Principle of Hydraulic Machines and System Design

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Lecture – 14
Pumps Operation: Series and Parallel, Problems – II

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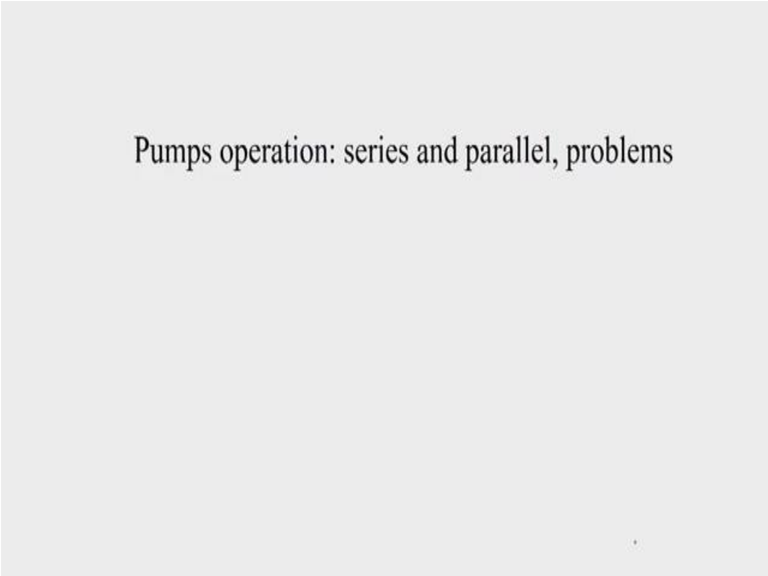

We will continue our discussions on Principle of Hydraulic Machines and System Design. Today we will discuss about, Pumps Operation that is Series and Parallel connection of the pumps and will work out one or two problems, which are related to the, you know, theories that you have discussed in my previous lectures. So now, sometimes we need to go for series and parallel operation of pumps, why we need to go for series and parallel operation? It is very important we need to know, in particular there are many industries, where there is a pump house sometimes. Whenever and you know pump house may be one or two pumps are walking and in a standard on mode or they are walking together. There might be a situation when one or you know, one pump is not able to cater or is not able to meet the demand of the system and then we need to go for an installation of another pump, that pump may be similar to the pump, which is there in the pumping station or sometimes you have different kind of pump, but we need to you know, connect those pumps either in series or parallel.

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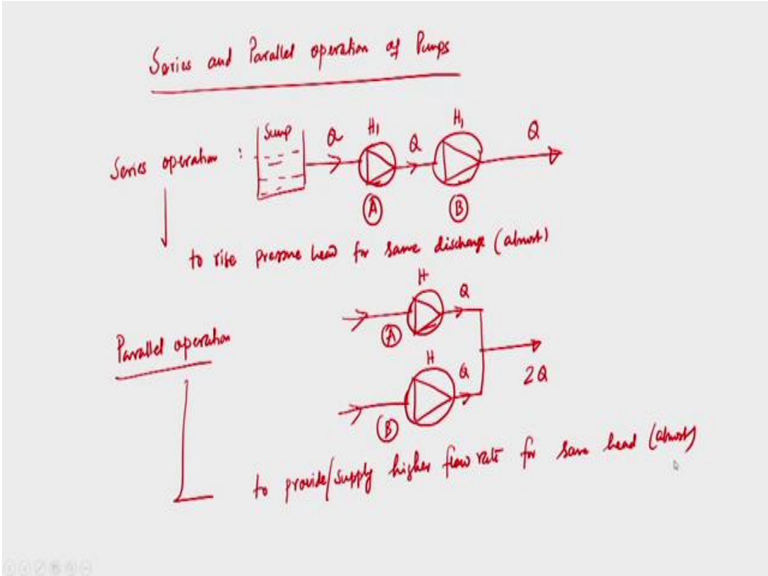

So, we need to know the series and parallel operation of the pump. So series and parallel operation of the pump, this is very important operation of pumps, because we need to know, when we need to go for series and parallel operation and even we go for a series and parallel operation. If, we need to connect two similar pumps in series or two similar pumps in a parallel then, what would be the head or discharge characteristics or sometimes. As I said that, we may need to install another pump with the existing pump house of the existing pump where the new pump is not, new pump is different that different from the existing pump. In that case, if we connect two dissimilar pumps in series or parallel, then what would be that head discharge characteristics that we need to know.

