=	156	cu.m/hr
Give Detention Time in Compartment	=	10	min
	=	600	sec

Theory $$Q = \frac{V}{t}$$

2 Volume of the Tank required	=	26.042	m^3
Give the average water depth	=	4.25	m.
∴ Tank Area	=	6.127	m^2
length (L)	=	Width (W)	
∴ Tank Area	=	W^2	
Solve for W W	=	2.475	m.
∴ Width of Rapid Mixing Tank	=	2.475	m.
Length of Rapid Mixing Tank	=	2.475	m.
Depth of Rapid Mixing Tank	=	4.250	m.

The sustained temperature of raw water is excepted to be in the range from 5^{o} to 28^{o}.

The lowest temperature will present the critical condition in the mixer design

μ =	=	0.000895	Kg/m.s	at $25^{o}C$
ρ =	=	997.1	Kg/m^3	at $25^{o}C$

Theory $$G = \sqrt{\frac{P}{\mu V}}$$

$\sqrt{\mu V}$

Where :

G = Velocity gradient, sec^{-1} (G = 700 to 1000 sec^{-1})

P = Power Imparted to the water, N-m/s or Watt or kg.m^2/s^3

V = Volume of the basin, m^3

μ = absolute viscosity of the fluid, N-s/m^2

Give Velocity Gradient (G) = 70 s^{-1}

3 **Power Imparted to the water,** P = 114.2 N-m/s or Watt or kg.m^2/s^3

= 0.1142 kWatt

P is the power imparted to the water. The power of the driver(P') is calculated by diving P by the efficiency of the gearbox, which is typically arounc 90 percent

∴ Power Imparted to the water, P' = 0.1269 kWatt

1 HP = 0.7457 kWatt

∴ **Power Imparted to the water,** **P** = 0.1702 HP

∴ Use Standard motor of P' = HP, rpm =

and efficiency = 90 percent

4 **Impeller Design**

Calculate impeller size and rotational speed. The rapid-mix basin will be an "up flow" type.Experience shown that radial-flow mixers perform batter than axial-flow mixers in a vertical-flow basir

Use axial flow 45oPitched blade 4 blade mixer

Blade width-to-Diameter ratio = 0.2

N_P = 1.94

Theory

$$P = N_P \rho n^3 d^5$$

$$n = \left(\frac{P}{\rho N_P d^5}\right)^{1/3}$$

Diameter of mixing tank (D)	=	2.475	m	= Width of Rapid Mixing Tank
Diameter of impeller (d)	=	0.2 to 0.4D	use 0.3D	
∴ Diameter of impeller (d)	=	0.743	m	

∴ n = 0.662266849 rps

= 39.73601092 rpm

∴ use gear box to convert rpm(standard motor) to 39.73601 rpm

5 Check Reynolds number for turbulent flow

Theory $$N_R = \frac{d^2 n\rho}{\mu}$$

∴ N_R = 406884.4118 > 10,000 OK

Therefore this equation is Valid

6 Dimentions of impeller are as follow

- Diameter of impeller (d) = 74.3 cm.
- Width of impeller (W) = 14.9 cm.

7 Check Impeller shaft torque

Theory $$P = 2\pi nT$$

∴ T = 27.45966479 N-m

∴ choose motor gear = 39.73601092 rpm.

Shaft torque = 27.45966479 N-m

Use Standard motor of P' = 0.1702 HP

8 Check Mixer Tip Speed

Theory $$Tip\ Speed = \pi Dn \text{ m/s}$$

∴ Tip Speed = 1.545 m/s < 1.8 m/s to 2.7 m/s OK.

9 Head loss through the mixer

Theory $$G = \frac{g\rho\sqrt{h_L}}{t\mu}$$

$\therefore$ h_L = 1.476826E-05 m.

