Surface Facilities for Oil and Gas Handling

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Introduction to Pumps-02

So, this was same impeller actually we have tested and you see this one volute casing I said right this is volute casing. So, this impeller will be going inside that one ok. Then your fluid will be exiting here and fluid will be entering through here and if you see previous picture the same thing actually if you see this color this area ok. So, same thing it is here ok. So, shaft you can see here ok and impeller is here at this location at this location impeller ok. So, impeller will be rotating at a very high speed it will be delivering fluid here ok.

So, this one same fine radial axial ok. Now I will explain what is radial what is axial head? Head actually it is meter of water column you can water column you can raise ok. So, normally we do not say in terms of pressure. So, we say how much water column height it can dip.

So, it will be easy to compare ok. The radial flow this is radial flow impeller I said like actually going vertically up. Now what is mixed flow what is axial flow? Let us say I have one shaft here ok and my impeller is here ok fluid entering. So, what is the angle this is 90 degree ok fluid entering sorry this one fluid entering going up. So, directly 90 degree, but in certain design fluid will be like this ok.

So, fluid will be entering and it will be going like this. So, in this case actually it will be 45 degree ok fluid entering and it is going like this. So, it will be 45 degree. So, it will not be so compact rather it will be little bit longer and fluid will be entering and it will be going like this. Entering actually this is axis shaft axis may axis ok axial entering and it will not be going like this it will be going like this.

So, this length will be longer ok for especially ESP application it is some possible form you need many stages many streams many pumps will be connected in series. So, in that case if it is mixed flow it will be very long. So, in that case this radial flow is better it will make very compact system ok. And another is axial flow axial flow means like fan ceiling fan wind turbine

fluid is entering like this and going like this ok axial mixed flow and radial flow ok. So, when you are talking about radial flow it will give higher head or higher pressure or ok.

Normally we say h ok and axial flow low head. Axial like a ceiling fan if it is giving very high amount of head actually cannot work here paper will be going here and there ok. So, small amount of air will be delivering right low head or low h and radial flow flow rate how much flow fluid is it will be delivering per second flow rate will be lower ok. And axial flow high flow rate ok. So, wherever like wind turbine very high amount of fluid it can deliver, but high pressure if you are giving let us say cyclone coming wind turbine will not work actually it will break ok.

So, very high amount of fluid if you give low head things will work certain design, but for this case very high flow rate I cannot give, but high head or high let us say 10 storey building I can deliver using this one. But using axial fan type impeller if I design it will not be able to deliver ok, but it can deliver very high volume flow rate. So, now difference clear axial flow radial flow. So, mixed flow will be in between two ok. So, many cases people will be mixed you will be using mixed flow because it will be giving moderate flow rate moderate head.

So, if you want to compromise both then mixed flow will be ok, but any ah. So, so you want to deliver fluid 134 120 more than 120 flow rate like Burj Khalifa or maybe 5000 feet wellbore depth. So, one pump will not work ok. So, it will be having limitation one ok. So, then what they do they will be putting in series 1 2 3 4 5 6 ok.

So, how this look like I have another model this is actually actual ESP system electric sub muscle pump system. So, multiple staging how is centrifugal pump multiple staging will be done. So, this is radial flow I have small impeller this is also radial flow ok. It is having I this is sharp ah, there is sharp this one sharp ok. And if c i is here above and impeller inside impeller is the impeller exiting here I do not know whether in camera it will be coming impeller exiting here ok.

Then my casing is here ok. So, impeller i fluid is entering and so this is my casing, but why is the diffuser? Diffuser the white portion white portion is diffuser ok. In white portion design such a way like opposite of impeller similar way ah. It will be taking high velocity fluid and reduce fluid velocity increase fluid head and impeller we put inside and you become one stage one rotor this is called rotor rotating and stator or casing not rotating this will be fixed on this one if you if I put it here ah. So, sharp can rotate my impeller ok, sharp can rotate, but this is not rotating my casing, casing be fixed on separate pipe ok.

So, that is why it is stator, stator means casing part not rotating ok, casing part not rotating only my impeller rotating. Sharp can rotate only impeller ok that is why called rotor ok . Again you see this design such a way and this sharp design such a way you put it. So, there will be no relative motion. So, I if I rotate it impeller will be rotating ok.