So, before I discuss about the pump characteristics, when a single pump is operating or if two similar pumps are connecting in series or parallel. I will now, briefly discuss about, why when, why and when, we need to go for this kind of operation. So, series is series operation of a pump, this is very important. Series operation of a pump, I will discuss systematically series operation of a pump; series operations. Whenever may be as I said, that there are two important characteristic of pump one is head another is discharge. So, whenever we are installing a pump in a pumping station, either radial flow pump or axial flow pump, normally axial flow pumps are used in a place, where we require low head and high discharge.

Otherwise generally, you go for radial flow pump, where you need you know relatively, you know moderate to high head and discharge is low. So but, sometimes it might happens that we need to have relatively higher discharge from the same pumping station then, what should we do? Or sometimes it may require that, we need higher discharge from the same pumping station. So, it is always advisable to use the same pumping station in a industries, it is always advisable to use same pumping stations, instead of to go for a new pumping stations. Because there might be a space constant or if we go for a new pumping station again, we need to employ another operator and that is again costly. So, it is always advisable to use the existing pump house, if we can connect another pump, may be similar to the pump, which is there or dissimilar pump either in series or parallel mode. So, series operation is required, when you need to go for, I mean may be discharge is remaining almost same, but we need to go for a higher head.

So, for the same pumping station may be the head developed by the pump is not able to meet the demand or meet the system demand then, we need to connect two pumps in series, essentially to raise the pressure. So, if we connect two pumps in series, I am drawing the schematic, suppose one pump is drawing water and this pump is you know discharging let us say, Q amount of water, Q meter cube per second and output rather delivery from one pump is again taken to the inlet of another pump. This pump may be similar to the previous pump or may not be similar to the previous pump.

And then we eventually, get the final discharge. So, may be this is sump and from this sump this sump or this reservoir, pump A is, you know drawing water and that water is again fed, is fed in to the you know and pump B and then ultimately, we get the you know Q amount of water, this is Q and finally, we get that same product, but with relatively higher to meet the system demand.

So, suppose if H 1 is the head developed by the pump A and H 2 or let us say, H 1, I do not know, whether the pump B will be similar to the pump A or may not be similar to the pump A. So, if another suppose. If, I consider pump B is similar to pump A and then again, pump B will try to rise H 1 head, then ultimately, we will get H 1 plus H 1, that is we will have connecting series. So, head will be developed. So, series of operation is done essentially, to rise to rise pressure head, to rise pressure head for almost same discharge; for almost same discharge.

We will see the discharge will be changed for same discharge is am writing almost, I am writing the word almost, because we will see that the discharge will change, I mean what fraction it will change, that will see the discharge will be relatively higher, I mean, why it is going to be higher that will discuss. So, the objective of having series operation of a pump is to essentially, develop higher head for a same discharge and whenever either two similar pumps are working or two dissimilar pumps are working.

Whenever two dissimilar pumps are working then, connection is little bit you know complex, but when two similar pumps are working, then these are very, I mean not very problematic, but when you go for parallel operation sometimes, you need to go for parallel operation may be as I said, you that radial flow pump, radial flow pump are normally used for moderate to high discharge, but relatively low heads, low discharge moderate to high head and low discharge. So, whenever relatively radial flow pumps are installed, it always provides moderate to high head and low discharge. But may be after sometimes because of new units in a industries, because of other purposes we need to have higher flow rate from the same pumping station. So, then again, we go for parallel operation, that is we in parallel operations. Suppose, we are having one pump, which is drawing water from the sump and from the same sump again, we are connecting another pump in parallel mode, this pumps and these pumps are again connected at delivery at the delivery point and it discharge.

