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Comparison of Performance for Reciprocating and Centrifugal Compressors using Capacity Control methods

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Abstract: Compressors are vital components in refrigeration, air conditioning, and process industries, where they are used to compress and transport gases. Among the most widely used types are reciprocating compressors and centrifugal compressors. While reciprocating compressors are known for their high-pressure handling capabilities and suitability for small to medium capacities, centrifugal compressors are preferred for large flow rates and continuous operation. The choice between these compressors largely depends on efficiency, load adaptability, and operational economics.

Different methods such as suction valve control, and speed variation in reciprocating compressors, and inlet guide vanes, variable speed drives, or blow-off control in centrifugal compressors significantly affect efficiency, stability, and operating cost. A comparative analysis is necessary to determine the suitability of each compressor type under varying load and operational conditions.

Keywords: Capacity control, Reciprocating Compressors, centrifugal compressors, back pressure.

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I. Introduction

There are many refrigeration applications in which the refrigeration load is not constant. It is, therefore, necessary to provide some means to control the capacity of a compressor according to the load. It may be noted that the compressors operating under partial loads and low back pressure creates a condition where the coil may freeze or damage may result. Here we shall discuss some of the control systems used for reciprocating and centrifugal compressors.

II. Capacity Control for Reciprocating Compressors

Following are the various methods used for controlling the capacity of reciprocating compressors:

1.By using multi-speed motor

It is a simple and satisfactory method of controlling capacity of a compressor. The capacity of a compressor is proportional to the speed of the driving motor. When the suction pressure of the refrigeration system is high, the motor speed and the compressor capacity must be increased. Due to this reason, electric motors with two or more speeds are used. The variable speed motors find limited application because the motors and their controls are expensive to use on large installations.

2.By suction valve lift control

In multi-cylinder compressors, the capacity may be controlled by forcing the suction valve to remain open in one or more cylinders and making them ineffective according to the load on the system.

3. By using multiple compressors

The multiple compressors of the same capacity can be used to provide capacity control. The operation of all units will provide the maximum desired capacity and the operation of the various combinations of the units will permit efficient capacity reduction. When this system of capacity control is used, the units are usually installed with common suction and discharge headers.

4. By cylinder by-pass system

The cylinder by-pass method of controlling capacity is activated by either temperature or pressure controls. In this method, used with multi-cylinder compressors, one or more cylinders may be made ineffective by by-passing the gas from the cylinder discharge to the intake port. A solenoid valve with thermostat is used to operate the by-pass. A check valve is provided in the system in order to isolate the inactive cylinders from the active cylinders. In this method, the power does not decrease in proportion to the load on the system.

5. By hot gas by-pass system

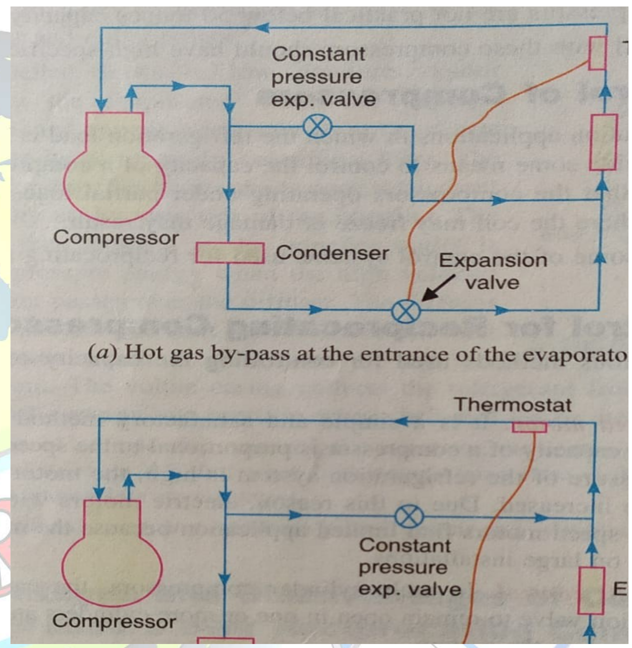

Figure 1 Hot gas by-pass system

The capacity of a reciprocating compressor can be controlled by putting an artificial load on it. This is done by passing the hot gas from the discharge side to the suction side through a constant pressure expansion valve, as shown in figure. When the evaporator pressure tends to fall, the hot gas by-pass will maintain the constant suction pressure. The hot gas by-pass to the entrance and exit of the evaporator is shown in figures (a) and (b) respectively. Since this is a method of loading and not unloading the compressor, therefore the brake power of the compressor remains constant irrespective of the load on the evaporator. Thus by employing the hot gas by-pass system, there is no saving of power. This method only prevents the evaporator surface from frosting up and avoids the working of compressor at excessive back pressure. When this system is used to

