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Fans, Blowers, and Compressors

Problem 1

Boilers in a thermal power plant frequently work with forced draft/induced draft systems. A forced draft blower supplies air to the combustion zone, maintaining a higher pressure zone below the fire grates. An induced draft fan creates lower pressure zones, somewhere in the flue-gas path, near the chimney (after the combustion gases transfer the heat to boiler, then to the economizer, etc.).

Conduct a small survey to find the range of higher or lower pressures mentioned above. Also make an estimate of air requirement for the combustion, on the basis of unit output (say, per MWh) or unit input (per ton of coal burnt) so that the flow rate of air (expected duty of the fans/blowers) can be readily reckoned.

Check the parameters of any one fan/blower of the solved/unsolved problems of this chapter to match with a power plant of a specified capacity.

Solution: Coal is the fuel for a thermal power plant. There are varieties of coal, having their calorific values varying over a wide range. A common value of the calorific value of coal is about 4.65 MWh/ton of coal (4.65 kWh/kg of coal). A thumb rule is that, at 33% overall efficiency, $4.65 \times 0.33 = 1.53$ MW capacity of plant requires coal equal to about 1 ton/hour. In other words, a thermal power plant producing power at the rate of 1 MW consumes coal at the rate of 1000/1.53 or 653.6 kg/hour.

Thus, for a nominal 10 MW power plant, the coal consumption is 6536 kg/hour or 1.81 kg/s.

Further, on an average, about 7.1 kg of air is required for the combustion of 1 kg of coal. This indicates that a 10 MW plant requires air for combustion at the rate of $7.1 \times 1.81 = 13$ kg/s.

Now, the pressure required for the air supply depends on the following components of pressure:

(1) Pressure drop across the fuel bed on the grate;

(2) Pressure drop as the air (or combustion gas) flows across the equipment components;

(3) Pressure drop as the combustion gas flows in the duct and chimney;

(4) Pressure drop equivalent to velocity head.

The following factors influence the pressure drop:

(1) The fuel bed resistance depends on factors such as fuel size, bed thickness, rate of combustion, area of the grate and so on.

(2) The pressure drop of flue gas, as it flows across the different components, depends on the tube-bank layout of water tubes, super-heater tubes, economizer tubes, air pre-heater tubes, number of flow reversals, etc. Generally, these data are specified by the manufacturers for individual designs.

(3) The pressure drop in ducts and chimney also depends on individual design, height of chimney, etc.

(4) The pressure drop equivalent to velocity head is the usual $V_2/2g$ meters of air.

All the above components of pressure drops have to be added together to determine the total pressure drop, required to be designed.

Now, because there are too many factors affecting the pressure and flow rate of air required, one has to be really discrete in designing a blower. The same power plant may get different types of coal supply at different time intervals. A 30 MW plant cannot be said as a 10 MW plant multiplied thrice, when it comes to design. However, the above discussion is presented to stress the need of individual design. The data of all the fans and blowers of the present chapter are recorded in Table 8.1.

Table 8.1 Parameter values of equipments

Example or Problem	D_1 **(m)**	D_2 **(m)**	N **(rpm)**	$\frac{p_2}{p_1}$	Q **(m^3/s)**	$\dot{m}$ **(kg/s)**	W **(kJ/kg)**	P **kW**
8.1	0.3324	0.6648	12000	4	10	11.612	174.254	2023
8.2	0.3	0.6	10000	2.466	6.786	7.88	88.596	698.138
8.3	0.25	0.58	15000	4	5.3	6.156	187.67	1155.23
8.4	One stage of 12 stages			1.15		(1)	12.048	12.048
8.7	Axial flow	2.0(tip) 0.5(hub)	500	1.0022	30.9	37.41	0.155	6.443
8.8	AFC:	0.6	12000	3.47		20	98.721	2015

	mean							
1		0.6	6000	1.25		(1)	28.426	28.426
2		0.85	8000	2.5		(1)	112.661	112.661
3			580	1.02		3		44
4		0.9	7200	2.4		40	106	4240
5				2.5		1.1	125.831	136.8
6	Multistage			6		4.5		980.4
7	Multistage			6		(1)	240.48	240.48
8				1.7		10		579

From Table 8.1, it is seen that none of the blowers actually match the requirements of a 10 MW plant. The pressure drop required may be estimated at hardly about 1 m of water, which is equivalent to a pressure ratio of 1.1. The nearest one is the one stage of the axial flow fan, having 1.15 as the pressure ratio.

A blower of Problem 1 (of exercises) has a pressure ratio of 1.25. In this problem, if the width of blade at outlet is specified as additional data, B_2 = 0.0625 m, the flow rate works out as 11.2 m^3/s or 13 kg/s. The power of the blower, 28.426 kW/(kg/s) works out to 370 kW. This blower having 1.25 pressure ratio is one suitable blower for a 10 MW plant. This blower may be used as the forced-draft equipment without the need of any induced draft fans.

With necessary controls (such as damper control or speed control), this blower may be the best possible selection.

Theoretically, it is not absolutely correct to say that 20 MW plant requires 2 such blowers or 80 MW plant requires 8 such blowers. Each case has altogether different layout of equipment and other details. However, as a starting point, it can still be accepted as a solution.