So, this is this pump is providing Q, this pump is also providing Q amount of discharge. So, we may get 2 Q head, let us say remaining h. So, for pump A and for pump B, now pump A and pump B, may not be equal to pump A and pump B. Pump A and pump B may not be the same or may be different. So, when pump B is different from pump A then, we need to go for parallel operation, but in that case, our you know connection will be relatively you know complex.

So, now whenever we go for parallel operation then, what will be the head discharge characteristics that we need to know and that is what will discuss slowly. Now question is if we go for; that means, both the pumps are drawing water from the same reservoir and both the pumps are discharging Q amount and ultimately, at the delivery we are getting 2 Q amount, against the head of H. So, this is very important. So, we need to while you go for parallel operation that is to provide or to supply, to provide or supply, higher flow rate, higher flow rate for same head. Again I am writing for same head almost, but head will be changed.

So, that will see from, the scheme from the H cube characteristics that, if we go for series and parallel operation objectives are different. That is in series operation, we need to go for higher head at a given or constant discharge, but discharge might change that will see. While for parallel operation, we need to go for a relatively higher discharge at a same head, but same head will be changed ok. So, these are the objectives and will now discuss, if we connect two pumps two similar pumps in series mode or two dissimilar pumps in series mode then, what will be the discharge characteristics? Ok. So, let us first discuss about the series operation of two similar pumps then, what will be the head discharge characteristics.

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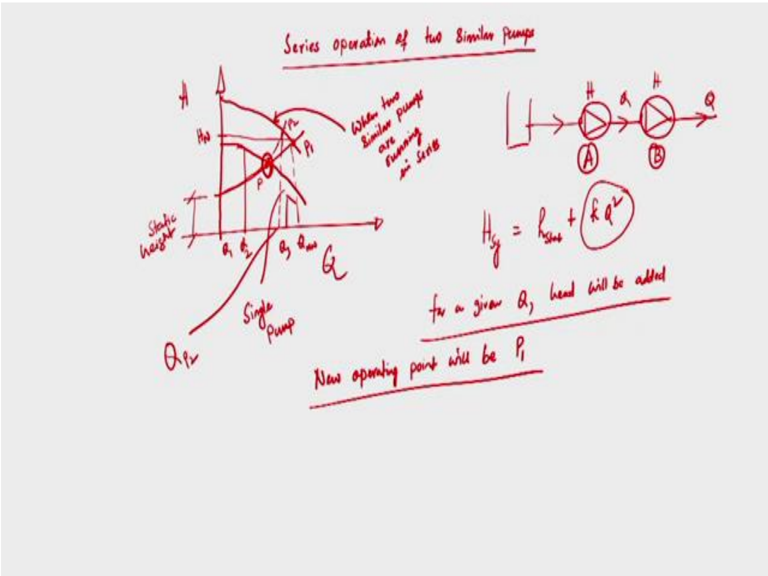

So I am writing that series operation of two similar pumps. So, series of operation of two similar pumps, as I said you that series operation two similar pumps, objective is to provide higher head. Suppose if I draw, the H cube characteristics as I said that are two pumps.

So, this is H and this is Q. So, we are having one pump, let us say, A and we are having another pump, this is B so, this is Q, this is Q, this is I mean this is drawing water from a reservoir. So, this is pump A and this is pump B. So, whenever pump A is drawing water from a reservoir and it is supplying or it is supplying that amount of water in the suction side of another pump B and eventually, you are getting high head. So, may be the two similar pumps so, head developed by both the pumps by H. So, if I draw the draw, the H

Q characteristics for a single pump. Let us say H Q characteristics for a single pump is like this so whenever, this is for a single pump, this is for a single pump. So, this is for a single pump.

Now there will be a system resistance. So, may be this pump in station is supplying water or in different places whereas, I know that the total system resistance, that is total H system= H_{static} + k Q^2. So, total frictional loss into Q square. So, if I draw the system resistance curve, we will get like this. So, this is the static height, this is the static height and this is, this is the dynamic this parabolic shape is for the dynamic, you know resistance and this is the operating point. Let us say, this operating point is P. Now, how to construct, how we can construct when two similar pumps are operating in series? As I said you the objective is to get higher head for a given discharge. So, discharge will remain same that is our, you know that is the key point.