So, this is called rotor and casing or volute casing this part stator not rotating ok, this is fixed on something hold it and this is rotate. So, in rotating it will give you a high velocity fluid this will be reducing fluid velocity. So, together become one stage ok, together become one stage. So, this will be giving maybe 2 meter 3 meter head I did not calculate, but maybe like this about you need 5000 feet right 5000 feet fluid when you have to deliver ESP system electric sub muscle pump. Electric sub muscle pump actually centrifugal pump, centrifugal pump this is centrifugal pump this can be used as a electric sub muscle pump ok.

So, 100 to 100 stages will be there. So, one stage I have how many stages 1 2 3 4 5 6 7 7 stages ESP ok, I have 7 stages ESP. So, fluid will be entering here and exiting here ok and motor will be connected here motor will be rotating continuously. So, when it is connected the upper outside this black portion will not rotate inside that impeller will be rotating ok. And one impeller one stator or rotor and this impeller rotor also impeller or rotor impeller or rotor ok, it will be rotating stator not rotating.

So, all the impellers will be rotating together stator not rotating and you are delivering fluid. So, how much total head it will be arriving I say one stage developing 1 meter. So, 6 stages I have so 6 meter total. So, if I have 100 stages 100 meter head I can develop the simple calculation fine you can remember it is one stage developing 10 meter. So, 100 stage 10 into 100 simple solution right ok.

Now, surface production operation why I am talking about ESP? In surface production operation also in many cases you need higher flow rate and you need higher head also. So, in that case you can create multiple stages of ESP ah centrifugal pump. In that case I will not say ESP this is not submerged submerged it will be on the surface. So, in that case I can create rotor casing another rotor casing rotor casing. So, one stage two stage three stage four five stages I can make I can make very high amount of head ok.

Many surface production operation cases for example, hydraulic jet pump and other you need very high pressure fluid to pump. So, in that case reciprocating pump you can use or in some

cases you can use centrifugal pump multiple staging ok. So, multiple staging you are creating purpose is that to increase total amount of head one is given 10 meter. So, 5 means 5 into 10 50 simple solution ok. So, I in my laboratory I did only one stage calculation one stage experiment I did not check many stages I had planned to use this multiple staging, but I did not do this one, but I purchased this one for class demonstration.

So, that you can understand easily and normally this ESP system in actual ESP this is nonmetal actually metallic also that will be like 1 or 2 inch thickness maximum. So, they can can create a very long ESP system, but very large number of ESP also I mean stages this is called stage one rotor one stage stator called stage 1 ok. I said like centrifugal pump will have a higher flow rate positive pressure pump lower flow rate. So, how does it look like? So, centrifugal pump will have the basic thing is that to know the difference you have to draw Q and H curve flow rate and head. So, flow rate this is flow rate ok and this is head normally meter of water column and flow rate normally like if I using SI unit and meter then flow rate will be meter cube per second or meter cube per minute or bar per hour then the curve will be normally looking like this ok.

This horizontally it will start and finally, it will be coming to 0 almost ok and efficiency curve this is H cube ok and efficiency will be like this at certain point efficiency will be maximum then this is eta. So, I can put eta also next same axis efficiency ok. So, centrifugal pump this is for centrifugal ok. So, for centrifugal pump will have efficiency maximum this is called best efficiency point ok. So, best efficiency point or BEP.

So, best efficiency point means you are getting very high amount of head and using low amount of energy ok and your target should be to run pump at BEP, but exactly BEP running is difficult. So, normally the company say you run within certain range maybe plus minus 20 percent maximum within that range this is called range operable operation operating range ok. If you are running within this operating range the cavitation probability will be lower your system efficiency will be much higher and system will be running smoothly, but if you are violating this norm then maybe cavitation will be coming or maybe some other issue will be coming ok. So, whenever you are running a pump you should maintain this one ok. Now, another curve will be coming system curve almost straight line ok system curve means ah how much power it is consuming or break power ah here one term is called break power hydraulic efficiency break efficiency break horsepower have you heard the term break horsepower is like this like pump shaft is there ok the shaft now I am applying break to resist it.

So, how much energy will be required to resist the break ok that they call high break horsepower. So, the term you will be hearing many times break horsepower because I am just

using break you are reducing the speed you are making 0 ok. So, how much force you are applying. So, using that if you calculate then that will be giving break horsepower ok that will be more than your hydraulic horsepower. Hydraulic horsepower means ah your pump is delivering a certain fluid.

