AL - MUSTAQBAL UNIVERSITY COLLEGE
Iraq – Babylon

Refrigeration and Air conditioning Engineering.

3rd year – refrigeration and Air conditioning Course

Lecture -12-

Fans part2

Msc. Zahraa AL-Khafaji

3.4 Fan Characteristic:

The fan supplies energy to the air stream which replaces the energy lost due to friction. The energy supplied by the fan is measured in terms of pressure just as the energy lost due to friction is measured in terms of pressure loss. Fan sizing involves selecting a tail which will provide just enough pressure energy to produce the design air flow rate. Over-sizing the fan will inject more energy than necessary into the air stream resulting in excessive flow rate or the need to add additional resistance during balancing to absorb this energy. Energy is also wasted. The pressure produced by a fan depends upon the volume flow rate of air which in turn depends upon the resistance of the ductwork. So, in order to select a fan, the pressure/volume characteristic of both fan and ductwork needs to be known. Fan characteristics vary depending upon fan design, (centrifugal, axial etc); fan size and fan speed. This information is usually given in the form of data in graphs from the manufacturer.

The ductwork system characteristic follows a quadratic law:

$$\Delta p = R.Q^2 \qquad (3\text{-}8)$$

Where:

Δp: Pressure loss (kPa.)
R: Constant (is found from the calculated pressure loss at design flow rate (duct sizing)
Q: Volume flow rate (lit/s)
When system and fan curves are superimposed on one graph, as shown in Fig. 8., the fan performance with in the system can be found from the intersection of the two curves.

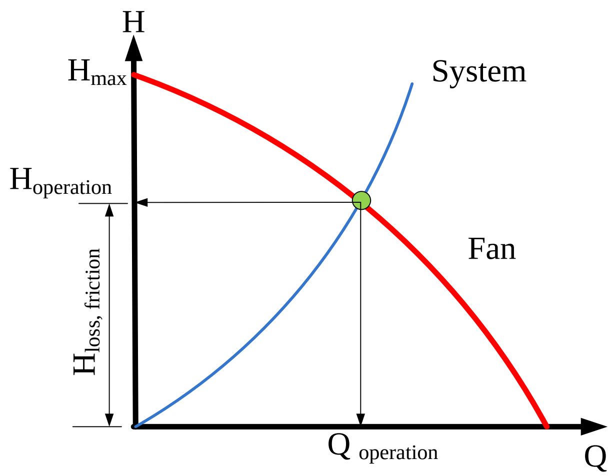


Fig. 7 Fan and system curve

Fan total pressure equals fan static pressure plus fan velocity, In theory, the tan total pressure is available but much of this can be lost at the fan exit (and entry) which will not have been allowed for in the duct sizing calculations. It is usual therefore to select the fan on fan static pressure rather than fan total pressure. Fan static pressure is the measured pressure difference between the fan inlet and the fan outlet.

$$P_s = P_t - P_v \qquad (3\text{-}9)$$

Where:

: Velocity pressure (Pa.)
: Total pressure (Pa)
: Static pressure (Pa.)

3.5 Dual fans:

Sometimes dual fans are used either in series or parallel. When comparing the fan characteristics of a single fan and dual fans in series (all identical) the pressure is doubled for a given volume flow rate.
When the system curve is plotted on the same graph the new operating point can be determined and compared with pressure that of a single fan as shown in Fig. 9.
The same applies with parallel fans where the volume flow rate is doubled for a given pressure. As shown in Fig. 10.

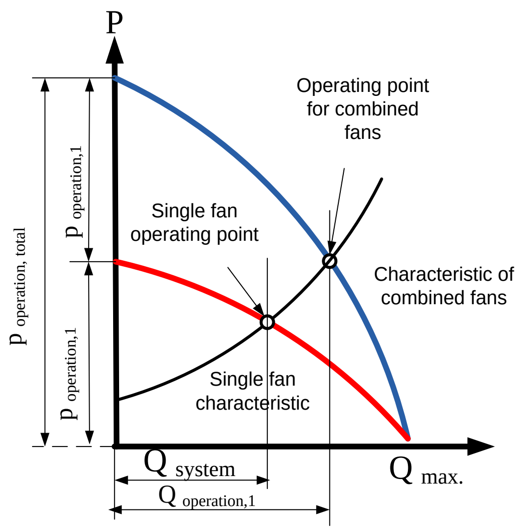


Fig. 9 two fans in series

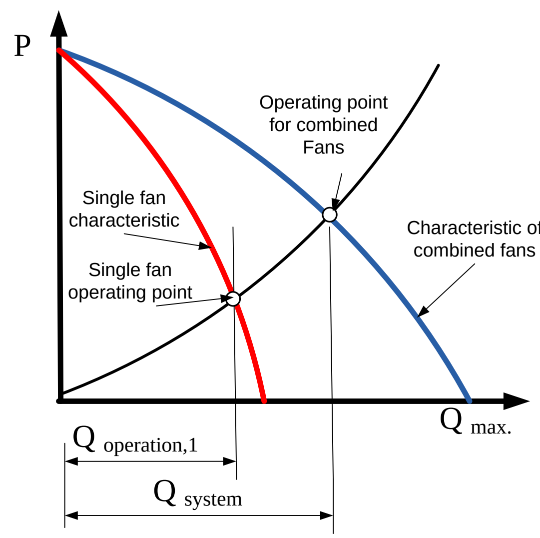


Fig. 10 two fan in parallel

3.6 Fan sizing:

Calculation procedure:

Step I. If not already available, calculate the ductwork index run pressure-drop and total system flow rate.