So, suppose single pump now if I draw the, you know H cube curve, when two similar pumps are walking in series then for a given. So, drawing of the H Q curve for two similar pumps is for a given Q, for a given Q head will be added for a given Q, head will be added, for a given Q, head will be added.

So, now for a given Q if I add the head then probably, I may get a system, I may get the curve like this. I have a curve like this. So, when this is the curve, when so; that means, if I get let us say, this is the Q 1, this is Q 2, this is Q 3, just for a given Q, I have added up the H. So, this again schematic, this is not there for the scale, but the objective, but the procedure is two for the given Q, just we are adding the head. So this is, when two similar pumps are running in series.

So, this is the H cube curve, when two similar pumps are running a series. Now, note that here as I said you, the objective is to obtain higher head, but the discharge remains same, but this is not the case that I will discuss now. Now see here the system resistance curve cross, the new H Q curve at this point. Let us say, if you see it is P 1. So, new operating point, new operating point will be P 1. So, new operating point will be P 1. So, if I now obtain the head or you know discharge corresponding to that point P 1, we can see fine I have obtained higher head, maybe I have obtained higher head, I have obtained higher head. Let us say, this is the new, H new and this is the Q new. So, note that fine for a given Q, I have obtained the higher head, but not only that now the new Q is getting increased.

So, the Q, not Q will not remain same, but there will be a little increment of Q, why now question is Q should not be increased that much, because whenever two pumps are running the system resistance curve is like this and new operating point is P 1. So, this is true that ok. Because now, suppose one person is, if I give an example suppose, one person is you know, you know pulling some amount of you know mass. Now, if that mass is you know another and one person is pulling some amount of mass, if two persons pulling the mass again, the amount of mass that will be pulled by two persons will be higher.

So, similar to that here whenever one pump is drawing water from the reservoir, that pump will draw Q amount for a given head, but when two pumps are drawing water from reservoir, there will be little amount of increment of water, that is true. Now question is whenever there will be an increment of water that is it, it is deliberately getting high discharge, either is if we recall that the total resistance system curve is having two parts, one is the static part another is the dynamic friction, that depends upon Q square. So, whenever there will be an little increment of Q, because of the two pumps are drawing water from the same reservoir. So, as Q increases, the system resistance curve will be stiffer. So, although this is the new system, this is the system resistor, this is my new system resistance to relatively much stiffer and in that case, our operating point will be shifting towards. Let us say, this is P 2 and will get another head and this point will be new Q, this is Q corresponding to P 2.

So, our initial point, where you obtain the head and discharge was at, you know corresponding to point P, you know corresponding to point P. Now what we are obtaining, whenever we are having two pumps in series initially, operating point is P 1, but as I said, whenever two pumps are drawing water, Q will be higher as Q increases, frictional loss or dynamic loss will increase which will make the system resistance stiffer and it will have it will now, eh give us a new operating point P 2. So, the head and discharge corresponding, to the point P 2 will be the actual and here still we can see, that head will be relatively higher, that is what our objective is, but there will be a little increment of Q. That is why, we obtain, so that is why, I wrote that Q will remain almost same, it would not be same, there will be a little increment of Q, but the head will be increased.

So, this is all about the when twos, you know pumps are similar pumps are connected in series. We will discuss later that, when two dissimilar pumps are connected in series.

