Cooling Technology: Why and How utilized in Food Processing and allied Industries

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Lecture 47
ROTARY, POSITIVE DISPLACEMENT TYPE COMPRESSORS

Good afternoon my dear boys and girls and my friends. We are at the verge of end of this, no, this is, of course, compressor, but one compressor which, we have not finished that was screw type right. So, this we are calling rotary positive displacement type compressors, right rotary positive displacement type compressors. There are many compressors under this head right. In the beginning of compressor, we had said, there are many types of compressors, we gave more importance to this, to and fro, that is, our, not centrifugal, the other one, that was your, and positive displacement, of course, and this was to and fro normal compressors which, are used for most of the refrigeration systems, right. So, we have also completed the centrifugal type, right, that is rotary type centrifugal also we have completed.

Now, we are left with the rotary positive displacement type compressors, right. So, what we can say that, the first one could be rolling piston, or fixed vane type compressors, these are used in small refrigeration system around 2 kilowatt capacity, that is, less than a tonnage of refrigeration. If you remember, the relation between tonnage of refrigeration and kilowatt. So, one tonnage of refrigeration was somewhere 3.5 kilowatt. So, it is less than a tonnage of refrigeration capacity. Such as domestic refrigerators, or air conditioners, domestic, of course. These compressors belong to the class of positive displacement type, as compression is achieved by reducing the volume of the refrigerant. And, in this type of compressors, the rotating shaft of the roller, has its axis of rotation, that matches with the centre of the cylinder. So, we can say, or however, it is eccentric, with respect to the roller, right. I will show that in the next figure. And this eccentricity of the shaft, with respect to the roller, creates suction, and compression, of the refrigerant, that is, we are showing in the figure.

Let me show them the figure. The figure is like this, right. This is the working principle of rolling piston type compressors, right. As you see, from here that, the fixed vane is this, suction is happening through this, and this is the roller, and this is the cylindrical block. Once suction is over, then discharge valve is like that.

So, what is happening after this entry? This roll is moving like this, right. So, it is sucking and compressing, and then, discharging like this, which in subsequent, 1, 2 and 3 figures, we have shown, right. Everywhere, the outer casing, that remains same, here, here, here, everywhere, that remains same, but, an inlet also remains same, exit, also remains same, but what we have done this roller, that we have moved from this position, to this position, to this position, and you see, everywhere, though both are circle. So, circles are of point contact. So, it is taking away the suction like this, like this, and compressing, and then, it is going up to the outside vane, remaining in the same position, that is the fixed vane, right.

This is how this typical, yeah this is how this typical rolling piston type compressors work, right. A single vane or blade is positioned in the non-rotating cylindrical block. The rotating motion of the roller causes a reciprocating motion of the single vane, right. So, the other one, when I started, I was not able to remember that, memorize, what was that, positive displacement, and that was a reciprocating positive displacement type, right. However, as we have seen, from this figure, the working principle of the rolling piston type compressor, right.

Next, we show, as it was seen, in the figure previously shown, this type of compressor, does not require a suction valve, but require a discharge valve, because, suction, it is sucking, and the roller is, roller is controlling the sucking. Not only that, it is not, it is not getting away, right. The sealing between the high end low pressure sides, has to be provided, and for that, along the line of contact, between roller and cylinder block, it can be, or along the line of contact between vane and the roller, or it should not be, or and also between the roller and end plates. So, this can be provided. The leakage is controlled through hydrodynamic sealing and matching between the matching components, the effectiveness of the sealing depends on the clearance, compressor speed, surface finish and oil viscosity.

Closed tolerances and good surface finishing is required to minimize internal leakage. Then, unlike in reciprocating compressors, the small clearance volume, filled with high pressure refrigerant, does not expand, but simply mixes with the suction refrigerant in the suction space. As a result, the volumetric efficiency does not reduce drastically with increasing pressure ratio. Pressure ratio, earlier also, we have said, indicating small re-expansion losses. The compressor, runs smoothly and is relatively quiet as the refrigerant flow is continuous.