So, I have some formula for hydraulic horsepower like rho Q H ok this is your formula for total amount of energy ok. So, pump will have certain efficiency ah. So, how much energy it is taking actually for delivering certain amount of fluid. So, this much of energy it is taking, but if I calculate break horsepower it will break horsepower more energy ok, but if you want to calculate electrical energy it will be much more. So, you are giving let us say 100 kilowatt electrical energy.

So, after motor losses it may be 90 kilowatt remaining then after other losses may be 80 kilowatt remaining then finally, pump will be delivering may be 70 kilowatt ok everywhere there will be losses. So, 100 you are giving maybe you are giving 70 getting ok. So, that is why overall efficiency when you are calculating then you have to calculate electrical to how much you are getting how much you are getting means rho Q H by eta rho means density of fluid eta means efficiency of the pump this is theoretical power ah ok efficiency and density ah and you know flow rate then head ok. So, this is for centrifugal pump. So, centrifugal basically 3 curves will be there one will be HQ curve flow rate and head and another efficiency curve another way system curve or break power curve and some cases they have written break power, but normally we say system curve ok and if you like VFD if you have.

So, VFD what will do VFD if you change the speed actually my HQ curve will be changing like this. So, Q H so, if you are increasing speed head and Q will be increasing ok when you are increasing speed actually your energy consumption also will be increasing ok. So, every pump will have their optimal speed range. So, company will be providing this one this is called pump characteristic curves ok. So, you see the title I have given characteristic curves.

So, pump characteristic curve will be given by company because company will be testing pump and they will be drawing the curves many curves will be there actually similar ok parallel curve this curve this that curve. So, you have and the company will say ok you run your pump within that range then things will be ok if you are violating the norm then things will be wrong. Now, positive displacement pump positive displacement pump normally curve will be like this HQ ok especially HQ curve we show two difference why HQ curve because in positive displacement pump does not matter whatever flow rate is there whatever head is there flow rate will be same ok. Say you take certain reciprocating pump and you keep speed same ok. So, when you are keeping speed same you can it can raise infinity head infinity pressure any 100 floor 200 floor

1000 floor water lifting once reciprocating pump can work, but centrifugal pump cannot work because you can see HQ curve in centrifugal pump is like this ok.

So, centrifugal pump is having limitation ok is the maximum head limitation per stage, but reciprocating pump there is no limitation. So, any amount of fluid you can deliver this one difference one difference is that flow rate and head centrifugal pump can develop limited amount of head ok this is the this picture limited head all right, but reciprocating pump there is no head limitation Q vertical line there is no touching to H. So, any amount of pressure will be possible infinity possible actually, but they practically infinity not possible because there will be certain leakage and other thing I will explain later how the leakage is occurring, but ideally it will be infinity. For centrifugal pump ideally practically it will not be infinity it will be having certain the range, but you see the Q amount of Q centrifugal pump will be higher Q means flow rate flow rate will be higher ok. So, that is why many cases the users will be deciding which one to use for their application ok.

For example, you want a very high flow rate, but head not very important for example, some water logging is there in road nearby road. So, the centrifugal pump using the no does not make any sense you will be using a centrifugal pump and quickly you remove the water right because high volume water is there. So, just you have to remove all right many cases like building basement water will be filled and you have to remove the water as soon as possible. So, head not matter in that case you need flow rate high. So, you will be buying or hiring one centrifugal pump ok, but you are like say new buildings are there in IIT you want to lift fluid.

So, centrifugal pump one stage may not be working. So, you have to use multiple stage or use reciprocating ok. So, I said like characteristic curves h q curves are there, but how to draw it let us try ok. Let us say this experiment I want to do in laboratory ok. So, what we will do initially open all the valves ok.

You see all the there is no restriction switch on the pump ok and pump will be running normally 1400 rpm actually in my laboratory it was 1400 rpm pump ok. If I change pump speed my flow rate and other things will be changing. So, initially you start with 1400 rpm what is existing company said and piping whatever any valves anything is there completely open. Now, start switch on the pump what will happen it will give you maximum flow rate this is centrifugal pump ok. So, it will be giving maximum q h it will be giving maximum flow rate here.

So, that time my pressure gauge where is my pressure gauge ah flow valve. So, maybe

somewhere pressure gauge will be here ok. Oh pressure gauge is here I think this one pressure gauge ok. So, pressure gauge will be showing very low pressure because there is no restriction of fluid ok. So, I will be getting is right side I have put one dot you see this curve.