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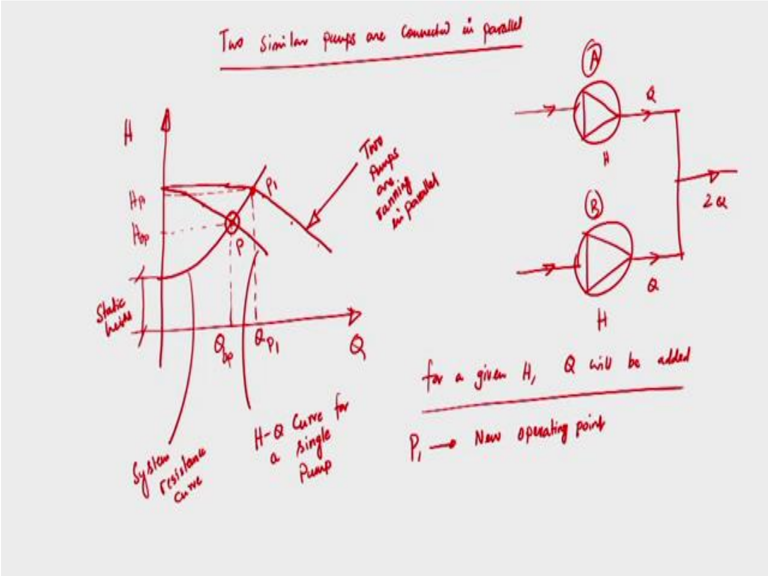

So, with this again we go for when two pumps, two similar pumps are connected in parallel. So, now two similar pumps, again am talking about radial flow pumps so, two similar pumps are connected in parallel. So, when two similar pumps are connected in parallel beginning, at the beginning, I said the objective of having parallel operation is to have higher discharge at a same head; again will see that head may not be remain same, but will see from the graph. So suppose, if I draw the schematic suppose, one pump is drawing water from a reservoir. Let us say, this pump is A and another pump is also drawing water from the same reservoir and they are connected, they are discharging to the same delivery line and eventually, you are getting two Q.

So, this is twice Q. So, head developed by pump, both the pumps are same supposed, pump A and pump B. So, head developed by both the pumps are same these are two similar pumps. So, if I now, draw the H Q curve for a single pump. So if I draw, the H Q curve, for the single pump. So, this is Q, this is H. So suppose, this is, the H Q curve for a single pump. So, this is H Q curve for a single pump and again these pumps are installed in a station. So, of course, there will be system resistance. So, if I assume, this is the static height. So this is static height, that pump needs to raise or overcome and also, there will be dynamic loss that is the, this is the point. So, this is system resistance curve, so, this is system resistance curve. Now our operating point is this point. So, this is our operating point let us say, P and the discharge and head corresponding to this operating point is our H operating and Q operating.

So, this is point P. So, the head and discharge corresponding to this operating points H operating and Q operating at the head and discharge that, we obtain if a particular pump is running in the in that system. Now if, we connect another sim, another pump, which is similar to the previous pump in parallel then how can, we construct the H Q curve. So here as, I said that H will remain same, but only the Q will be added so for the you know, keys for a given H, Q will be added, for a given H, Q will be added. So if I draw let us say, this is H, H 1, this is H 2, this is H 3. So, corresponding to this Q phi add, maybe I will get, this one, I will get this one, I will get this one and I will get this one. So our, you know shut off head will remain same will get like this. So, here this is the curve, where two pumps are running in parallel.

Note that, here shut off H will remain same, because both the pumps are having same characteristics, so I mean, here if you add Q is 0. So, if you add 0 plus 0 so, it will remain 0, so shut off head will remain same, but if I go back to my previous slide where you can see that even at the shut off head, if you add the head, when discharge is 0 and then if you had shut off head add the shut off head then it will increase, that is your here curve look like this. So, here, when two pumps are running in parallel then again, I get this curve, now question is here we see that, our new operating point is P 1. So, P 1 is our new operating point.

So, the discharge and head corresponding to new operating point is of final discharge and final head that, we are going to have. So, if we now take the discharge and head corresponding to this P1, so HP1 and QP1, so now, QP1 is the actual discharge that we are going to have, whenever two pumps are running in parallel and because system resistance will remain same somehow.

So, we are not going to add any kind of more system resistance will be high, because as probably for the new pump, we need to install new valve, new vents all those things. So, system resistance will be little bit changed, but if we consider the same system resistance then probably, we will get this Q P 1 and corresponding head. Note that, our objective was to obtain a higher flow rate at a same head, but if you, if you look at this diagram probably, we can see ok. Fine, we are in we are getting higher Q, but H is also getting increased.

