POWER CONSUMPTION OF MIXING

Dimensionless numbers

$$Eu_{mix} = \frac{P}{d^5 \cdot n^3 \cdot \rho} \qquad Re_{mix} = \frac{d^2 \cdot n \cdot \rho}{\eta}$$

ahol	P	net power consumption	[W]
	d	paddle diameter	[m]
	n	turning number	[1/s]

Relation between Eu_{mix} és Re_{mix} között

$$Eu_{mix} = \frac{A}{Re_{mix}^s}$$

where A and s are constants depending on the device.

Gross power consumption

$$P_{gross} = \frac{P}{efficiency}$$

Efficiency includes that of the transmission and the motor.

Problem 1

Oil fraction is warmed up, before sulphochlorination, during continuous mixing with an anchor mixer of four arms. Motor of what power is needed if the power consumption at start-up is three times of the operation power need?

Data:

d = 1 m	ρ = 800 kg/m^3	efficiency = 0.8
n = 90 1/min	$\eta = 1.5 \cdot 10^{-2}$ Pas	

Solution

n = 90 1/min = 1.5 1/s

Mixing Reynolds number

$$Re_{mix} = \frac{d^2 \cdot n \cdot \rho}{\eta} = \frac{(1m)^2 \cdot 1.5\frac{1}{s} \cdot 800\frac{kg}{m^3}}{1.5 \cdot 10^{-2}\,Pas} = 8 \cdot 10^4$$

Parameters of the four arms anchor mixer as given in table:

A = 6,0 s = 0,25

$$Eu_{mix} = \frac{A}{Re_{mix}^s} = \frac{6}{(8 \cdot 10^4)^{0.25}} = 0.357$$

Net power consumption

$$Eu_{mix} = \frac{P}{d^5 \cdot n^3 \cdot \rho}$$

$$P = Eu_{mix} \cdot d^5 \cdot n^3 \cdot \rho = 0.357 \cdot (1m)^5 \cdot \left(1.5\frac{1}{s}\right)^3 \cdot 800\frac{kg}{m^3} = 963.26W$$

Gross power consumption

$$P_{gross} = \frac{P}{efficiency} = \frac{963.26\ W}{0.8} = 1204\,W$$

Power consumption during start-up

$$P_{max} = 3 \cdot P_{gross} = 3 \cdot 1204\,W = 3612\,W = 3.6\ kW$$

Problem 2

How strong motor is needed for mixing 60 % sugar solution if cosφ of the electromotor is 0.83, the transmission efficiency is 0.75, viscosity is $1.5\cdot10^{-2}$ Pas, density is 1260 kg/m^3, diameter of the paddle is 150 mm, and the turning rate is 480 1/min, and the model of the mixer is $Eu_{mix} = \frac{6}{Re_{mix}^{0.18}}$?

What is the gross power consumption if the turning rate is 600 1/min ?

Solution

d = 150 mm = 0.15 m

n = 480 1/min = 8 1/s

$$Re_{mix} = \frac{d^2 \cdot n \cdot \rho}{\eta} = \frac{(0.15\text{m})^2 \cdot 8\frac{1}{s} \cdot 1260\frac{kg}{m^3}}{1.5\cdot10^{-2}\,\text{Pas}} = 15120$$

$$Eu_{mix} = \frac{6}{Re_{mix}^{0.18}} = \frac{6}{15120^{0.18}} = 1.06$$

$$Eu_{mix} = \frac{P}{d^5 \cdot n^3 \cdot \rho}$$

$$P = Eu_{mix} \cdot d^5 \cdot n^3 \cdot \rho = 1.06 \cdot (0.15\text{m})^5 \cdot \left(8\frac{1}{s}\right)^3 \cdot 1260\frac{kg}{m^3} = 52\text{W}$$

$$P_{gross} = \frac{P}{\text{transm.eff.} \cdot \cos\varphi} = \frac{52\text{W}}{0.75 \cdot 0.83} = 83.52\text{W}$$

What is the gross power consumption if the turning rate is 600 1/min ?

n’ = 600 1/min = 10 1/s

$$Re'_{mix} = \frac{d^2 \cdot n' \cdot \rho}{\eta} = \frac{(0.15\text{m})^2 \cdot 10\frac{1}{s} \cdot 1260\frac{kg}{m^3}}{1.5\cdot10^{-2}\,\text{Pas}} = 18900$$

$$Eu'_{k} = \frac{6}{Re'^{0.18}_{mix}} = \frac{6}{18900^{0.18}} = 1.02$$

$$Eu'_{mix} = \frac{P'}{d^5 \cdot n'^3 \cdot \rho}$$

$$P' = Eu'_{mix} \cdot d^5 \cdot n'^3 \cdot \rho = 1.02 \cdot (0.15\text{m})^5 \cdot \left(10\frac{1}{s}\right)^3 \cdot 1260\frac{kg}{m^3} = 97.55\text{W}$$

$$P'_{gross} = \frac{P'}{\text{transm.eff.} \cdot \cos\varphi} = \frac{97.55\,\text{W}}{0.75 \cdot 0.83} = 156.7\,\text{W}$$