Flocculator Compartment 2

Give

1 Flow rates

$Q_{aveage\ flow\ rate\text{-}day}$	=	5000	m^3/d
$Q_{maximum\ flow\ rate}$ $(1.5Q_{average\ flow\ rate\text{-}day})$	=	7500	m^3/d
	=	313	m^3/hr
Use Mixing Tank	=	2	Tank
∴ Flow rate per tank	=	156	cu.m/hr
Give Detention Time in Compartment	=	10	min
	=	600	sec

Theory $$Q = \frac{V}{t}$$

2 Volume of the Tank required	=	26.042	m^3
Give the average water depth	=	4.25	m.
∴ Tank Area	=	6.127	m^2
length (L)	=	Width (W)	
∴ Tank Area	=	W^2	
Solve for W W	=	2.475	m.
∴ Width of Rapid Mixing Tank	=	2.475	m.
Length of Rapid Mixing Tank	=	2.475	m.
Depth of Rapid Mixing Tank	=	4.250	m.

The sustained temperature of raw water is excepted to be in the range from 5^o to 28^o.

The lowest temperature will present the critical condition in the mixer design

μ =	=	0.000895	Kg/m.s	at 25^oC
ρ =	=	997.1	Kg/m^3	at 25^oC

Theory $$G = \sqrt{\frac{P}{\mu V}}$$

Where :

G = Velocity gradient, sec^{-1} (G = 700 to 1000 sec^{-1})

P = Power Imparted to the water, N-m/s or Watt or kg.m^2/s^3

V = Volume of the basin, m^3

μ = absolute viscosity of the fluid, N-s/m^2

Give Velocity Gradient (G) = 40 s^{-1}

3 **Power Imparted to the water,** P = 37.3 N-m/s or Watt or kg.m^2/s^3

= 0.0373 kWatt

P is the power imparted to the water. The power of the driver(P') is calculated by diving P by the

efficiency of the gearbox, which is typically arounc 90 percent

∴ Power Imparted to the water, P' = 0.0414 kWatt

1 HP = 0.7457 kWatt

∴ **Power Imparted to the water, P** = 0.0556 HP

∴ Use Standard motor of P' = HP, rpm =

and efficiency = 90 percent

4 **Impeller Design**

Calculate impeller size and rotational speed. The rapid-mix basin will be an "up flow" type.Experience

shown that radial-flow mixers perform batter than axial-flow mixers in a vertical-flow basir

Use axial flow 45oPitched blade 4 blade mixer

Blade width-to-Diameter ratio = 0.2

N_P = 1.94

Theory $P = N_P \rho n^3 d^5$

$$n = \left(\frac{P}{\rho N_P d^5}\right)^{1/3}$$

Diameter of mixing tank (D) = 2.475 m = Width of Rapid Mixing Tank

	Diameter of impeller (d)	=	0.2 to 0.4D	use 0.3D	
∴	Diameter of impeller (d)	=	0.743	m	
∴	n	=	0.456044949	rps	
		=	27.36269695	rpm	

∴ use gear box to convert rpm(standard motor) to 27.3627 rpm

5 Check Reynolds number for turbulent flow

Theory $$N_R = \frac{d^2 n \rho}{\mu}$$

∴ N_R = 280185.5193 > 10,000 OK

Therefore this equation is Valid

6 Dimentions of impeller are as follow

- Diameter of impeller (d)	=	74.3	cm.
- Width of impeller (W)	=	14.9	cm.

7 Check Impeller shaft torque

Theory $$P = 2\pi nT$$

∴ T = 13.02100482 N-m

∴	choose motor gear	=	27.36269695	rpm.
	Shaft torque	=	13.02100482	N-m
	Use Standard motor of P'	=	0.0556	HP

8 Check Mixer Tip Speed

Theory $$Tip\ Speed = \pi Dn \quad \text{m/s}$$

∴ Tip Speed = 1.064 m/s < 1.8 m/s to 2.7 m/s OK.

9 Head loss through the mixer

Theory $$G = \frac{g\rho\sqrt{h_L}}{t\mu}$$

$\therefore$ h_L = 4.822288E-06 m.