So as I said, you that H will remain almost same, that is almost because there will be a little increment of H, that is quite obvious. Because you know, two pumps are giving you know flow rate. So the you know, head that will develop by both pumps will be not added here exactly, but still there will be increment on the you know head. So, this is the operation. So, what is a conclusion that, whenever two similar pumps are running in parallel, we are getting higher discharge that is true, but H is no longer remains same, there will be a little increment of H also and because since two pumps are running. So, may be two pumps are giving, providing discharge and so there will be, little increment of it. Now will go, we will go to see, what will be the H Q characteristics, when two pumps are running in series and parallel, but they are not similar.

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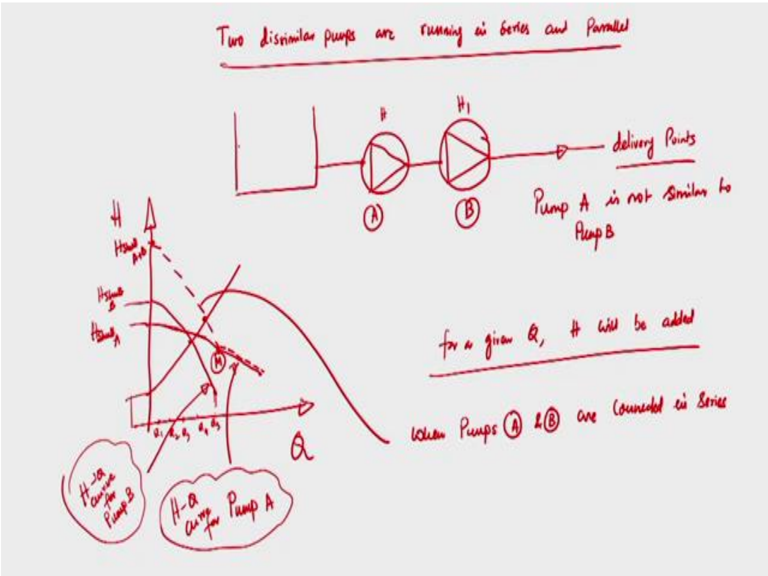

So, we will go to our next slide and we will discuss this very important than you know, when two similar, two dissimilar pumps are you know running in series and parallel. So, two dissimilar pump pumps, are running in series and parallel, this very important. Before I go to construct the H Q curve, let me tell you one important thing, I am telling from my own experience although, I have a very tiny experience because, I was there in industry for over a very small period. So, from there, I have seen that, it is very difficult to have similar pumps. So, may be in an industry, whenever an industry was you know when pumping was you know developed or built that time, may be some radial flow pumps are installed over there to caterer to meet the cater water in the industry different parts of the industry, different places of the industry.

May be after 10 years or 15 years down the line, if that industry requires relatively higher head or higher flow rate, then of course, it is common practiced that the industry people will try to use the same pump house, if space is there. Because of two reasons, one reason that I said you that one may be the space constant. Other is, having another pump house; again very you know there are two different costs one is running cost another is the, one time you know constructional cost. So, whenever we need to go for another pump house construction cost is there not only that, if we have another pump house then again, we need to employ another new operator. Because one operator cannot be you know, cannot handle you know, operation in two different pump houses, so that is the running cost. So, it is always advisable rather, it is always suggested that, we should need to go for installation of another pump in the same pump house.

Unfortunately, if the pump which was installed may be 20 years back, 10 years back, that was having characteristics, but now because of you know, long after long period, if we do not get the same characteristics, same H Q curve of the pump then, we need to have another pump.

So, if we have another pump, which is not matching with the existing pump, then of course, we have to have some solution, because we need to install with the same pump house as demanded by industry people. So in that case, we need to go for installation of a dissimilar pump with the similar pumps, and for that what will be the H Q characteristics, that we need to know, this is very important and this is very common. Because having two similar pumps, whenever we are installing a particular pump, if we install initially to similar pumps in series or parallel that is fine, but after 10 years, 20 years down the line series, it is difficult to have similar pumps, it is a difficult to procure similar pumps.