Now, after few second or few minute you just turn ah this flow control valve you see one flow control valve is there try to close the valve little bit. So, you are closing means flow will be little bit lower and pressure will be increasing in the pressure gauge pressure will be showing little bit little changing ok. So, that time flow will be little bit reduced pressure will be increasing little bit ok. Then again there will be close close close close close ok you will get. So, I ask this one not to close completely because if you are closing suddenly pressure will be shooting up and system can fail.

So, just try to close up to certain level then just draw a curve and join the curve to y axis. So, this way I get h q curve ok ah. So, if I see h q data if I take like h may be like initially 0 ok needle is not moving and flow rate may be 4 meter cube or 4 ok. So, some value I am not writing unit then h 2 3 ah 2.

5 2 3 1 ok 3 head is not changing ah maybe 0.5 ok. So, that way I can draw the curve ok, but if I have p c p I I tested p c p also progressive p c p I told ok. So, this p c p will be giving different story how instead of centrifugal pump same place I put p c p ok. So, in that case what will happen ah I will be changing h this is centrifugal this is p c p or positive displacement pump ok. So, in that case ah I will draw separate another one q h ok. Initially everything open my flow rate will be very high h will be very low.

Now, we close a little bit keeping rpm same. So, it will be delivering same amount of fluid ok. So, my same amount of fluid, but pressure it will be showing higher that pressure gauge. Again close further flow rate will not change flow rate will not change flow rate will not change ok like your heart if you have any blockage heart will try to pump ok, but same amount of pressure it will try to generate, but you are restricting. So, what will happen you will have pain or some heart extra pulsation or something will be coming right.

So, that is also positive displacement type. So, it will be giving same amount of flow rate same flow rate ok irrespective of pressure ok. So, curve is vertical fine. Now, in centrifugal pump in VFD if I can measure my power how much I am giving VFD variable frequency electrical input part right VFD is electrical input input ok. So, if I know the power how much giving power

electrical and then how much hydraulic head pressure we are developing like say theoretical ah power required for pump to deliver certain amount ah rho Q H by eta eta means pump efficiency

ok.

So, and if you know motor efficiency eta motor eta pump. So, overall efficiency will be like eta pump into eta motor ok. So, from here actually you can calculate how much you are giving input how much you are getting how much losses is there fine ah. Whenever you are talking about pump. So, pump some will have some specific speed from there also ah actually you can differentiate between different pumps ok among different pumps. So, specific speed formula is it N s equals N root over Q H power 3 by 4 ok this formula N is your rotational speed of shaft ok.

I have shaft rotation speed N normally it will be rpm Q is flow rate H is differential head at B best efficiency point I will write B best efficiency point I BP ah N is specific speed. So, from this specific speed actually we can check whether my pump will be coming under centrifugal category axial category centimeter radial or maybe positive displacement category ok. So, if I see this one this is radial tall blade tall blade radial and this is axial. So, axial flow means like this and this tall blade means fluid will be moving like this this short blade also like this this is mixed flow more 45 degree ok. So, specific speed will be low here high here ok low specific will be high specific speed and my ah reciprocating pump will be coming here reciprocating or ah positive displacement type will be coming the tall blade nearby tall blade ok.

ah If I if you are using rpm let us say this is rpm gpm this is meter ah then this value will be coming like this is 500 this is about 1000 this is 15000 ok. ah So, this is unit dependent. So, it is not universal if I give value in let us say barrel and meter. So, this value will be changing ok. So, you should not remember exactly the values for all the unit universal because it is unit is having.

So, it will not be universal ok based on unit you have to check specific speed fine. So, low specific speed means high head ok head high flow rate low high specific speed means flow rate high head low fine. So, you should remember. So, low specific speed pump reciprocating type tall ah radial blade pump and high specific speed axial flow pump or axial flow machines maybe turbine also possible.

So, their flow rate is very high, but head is very low ok. So, in exam I can give question like this if two pump different values I give I can ask you in which range it will be it will be low specific range or high specific range or you have to select a pump for certain application ok. So, then you can quickly calculate and you can check fine. NPSH when you are talking about insatiable pump ah it will have two component one will be NPSH A and will be NPSH R NPSH net positive

suction head suction head ok. Whenever you are using any pump centrifugal especially so, you must know centrifugal pump NPSH. So, company will be providing the data and company is saying like NPSH A is 5 meter then you have to keep more NPSH NPSH R 5 meter then NPSH A must be more than 5 meter.

