Fan Laws

The relationships of discharge Q , head H and Power P with the diameter D and rotational speed N of a centrifugal fan can easily be expressed from the dimensionless performance parameters determined from the principle of similarity of rotodynamic machines as described before . These relationships are known as Fan Laws described as follows

$$Q = K_q D^3 N \qquad (40.1)$$

$$H = \frac{K_h D^2 N^2 \rho}{g} \qquad (40.2)$$

$$P = \frac{K_p D^5 N^3 \rho}{g} \qquad (40.3)$$

where $K_q, K_h,$ and K_p are constants.

For the same fan, the dimensions get fixed and the laws are

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$$

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2 \text{ and } \frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3$$

For the different size and other conditions remaining same, the laws are

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^3, \ \frac{H_1}{H_2} = \left(\frac{D_1}{D_2}\right)^2 \text{ and } \frac{P_1}{P_2} = \left(\frac{D_1}{D_2}\right)^5 \qquad (40.4)$$

These relationships are known as the Fan-laws. The Fan-lows can be summarized as

For the same fan:

Discharge $\propto$ Speed

Head developed $\propto$ (Speed)^2

Power $\propto$ (Speed)^3

For the fans of different sizes:

Discharge $\propto$ (Diameter)^3

Head developed $\propto$ (Diameter)^2

Power $\propto$ (Diameter)^5

Performance of Fans

For all three cases (backward, radial and forward swept blades) in Figure 39.3, we can write

$$V_{w2} = U_2 - V_{f2} \cot \beta_2 \qquad (40.5)$$

The work done is given by Euler's equation (refer to Modue-1) as

$$W = U_2 V_{w2} - U_1 V_{w1} \qquad (40.6)$$

Noting that $V_{w1} = 0$ (zero whirl at the entry) we can write

$$\frac{\Delta p}{\rho} = U_2 V_{w2} = U_2 (U_2 - V_{f2} \cot \beta_2)$$

or,
$$\frac{\Delta p}{\rho} = U_2^2 - U_2 V_{f2} \cot \beta_2 \qquad (40.7)$$

The volume flow rate (assuming no density change between the inlet and outlet)

$$Q = \pi D_1 V_{f1} b_1 = \pi D_2 V_{f2} b_2$$

Thus

$$V_{f2} = \frac{Q}{\pi D_2 b_2}$$

By substitution in (40.7)

$$\frac{\Delta p}{\rho} = U_2^2 - (QU_2) \Big/ (\pi D_2 b_2) \cot \beta_2 \qquad (40.8)$$

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