So, it is relatively quiet, unlike the reciprocating type, which has really, I mean, high noise. The mass flow rate of the refrigerant, through the compressor, that is, given by m dot equal to yeeta v into V dot s w over v e which is equal to yeeta v over v e into pi by 4 into N by 60 into A square minus B square into capital L. Then we must tell, what is what, because, so many nomenclatures, we have used, or not nomenclatures, so many, so many A, B, N, all these we have used. So, these characters must be explained. So, A is the inner diameter of the cylinder, B is the diameter of the roller, L is the length of the cylinder block, N is the rotation speed in rpm, and yeeta v is the volumetric efficiency, and v e is the specific volume of the refrigerant at suction, right.

$$\dot{m} = \eta_V \left(\frac{\dot{V}_{SW}}{v_e} \right) = \left(\frac{\eta_V}{v_e} \right) \left(\frac{\pi}{4} \right) \left(\frac{N}{60} \right) (A^2 - B^2) L \quad \ldots(1)$$

Where A = Inner diameter of the cylinder
B = Diameter of the roller
L = Length of the cylinder block
N = Rotation speed, RPM
η_V = Volumetric efficiency
v_e = specific volume of refrigerant at suction

So, this way we have found out, what is the volumetric efficiency through, or mass flow rate, knowing through the volumetric efficiency, safe volume, and v e right, volume of the refrigerant, v e, is the specific volume of the refrigerant at the suction end, right. So, this we have shown, yeeta v over v e into pi by 4 into N by 60 into A square minus B square into capital L. So, we have said A, B are the diameters, N, is the obviously, the rpm and yeeta v and v e, yeeta v is the volumetric efficiency, and v e is the specific volume of this refrigerant at the suction side, right. Then it comes, multiple vane type compressors, right. So, multiple vane type compressors, another type, so, this is as it is shown in the figure, like this, this is the multiple vane, ok.

And, you see, this is the suction, and this is the discharge, which was earlier also. Earlier, we had one vane, but here we have multiple vanes, right and we have, these are the sliding vanes, of course, and this is the cylinder block, and as the sliding vanes are moving, because this is moving to this, this is coming to this, this is coming to this, and this is going back to this. So, this way, when the roll is rolling, then, multiple vanes are, or these are called sliding vanes. They are working right. So, if you go back to, from the figure, to its description, that, in multiple vane type compressor, the axis of rotation coincides with the center of the roller, that is, as we have shown it to be like this, right. However, it is concentric with respect to the center of the cylinder, sorry, it is eccentric with the, with the, with respect to the center of the cylinder, and that is why, it is o prime.

The rotor consists of a number of slots, with sliding vanes, as it is shown here, right. This is o, as we have said, it is concentric, but eccentric with the cylinder, o prime, right. So, this we can say that, this is with respect to the multiple vanes, ok. Then, we come to, we come to that sectional view of a multiple vane rotary type compressor. Obviously, it has cooling water jacket as this one, right.

It has vanes, running position, like this, similarly, the suction and discharge are there, and there are some check valves, as in the discharge, which, we said earlier, and this is the casing, actually mounted on a base, and obviously, there are off center rotors. So, this is how the sectional view of a multiple vane rotary compressor works. So, working principle, we have said, next, this type of compressor does not require suction or discharge valves. However, that, as it is shown, in this figure, that, check valves are used on discharge side, to prevent reverse rotation during off time, right, due to pressure difference, and this is why that check valve is used. Since there are no discharge valves, the compressed refrigerant is opened to the discharge port, when, it has been compressed through a fixed volume ratio depending upon the geometry.

This implies that, these compressors have a fixed built-in volume ratio. The built-in volume ratio is defined as the ratio of a shell, as it is closed, off from the suction port to its volume, before it opens to the discharge port. Since, the volume ratio is fixed, the pressure ratio, that is, Rp, this pressure ratio as Rp, we have also talked about earlier right. This pressure ratio can be said to be equal to Pd over Ps and that is equal to Vb to the power k. Obviously, Pd and Ps are the discharge and suction pressures, and Vb is the built-in volume ratio, and k is the index of compression, right.

$$r_p = \left(\frac{P_d}{P_s}\right) = V_b^{\,k} \qquad \ldots(2)$$

where P_d and P_s are the discharge and suction pressures, V_b is the built-in volume ratio and k is the index of compression.