Step 2. Determine system equations for constant R. This can be done by substituting the Δp required and Q into the equation (4-8) and then solving for R.

Step 3. Select a tan that appears to operate within the required parameters and plot the system and fan characteristics on the same graph.

Step 4. Determine the operating point. Identify the operating pressure and flow rate.

Step 5. If there is a mismatch (for example the flow rate is too high), then either select another fan or change the fan output by either varying the speed (if necessary obtain new fan data and re-draw the graph) or restrict the flow by means of a damper.

Step 6. If a damper is required, calculate the pressure drop needed to achieve the system requirements.

Example 4

A system has a volume flow rate requirement of **2 lit/s** with an index run of 100 Pa. the fan speed is 15 rps. Find an appropriate fan. Pressure drop and volume flow rate are available in the units required. The fan characteristic is as shown in the table bellows:

ftp	197·5	190	177·5	160	137·5	110	77·5
Q	0·5	1	1·5	2	2·5	3	3·5

Step 2. The constant R in the system characteristic curve equation can be calculated as show below:

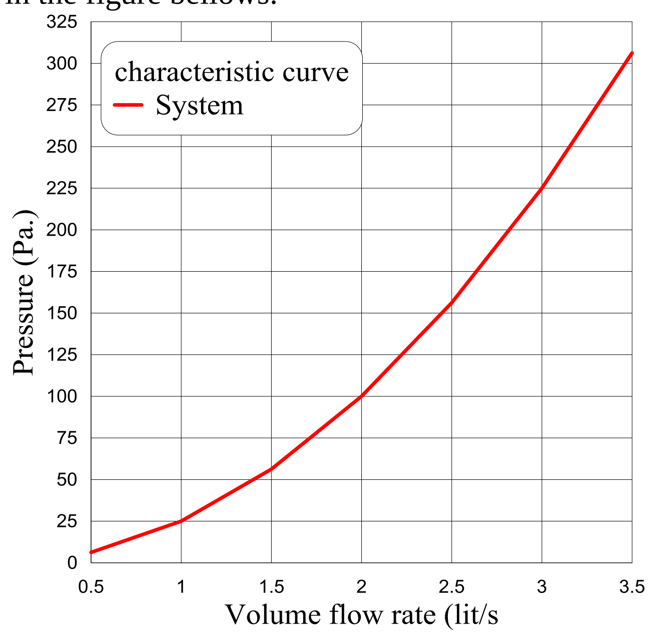
$$\Delta p = R.Q^2 \implies R = \frac{\Delta p}{Q^2} = \frac{100}{2^2} = 25$$

Rewrite the equation above as:

$$\Delta p = 25.Q^2$$

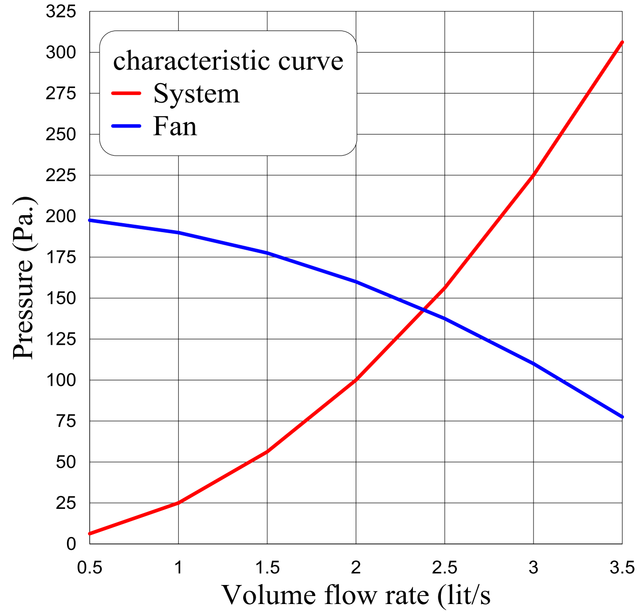
Draw the system characteristic curve as shown in the figure bellows:

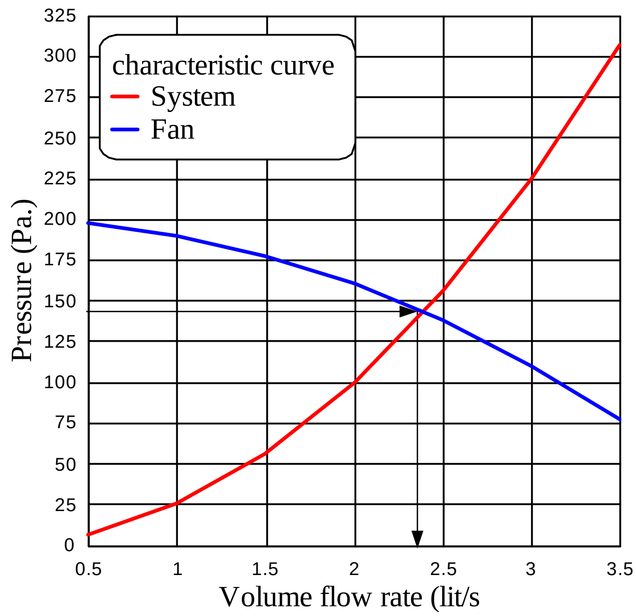
Q	$\Delta p = 25.Q^2$
0.5	6.25
1	25
1.5	56.25
2	100
2.5	156.25
3	225
3.5	306.25



Then draw the fan characteristic curve on the same graph, using manufacturer's catalogue, as shown bellows:

Q	Δp
0.5	197.5
1	190
1.5	177.5
2	160
2.5	137.5
3	110
3.5	77.5

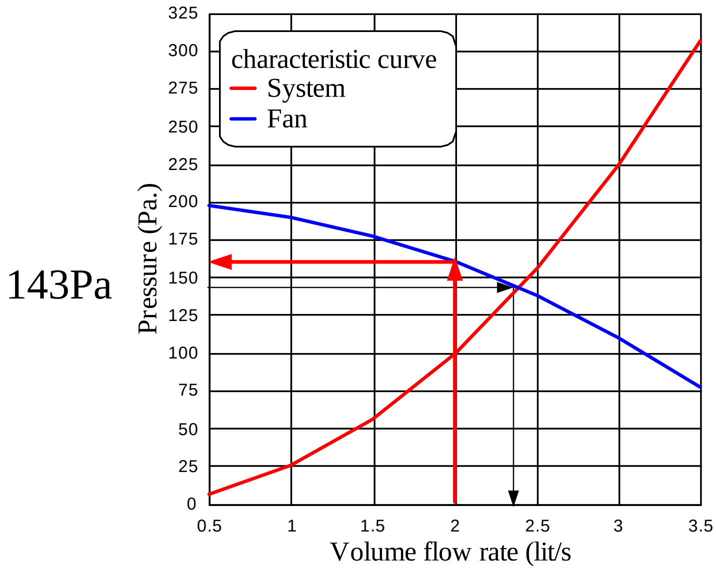




The operating point occurs when the two curves intersect, 2.39 lit/s, and 1 43 Pa.

As 2.39 lit/s is too high, the fan will need to be either slowed down or restricted in order to achieve the required flow rate. Alternatively, a different fan may give a closer value; this is worth considering when comparing the efficiency of different fans at different speeds and pressures.
If a damper were to be installed, what would the pressure drop be in order to achieve the requirements of the system?

Using 2 lit/s determine the Δp of the fan from the graph, Δp = 160 Pa > 100 Pa.



The fan is therefore developing more pressure than is required by the system. In order to match the fan to the system either the system characteristics must change (for example by adding a damper) or the fan characteristics must change (for example by changing the fan speed). The pressure drop required in the ducting is 100 Pa. Here a damper has been added therefore the pressure drop across the damper would need to be: 160 Pa - 100 Pa = 60 Pa The pressure drop required over the damper adds 60% to the system resistance that is effectively wasted energy ie the fan develops 160 Pa, 60 Pa of which are absorbed by the damper.
Alternatively the speed of the fan can be reduced to match the required volume flow rate.

$$\frac{Q_2}{Q_1} = \frac{rpm_2}{rpm_1} \quad (3\text{-}1)$$

$$rpm_2 = rpm_1 \frac{Q_2}{Q_1} = 15 \times \frac{2}{2.39} = 12.5\ rps$$

This can also be achieved by using equation (5-8) for example:

$$\frac{p_2}{p_1} = \left(\frac{rpm_2}{rpm_1}\right)^2 \quad (3\text{-}8)$$

$$rpm_2 = rpm_1.\left(\frac{p_2}{p_1}\right)^{0.5} = 15 \times \left(\frac{100}{143}\right)^{0.5} = 12.5\ rps$$

Design tip: Always review the pressure required if a damper is used to match fan and system and consider other approaches as required for example speed control, change of fan, or use of a variable speed fan etc.

Design tip: Using a damper to reduce the output is inefficient as it wastes fan energy. Varying the speed is preferred.