Because the you know pump supply may not supply that same pumps. So we need to go for different pumps, which we need to install, we need to connect with the existing pump (Refer Time: 28:55) either in series or parallel, depending upon the requirement. So, when we install a dissimilar pump either in series or parallel, then what will be the H Q characteristics? That we need to know, that is very important for the industrial applications. So suppose, I am drawing again a schematic, say one reservoir is there and one pump is drawing water from here.

Let us say, pump A. So, this is pump A and this pump is now connected with another pump in series. Now, this pump, this existing pump let us say A and it is, let us say developing head H. Now we are going to install another pump, let us say B in series, where head developed by the pump will be H 1 and Q might be different, but we have to supply the water in the delivery points. So, this is the case, when pump A is not similar to pump B. So, when pump A is not similar to pump B, but still we need to go for series operation then, what will be the H Q curve?

So, if I now draw let us say, we are drawing H Q curve. So, this is H and this is Q. So suppose I have a pump, let us say pump is this is let us say pump A. H Q curve for pump A and if we have another pump say, if we have another pump may be like this and this is H Q curve for pump B. So, we have H Q curve for pump A and we have H Q curve of pump B which are not same, but as I said you that it is quite common that we have to accept it that we have installed one pump 20 years back and probably that pump manufacturer. When he pumps up, when the pump manufacturer supplied that pump, the pump manufacturer itself is not existing now.

So, we have to now procure another pump probably, we can provide data to the new manufacturer, but that pump manufacturer may not be able to make or design a pump, similar to what that is there in the existing pump house. So, eventually you have to have another new pump, but still we need to connect this pump, eh these two pumps in series. So, this is the H Q curve for pump B and this is the H Q curve for pump A. This is for pump A and this is for pump B. So, if now you would like to connect these two pumps in series. So, the key points will remain same that is what is the key point where when we connect two pumps in series. That means, for a given Q, for a given Q, H Q will be added. So, for a given Q, H will be added.

Now see if we connect this, two pumps in series of course so, whenever Q is 0. So, we need to add the shut off head. So, suppose if we add the shut off head for these two pumps, will get shut off head here. So, this is the new shut off head. So, this is H shut off, H shut off for pump A. And this is H shut off for pump B, if we connect this two pumps in series probably we have, I get a new shut off H shut off, when two pumps are connected in series that is A plus B.

So, now if you would like to for a given Q; let us say, for if we divide Q 1, let us say, Q 1, Q 2, Q 3, Q 4. So Q 1, Q 2, Q 3, Q 4 like this then, if we add up the head then, what will get mind it that up to this; we can add the Q. So, this is the last, let us say Q 5. So I will get up to this so this is the Q this is the Q. So, up to this here Q is Q 5 and this Q. So, I will get a curve like this, but after that it will follow after that it will follow the characteristics of the pump B. So this is the curve, when pump, pumps A and B are connected in series. Why it will be like this? So as I said you, up to Q 5, we have just added, but here Q 5 is whatever amount of Q 5, if we add this, but after that no Q.

So, it has to follow the same, you know profile for pump A. So, up to this point, we are having the profile just we are adding the Q. So may be, I mean for a given Q adding H. So, here Q is this one and if we add, so here, H is this much and here H is this much. So, we just adding this H, after that I mean for a given Q, no I mean this; pump B is having no, no head development. So, you know combined operating characteristics, the combined curve will follow the profile of pump A, after this critical point. Let us say, this point is M, because after this point, pump B is not in a position to deliver any Q. So, how you can add the H, so this will be the pump, when two pump similar, dissimilar pumps are connected in series. So, if we have let us say, system resistance like this so I mean if we are system resistance is like this then, probably will get the operating point here.