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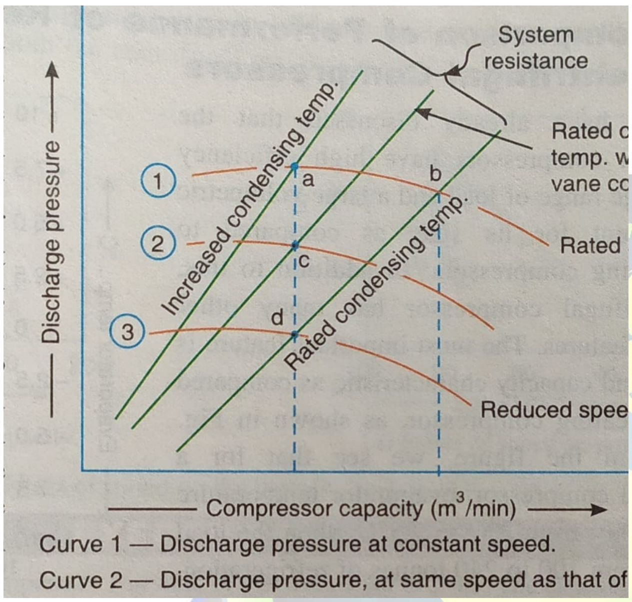
supplement another control system discussed above, a saving in power can be obtained.

III. CAPACITY CONTROL OF CENTRIFUGAL COMPRESSORS



The discharge pressure verses capacity relationship for a centrifugal compressor is very useful for capacity control. Generally, an impeller with backward curve blades is used because it gives a fairly flat pressure capacity characteristic. figure shows the graph between discharge pressure and capacity in m^3/min, for an impeller with backward curve blades, running at two different constant speeds. The graph also shows the different system resistances. It may be noted that the capacity of a centrifugal compressor can be reduced by increasing the system resistance. This may be done by using the following methods:

1.Condenser water control system

The capacity of a centrifugal compressor may be controlled by increasing the condensing pressure and temperature. This is done by reducing the quantity of condenser cooling water. It may be noted that when the cooling water passing through the condenser is reduced, the rate of condensate also reduces. This gives rise in condenser pressure and temperature, thereby forcing the compressor to self-adjust to the new part load capacity as shown by point a in figure.

2. Inlet Vane control system

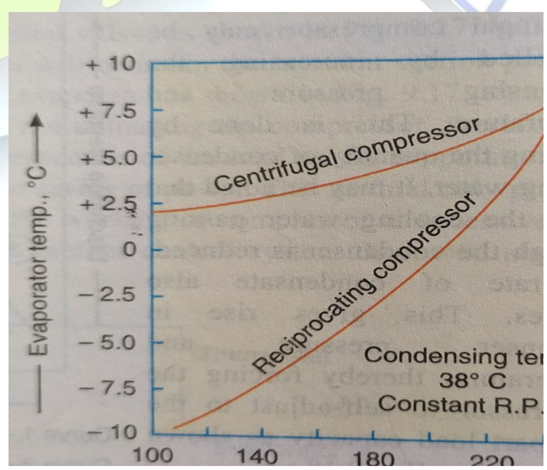
The capacity of a centrifugal compressor may be controlled by the inlet vane which throttles the flow at inlet and reduces the inlet pressure. The discharge pressure at the same speed of compressor gets reduced. The curve 2 in figure shows the performance with inlet vane control. Due to throttling at inlet, the system resistance increases at the same speed with the same condensing temperature as for the rated capacity shown by point b. The new operating point c will satisfy the part load requirement of the system.

3. Speed control system.

The capacity of a centrifugal compressor may be controlled by varying the speed of the compressor as the discharge pressure is function of the compressor speed. The variation in compressor speed changes system resistance due to the change in velocity of flow. The point d, as shown in figure, satisfies the part load requirements.

Out of all the three methods discussed above, the speed control system is most efficient but it is expensive. The inlet vane control system is cheaper and less efficient than speed control system. The condenser water control system is the cheapest among all the systems, but it is least efficient.