So, once, we know this, then, we can come to rotary screw compressors. Another type, where, the rotary screw compressors can be either twin screw, either twin screw type, or single screw type, right. Twin screw is more often used than single screw, because, better is its performance. So, twin screw compressors are like this. Twin screw type compressors consist of two matching helically grooved rotors, one male, and the other female. Generally, the male rotor drives the female rotor, the male rotor has lobes, while the female rotor has flutes, or gullies, right.

If we look at the picture, then, it becomes easier to understand that, this is the twin screw compressor with four male lobes, and six female gullies, right. So, six female gullies are 1, 2, 3, 4, 5 and 6, and 4 lobes of the male rotor is 1, 2, 3 and 4, right. It is made in such a way that, the female rotor gully will fit into the male rotor lobe, right. So, both are rotating. This is also rotating, this is also rotating, right. So, both are rotating in such a way that one lobe, when, in a gully of another rotor, then that is exactly fitting into as male female.

So, when it rotates, comes out, then, another lobe, that goes there, and the next, rather another, gully goes there, and the next lobe comes in, and fits into that. This is how is the principle of twin screw. Here, we have shown with four females, rather, four male, and six female, four male lobes, and six female gullies, right. This is direction of refrigerant flow in a twin screw compressor. As it is seen that, the suction is this way, you see, the lobes, this is the twin screw, discharges like that, and the lobes and the gullies are in such a way that, exactly, we are saying that, it is matching like male female, and there is no such leakage, right. Now, if we look at the lubrication, the lubrication and sealing between the rotors, is obtained by injecting some lubricating oil between the rotors.

The oil also helps in cooling the compressor. As a result, very high pressure ratios, up to 20 is to 1, are possible, without overheating the compressor. So, it is so high, that it, up to 20 is to 1, compression ratio, is possible without heating the compressor, right. Then, we come to single screw, because, twin screw, we are not having that much of time to tell. Detail analysis, because, this is the, perhaps, last class for the compressor, and the other part remaining is that single screw, right. So, when we are coming to single screw, as the name, it applies, single screw compressors, consist of a single helical screw. So, helical screw, just like before, we have shown, right, just like before we have shown, helical screw, these are helical screws, right.

So, but here, it is a single helical screw, right. So, it consists of a single helical screw compressor, that is, single helical screw and two planet wheels, or gate rotors, are involved in it, right. So, if we look at the working principle of a single screw, then we see, like the suction, this is the screw, that single screw is like this. So, and this is the discharge, and these are, as we said helical screws, only the section, we have shown, and these are gate motors, right. This one, this one,right. So, in principle, it is a single screw with the gate motors ok.

And, if we look at the, of course, we have only couple of minutes left. So, if we are skipping that, how the only, we have shown, the principle through the photo, through the, through the schematic diagram, but some other types like scroll compressors, right, scroll compressors are also there, under this heading, and there is a suction, there is a compression, and there is discharge, all three are there, it also has detailed analysis. So, this is the working principle of a scroll compressor, it also has detailed analysis, but, due to the shortage of time, we are not going into detail of it, right. Repeatedly, I have said that, we have given more strength or more emphasis on the to and fro, that is used in most of the refrigeration system, right. So, if we look at, no, perhaps we have come to the end of the class because time is, I am observing, is over, but, before I thank you, I request you, the detail of which, we could not cover up for the twin screw, if you can, if you are wishing, right.

So, if you are wishing, you can go through any standard book, or as we said ASHRAE handbook ASHRAE again I am writing that this is ASHRAE handbook, where, you will also get all the things in detail, right, or any standard book of refrigeration. I told also, my teacher, professor R. C. Arora, he also has a book, and if you can go through in detail, obviously, we could not cover the part, which you can go through them, right. So, with this, I really thank you, and next time,, we shall go to the application side, right.

Now, we shall go to condenser, first, sorry, this parts are not over, only compressor is over, condenser, then expansion device, and evaporator. So, after that, our refrigeration part is over. We will go to the 2 class 2 weeks for its application right. Thank you.