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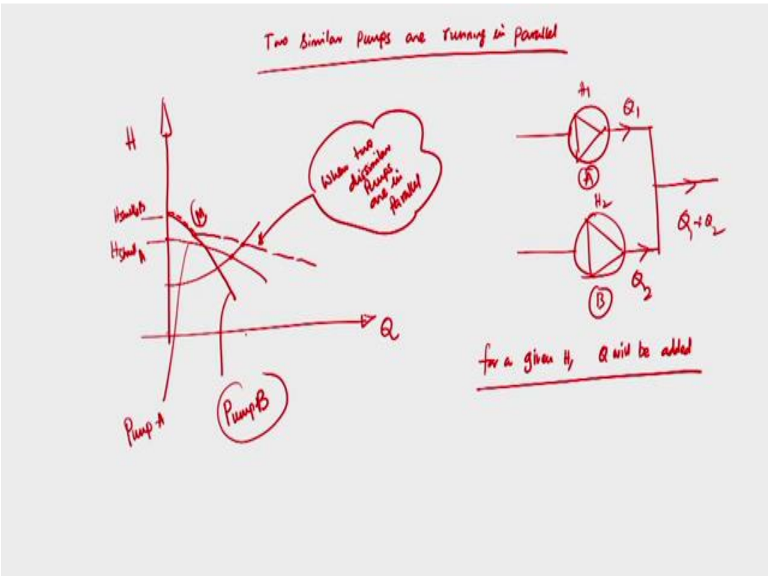

So, when one pump was here we are having now the operating point definitely you may get higher head ok.

So, now will discuss, when two you know dissimilar pumps are running in parallel. So, when two dissimilar pumps are running in parallel, this very important again. So I need to draw for schematic, before if I go to draw the H Q curve. So, as I said you suppose this pump A and we are having another pump B, both are connected in parallel. So, this is drawing Q, this is drawing Q 1, this is Q 2 and ultimately will get, Q 1 plus Q 2, but may be this is pump A, this is pump B, but they are different H 1. Let us say, this is H 1 and this is H 2. So this, two pumps are having different characteristics. So, and then suppose the two same pumps whatever we are added in the series operation, the two same pumps. Now we are connecting in parallel then, what will be the H Q curve?

So, if I draw the H Q curve, again then so this is Q, this is H. Suppose one pump is having characteristics like this. So, say this is pump A. So, if I go back to my previous slide. So, this is for pump B and this is for pump A. So, this is for pump, let us say pump B and we are having another curve that is for pump A.

So, this is for pump A. So, this is shut off head for pump, this is H shut off may be this is H shut off, may be shut off for pump B and this is H shut off for pump A, then how can we connect this two pumps. You know in parallel that we need to know. So, the key point is remaining same; that means what is the key point? When you are connecting two pumps in parallel point is for a given H Q will be added for a given H, Q will be added. So, pump A and pump B, both pump both the pumps are connected in parallel and then if we connect this to pumps in if we like to draw the H Q curve then, what will be the H Q characteristics? So, for a given H Q will be added mind it, this two pumps are connecting in parallel. So, shut off head for pump A is shut off head for pump B this is for this is for A, this is for A and this is for B. So, shut off head for pump B is higher.

So, whenever we are connecting because, Q will be added here Q is 0. So, for a given H, so it will follow the curve like this. So the, you know new curve will follow. So, Q will be added Q here is 0. So, if we add the Q 0. So, up to this point, the new resistance curve will follow like this then, from here if you add Q 1 plus Q this, then it will be like this. So, up to this point because this is Q 0 and up to this point, we if we would like to Q. Then up to this point no Q for pump, because pump s starts supplying Q from this point and in that case, if we add this 2 Q from this point it will be like this. So, this is the curve, when two dissimilar pumps, pumps are in parallel why? So, this is M point M, because up to point M Q will be added, because Q is 0 up to point M, which is supplied by the pump A.

So up to point M, the combined curve will follow the profile of the pump b and then only if you add up Q, it will the profile will be like this. So, this will be the, you know combined characteristics, characteristics H Q curve, when two pumps are connected in series and now if you have a system resistance then, it will be like this. So or operating point will be here, so, may be our operating point. So, here it will be the operating point. So, this pump will be the imparting head like this.

So, this will operating point and the head discharge corresponding to operating points of the discharge and head will what we are expecting to get. So, this is the you know mistakes, how we can draw H Q curves and whenever two dissimilar pumps are connected in series and parallel that you have discussed, this is very common because always we need to go for installing or a connection up to dissimilar pumps to rather than, similar pumps.

So with these discussions, I stop here today and will continue our discussion in next class.

Thank you.