IV. COMPARISON OF PERFORMANCE OF RECIPROCATING AND CENTRIFUGAL COMPRESSORS



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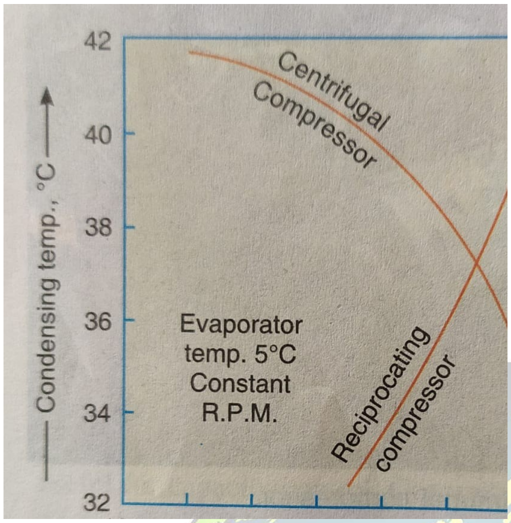

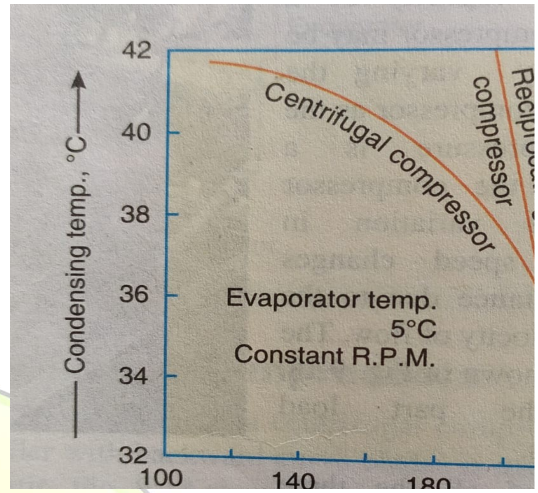

We have already discussed that the centrifugal compressors have high efficiency over a large range of load and a large volumetric displacement for its size, as compared to reciprocating compressors. In addition to this, the centrifugal compressor has many other desirable features. The most important feature is the flat-head capacity characteristic as compared to reciprocating compressor, as shown in figure. From the figure, we see that for a centrifugal compressor, evaporator temperature changes only from 2°C to 7.5°C when the load changes from 100 to 240 tonnes of refrigeration, whereas the evaporator temperature changes from-11°C to 6°C for the same load change for a reciprocating compressor.

Another advantageous feature of the centrifugal compressor is overloading characteristic, as shown in figure. We see from figure (a) that for a centrifugal compressor, there is a reduction in power requirement with the increase in condensing temperature. Also, there is a reduction in refrigerating capacity of the centrifugal compressor with the increase in condensing temperature as shown in figure (b). Hence there is no overloading of the motor as the condensing temperature increases. However, for reciprocating compressors, there is a small increase in power requirement with the increase in condensing temperature as shown in figure (a). Thus, there will be overloading of the motor. Also, there is a small decrease in refrigerating capacity of reciprocating compressor with the increase in condensing temperature shown in figure (b).

The effect of speed on the refrigerating capacity and power requirements is shown in figure (a) and (b) respectively for both the centrifugal and reciprocating compressors.

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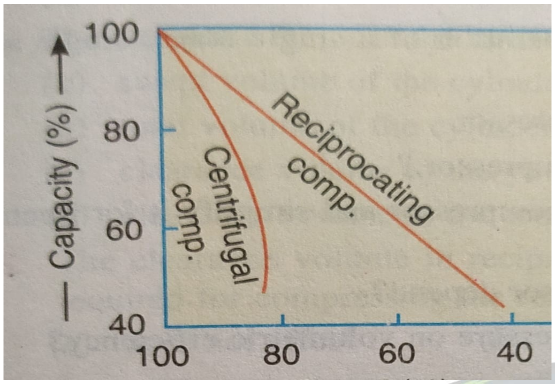

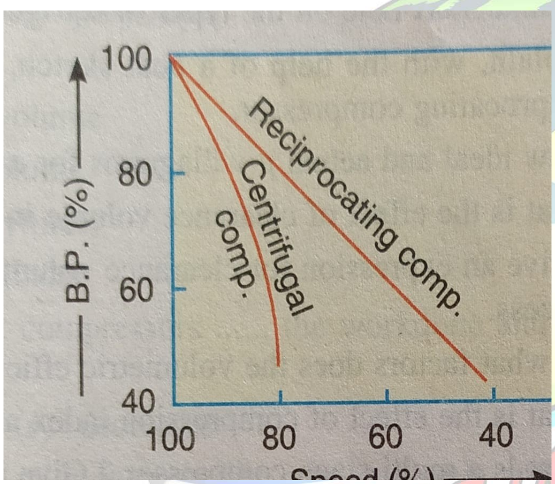

V. CONCLUSION

Centrifugal compressors are more efficient than reciprocating compressors over a wide load range and can handle larger volumetric displacements for their compact size. Hence, they are more suitable for applications requiring continuous, large-volume gas flow with consistent efficiency, while reciprocating compressors are preferred for smaller capacities and high-pressure requirements. By systematically comparing the performance of reciprocating and centrifugal compressors using capacity control methods, this study will contribute to better understanding and practical decision-making in compressor selection and operation.

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