9.10 Duty point and reduced speed of a centrifugal pump

A centrifugal pump with an impeller speed of 1200 rpm has the following characteristic:

Discharge Q, m^3s^{-1}	*0.000*	*0.002*	*0.004*	*0.006*	*0.008*	*0.010*
Head H, m	*40.0*	*39.5*	*38.0*	*35.0*	*30.0*	*20.0*

The pump is used to deliver a process liquid along a pipe of length 100 m and inside diameter 50 mm and discharges from the end of the pipe at atmospheric pressure at an elevation of 10 m above the open feed tank. Determine the duty point and the speed of the pump that would result in a reduction in flow of 25%. Assume a friction factor of 0.005 for the pipe and neglect entrance and exit losses.

Solution

The duty point is the maximum flowrate that the pump can achieve for a particular power demand and forms the intersection between the pump and system characteristic curve (a plot of discharge against head). The system characteristic is usually parabolic, since the frictional head loss is proportional to the square of the fluid flowrate. Applying the Bernoulli equation, the head to be developed by the pump is

$$H = \frac{v^2}{2g} + z_2 - z_1 + H_L$$

$$= \frac{v^2}{2g} + z_2 - z_1 + \frac{4fL}{d}\frac{v^2}{2g}$$

or in terms of flowrate

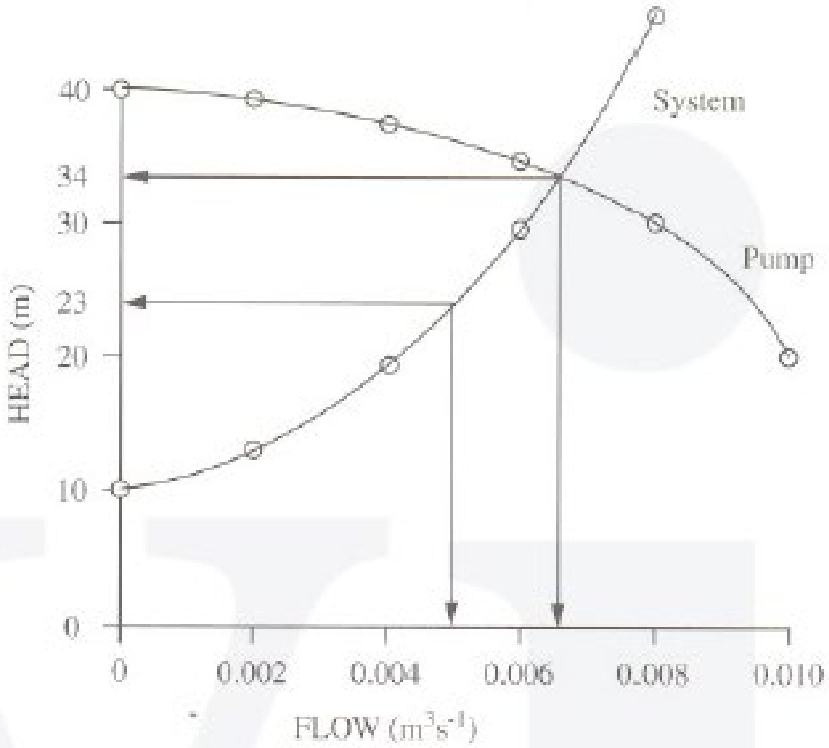
$$H = z_2 - z_1 + \frac{16Q^2}{2g\pi^2 d^4}\left(\frac{4fL}{d} + 1\right)$$

$$= 10 + \frac{8 \times Q^2}{g \times \pi^2 \times 0.05^4}\left(\frac{4 \times 0.005 \times 100}{0.05} + 1\right)$$

$$= 10 + 5.42 \times 10^5 Q^2$$

The pump and system characteristic are therefore

Discharge Q, m^3s^{-1}	0.000	0.002	0.004	0.006	0.008	0.010
Head (pump), m	40.0	39.5	38.0	35.0	30.0	20.0
Head (system), m	10.0	12.2	18.7	29.5	44.7	64.2



From the graph, the duty point corresponds to a flowrate of 0.0066 m^3s^{-1} and a head of 34 m. A 25% reduction in flow is therefore 0.00495 m^3s^{-1} with a head of 23 m. Since the head coefficient for the pump at the two speeds is

$$C_H = \frac{gH_1}{N_1^2D^2}$$

(see Problem 4.3, page 104)

$$= \frac{gH_2}{N_2^2D^2}$$

then the reduced speed is

$$N_2 = N_1\left(\frac{H_2}{H_1}\right)^{\frac{1}{2}}$$

$$= 1200 \times \left(\frac{23}{34}\right)^{\frac{1}{2}}$$

$$= 987 \text{ rpm}$$

The speed of the pump to reduce the flow by 25% is 987 rpm.