So, NPSH A NPSH A this must be maintained R means required company will give and NPSH A means available you must maintain ok. If you are a production engineer so, you have to check how much NPSH is available for you if you are not maintaining what will happen there will be cavitation. Vapor formation will be there so, vapor will be creating cavitation in your system so, system will fail. So, you must maintain the NPSH when you are running any pump ok. For a positive dissipation pump also certain amount of pressure is required, but for centrifugal pump it is very much serious ah cavitation will be more important in centrifugal pump ok.

The formula NPSH A equals P 1 by rho g minus P v by rho g plus V s square by 2 g ok. So, P 1 absolute pressure of the inlet at inlet of the pump absolute pressure at inlet ok and P v P v is vapor pressure at inlet. What happened when pump is sucking fluid ok from suction pipe is suction pipe pressure becomes very low so, bubble formation will be there ok. So, you have seen this at if create lower pressure so, bubble will be formed.

So, you should not create so much low pressure so, the bubble will form ok. So, this vapor pressure also we check vapor pressure depends on temperature ok. You are say initially company said like you maintain 5 meter ah NPSH r and you think everything ok, but fluid temperature increased. If fluid temperature increase vapor pressure will go down and vapor pressure will go down automatically vapor maybe will be creating ok. So, that also you have to check so, vapor pressure also very important for your NPSH calculation.

So, NPSH will be calculated in the suction side not delivery side ok. When fluid is sucking by pump sucked by pump ok, I have pump here right so, this side pressure will be checked ok, not delivery side. V s square, V square means friction velocity velocity of the fluid velocity of the fluid ok. Some more parameters will be coming ah ah here this is simplest form ah another parameter becoming for friction. If friction is very high again you are giving more resistance means some pressure drop will be there again cavitation probability will be increasing.

If you have some pipe bend lots of pipe bend again there will be problem. If you have sharp bend you have some notch or something so, everything will be will be giving pressure drop of friction high. So, that will be also hampering your NPSH ok NPSH a r you are not controlling r

given by company a you have to maintain. So, when you are check NPSH available or not you have to check fluid temperature fluid property instead of water you are using let us say petrol. So, your vapour pressure changed the boiling point change it will not work right then your pipe diameter you have to check you have any sharp bend if you have long pipe you have. So, all the parameter you have to check which will give you pressure drop or vapour pressure change ok.

If you are not checking your NPSH will be having problem ok that will be giving your cavitation pressure. So, NPSH a equals H p some other formula detailed formula is there H vapour H s t minus H f minus H a ok. So, detailed things are there whatever I was talking about H s t will be plus ok.

So, absolute head surface of the liquid tank ok. So, let us say ok. So, how much pressure is here ok then H f is friction head ok because of fluid friction some pressure will be dropped certain amount pressure already there because of atmospheric pressure, but that will be minus friction and H a will be acceleration head with fluid pipe diameter very low then again pressure drop will be high ok. So, pressure drop is very high then acceleration head ok and H v p H vapour pressure vapour pressure ok. So, vapour pressure is depending on temperature fine H static head ok. The static head means like if you have this is plus if your water level height is more than your pump, pump is here water level height is here.

So, that will be static head. So, that will be added actually, but it is below the pump then it will be minus ok. So, the static head above the ah pumps ah centre line above centre line ok. Now, cavitation. So, cavitation actually ah if you are not maintaining NPSH what will happen it will be sucking fluid and vapour will be created or bubbles will be created bubble is created when it is going towards exit bubble will be again collapsing.

So, vapour creation and collapsing is called cavitation. So, because of collapsing actually the metal particle will get removed slowly from the metal surface and it will be giving noise vibration and metal particle getting removed. So, because of that one your pump life will be longer or instantaneous fill may be possible or pump slowly it will be getting eroded. So, that will be having even negative impact. So, one term is called cavitation number. So, cavitation number or cavitation parameter number or cavitation parameter ok P minus PV rho V square by 2.

So, pressure pressure minus vapour pressure divided by ah inertial pressure ok. So, sigma less than 0 cavitation will occur ok. So, you should remember NPSH is important part when you are running in pump and it will have cavitation. So, cavitation parameter also you should remember

and this basic formula you should remember ok. Especially NPSH A NPSH are those terms full form ah where cavitation can occur impeller inlet fluid sucking then when pressure is developing.

So, that certain area cavitation will be occurring ok. Thank you very much for today's lecture we will start next topic next time. .