Surface Facilities for Oil and Gas Handling

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Introduction to Reciprocating Pumps

Now, single acting. So, how does it work? If you can remember if you have studied sucker rod pump it will have one valve I am going through the sucker rod pump because you may have studied already the sucker rod pumping system ok. So, if we this is piston rod or sucker rod piston rod or sucker rod and this is called plunger or piston. In mechanical engineering they will be saying piston, but normally oil industry they use the term specifically plunger instead of piston they use in plus and there will be one valve here and there will be another valve here ok. So, whenever we are moving piston up and down the valve will be opening simultaneously and it will be delivering fluid it will be sucking from here ok, well bore fluid and delivering to surface ok. So, well bore fluid will be sucked and it will be delivering to surface and how it is working? If piston be moving up and down or the plunger, plunger when it is moving down valve this is called standing valve standing this is called travelling valve ok.

So, travelling valve will be moving travelling standing valve will be moving simultaneously one by one ok. When piston is moving up travelling valve will be opening when piston moving down or plunger moving down the travelling valve will be opening ok. So, ok. So, there is sucker rod pump again if you want to know more about this one you have to go to my artificial lift lecture.

So, normally the pump will be like this ok, I said one piston or plunger will be there and one piston rod ok. This is called connecting rod or piston rod connecting rod or piston rod ok. This is called piston or plunger and this is called cylinder ok and it will be having two valves ok. And piston will be moving from top dead centre TDC to BDC this is called top dead centre top dead bottom dead centre ok. So, piston will be moving within this top dead centre bottom dead centre more than that this will not move ok.

And top dead centre and piston head this is called piston head this extreme end of this cylinder is called piston head ok. And cylinder head this is called cylinder head and this is face is called piston head piston head ok. So, piston head and cylinder head will not touch there will be certain small amount of gap for mechanical reason ok. If it is hitting continuously the system will be breaking. So, there will be small amount of gap.

So, that piston will be coming and going like this, but it will not touch ok, some small amount of gap will be there ok. So, TDC means maximum distance it will be travelling. So, this distance is called swept volume ok. BDC to TDC the distance is called swept volume and it will not cross this TDC mark ok. There will be small amount of gap.

So, that we for mechanical reason otherwise it will be hitting continuously it will fail ok. And there will be some expansion contraction also. So, if it is touching continuously and because of temperature it is expanding this piston rod then it will be creating too much pressure. So, that will be giving failure. So, there will be certain gap.

Now how does it work? This first I will draw one by one ok. Let us say initially I have two valve I will be drawing one valve only ok. And piston or plunger is moving this direction and this actually cylinder, cylinder and plunger or piston there is some small gap I have drawn ok. You can see this small gap ok, you can see small gap leakage. Practically we should not give any gap.

Ideally there will be no gap, but practically there will be certain amount of gap. So, that gap actually cannot control because friction will be there. If I make it tight fit piston is there metal and this cylinder also metal and continuously moving ok. So, and if it is touching continuously friction will be too high. When friction is high heat generation will be there and wear and tear will be there and if piston movement is very high then heat generation is so high it will there be spot welding.

Spot welding means heat will be generated so much that metal will be melted little bit

ok. Metal will be melted and this metal melted, this metal melted they will be fused together then it will not move at all ok. So, friction will be giving so much heat. So, that is why there will not be keeping tight fit or the some small gap or maybe zero clearance or little bit clearance will be there clearance we say or gap. So, that is because to reduce friction ok.

Now, when piston is moving this direction ok, this is my piston the shaded one and moving this direction let us say A to B A to B ok. And what will happen? This area pressure will be lower ok and fluid will be sucked let us say it is working in the atmosphere. So, this fluid will be sucking because piston moving right direction. So, inside cylinder pressure will be lower and this pressure will be little bit higher. So, higher pressure fluid will be entering to lower pressure area ok.