Flocculator Compartment 3

Give

1 Flow rates

$Q_{aveage\ flow\ rate-day}$	=	5000	m^3/d
$Q_{maximum\ flow\ rate}$ $(1.5Q_{average\ flow\ rate-day})$	=	7500	m^3/d
	=	313	m^3/hr
Use Mixing Tank	=	2	Tank
∴ Flow rate per tank	=	156	cu.m/hr
Give Detention Time in Compartment	=	10	min
	=	600	sec

Theory $$Q = \frac{V}{t}$$

2 Volume of the Tank required	=	26.042	m^3
Give the average water depth	=	4.25	m.
∴ Tank Area	=	6.127	m^2
length (L)	=	Width (W)	
∴ Tank Area	=	W^2	
Solve for W W	=	2.475	m.
∴ Width of Rapid Mixing Tank	=	2.475	m.
Length of Rapid Mixing Tank	=	2.475	m.
Depth of Rapid Mixing Tank	=	4.250	m.

The sustained temperature of raw water is excepted to be in the range from 5^o to 28^o.

The lowest temperature will present the critical condition in the mixer design

μ =	=	0.000895	Kg/m.s	at 25^oC
ρ =	=	997.1	Kg/m^3	at 25^oC

Theory $$G = \sqrt{\frac{P}{\mu V}}$$

Where :

G = Velocity gradient, sec^{-1} (G = 700 to 1000 sec^{-1})

P = Power Imparted to the water, N-m/s or Watt or kg.m^2/s^3

V = Volume of the basin, m^3

μ = absolute viscosity of the fluid, N-s/m^2

Give Velocity Gradient (G) = 20 s^{-1}

3 Power Imparted to the water, P = 9.3 N-m/s or Watt or kg.m^2/s^3

= 0.0093 kWatt

P is the power imparted to the water. The power of the driver(P') is calculated by diving P by the efficiency of the gearbox, which is typically arounc 90 percent

∴ Power Imparted to the water, P' = 0.0104 kWatt

1 HP = 0.7457 kWatt

∴ **Power Imparted to the water, P** = 0.0139 HP

∴ Use Standard motor of P' = HP, rpm =

and efficiency = 90 percent

4 Impeller Design

Calculate impeller size and rotational speed. The rapid-mix basin will be an "up flow" type.Experience shown that radial-flow mixers perform batter than axial-flow mixers in a vertical-flow basir

Use axial flow 45oPitched blade 4 blade mixer

Blade width-to-Diameter ratio = 0.2

N_P = 1.94

Theory $P = N_P \rho n^3 d^5$

$$n = \left(\frac{P}{\rho N_P d^5} \right)^{1/3}$$

Diameter of mixing tank (D) = 2.475 m = Width of Rapid Mixing Tank

	Diameter of impeller (d)	=	0.2 to 0.4D	use 0.3D	
∴	Diameter of impeller (d)	=	0.743	m	
∴	n	=	0.287290316	rps	
		=	17.23741893	rpm	

∴ use gear box to convert rpm(standard motor) to 17.23742 rpm

5 Check Reynolds number for turbulent flow

Theory $$N_R = \frac{d^2 n\rho}{\mu}$$

∴ N_R = 176505.8168 > 10,000 OK

Therefore this equation is Valid

6 Dimentions of impeller are as follow

- Diameter of impeller (d)	=	74.3	cm.
- Width of impeller (W)	=	14.9	cm.

7 Check Impeller shaft torque

Theory $$P = 2\pi nT$$

∴ T = 5.167389188 N-m

∴	choose motor gear	=	17.23741893	rpm.
	Shaft torque	=	5.167389188	N-m
	Use Standard motor of P'	=	0.0139	HP

8 Check Mixer Tip Speed

Theory $Tip\ Speed = \pi Dn$ m/s

∴ Tip Speed = 0.670 m/s < 1.8 m/s to 2.7 m/s OK.

9 Head loss through the mixer

Theory $$G = \frac{g\rho\sqrt{h_L}}{t\mu}$$

$\therefore$ h_L = 1.205572E-06 m.