And now next when piston will be moving B to A what will happen? piston is moving B to A again I am drawing same piston and now opposite A B outside pressure we assumed atmospheric pressure one atmosphere. So, again one atmospheric is here ok. Inside piston is trying to move pressurize. So, cylinder pressure P increased inside cylinder pressure increase. So, the high pressure fluid will go to lower pressure area ok.

So, continuously if you are moving right direction it will be sucking fluid from one valve when it is moving another direction it will be delivering. So, valve will be designed such a way that it will be it will be closing in one direction opening another direction ok. One valve let us say this is 1 this is 2 valve 1 will be opening one time when it is delivering valve 1 will be closing valve 2 will be opening ok. Same thing happening in your circular pump also, but different design ok. Here I have 2 valves one open another close another close one open like this ok.

So, this is the basic principle of reciprocating pump ok. Cycle cylinder the pumper that they are also having similar mechanism your hand pump they are also having similar mechanism ok. So, 2 valves will be there one will be opening one time next time it will be closing other will be opening one closed one open close open fine. Now, we have to do calculation also now double acting this is single acting actually this is single acting means one time delivering fluid ok. Now, if I am to create double acting double acting means I have same cylinder ok.

Now, what will happen double acting means this area A what should I write I write x y ok. So, piston moving A to B same way I am writing this is single acting ok. This is double acting in double acting what is happening I have piston cylinder everything arrangement is there 2 extra valve will be there ok. And there is one sealing area ok, you see seal I have written ok. In double acting when piston is moving A to B.

So, it is it will be single acting piston same way it is working it will be working the left side of the piston ok. This side actually single acting ok, this side will be working a single acting ok. Now, this side right side of the piston that also be working is single acting ok. When you are moving this direction left cavity filled with air right cavity you are exiting one valve may valve 4 will be opening and it will be giving high pressure fluid ok. Piston move B to A what will happen opposite will be happening ok.

So, what is happening in single acting you are delivering one time, but double acting when your piston moving this time delivering this time other cylinder delivering ok. A to B one cylinder delivering B to A other cylinder delivering. So, 2 cylinders is created here you can see ok. Left side and right side 2 cylinders created, but here one sealing section will be required ok. The rod piston rod is passing through certain cavity.

So, some properly it must be sealed other will be air will be leaked through that one I do not want air leaking there rather air should be passing through the valve ok. So, the leaking will not be allowed fine ok. Now, we will try to solve some problem using this very simple problem you see this I 1 piston single acting ok. Let us say valve I am not drawing ok for simplicity purpose. So, what is the area of this one? Let us say we assume A and piston BDC to LDC TDC to BDC L.

So, how much volume it will be delivering when it is moving this direction? A into L volume area into length there is volume right. So, volume delivered. So, A into L, but per minute one time it is giving power. So, it is AL volume and per minute how many? So, number of strokes I have to know per minute if I know the N number of strokes N the total volume will be ALN simple. So, ALN number of strokes N N is written there not written number of strokes per minute ok.

So, simple ALN now if I have 2 stroke or double stroke. So, this side volume A flow rate Q equals ALN sorry fine Q equals ALN and this side again it will be delivering per minute right. So, again Q maybe Q 1 this is Q 2 equals ALN, but A is changed actually why? Because piston rod is there ok. So, I can write A dash and if I ignore piston rod is very small if I ignore then total volume will be 2 ALN ok. So, if we ignore piston area sorry rod area.

So, Q will be 2 ALN simple right. Now here I did not consider leakage let us say because I select piston and cylinders there will be some small gap actually. So, small gap when you are pushing at very high speed. So, some will be leaking back. So, that means, whatever ALN you are trying to deliver actually you will be delivering little bit lower little bit lower you are delivering. So, let us say actual delivery actual delivery Q A ok.

So, percentage Q theoretical I can write Q theoretical Q means Q theoretical whatever you calculated ok, but actually there will be certain loss ok. So, Q theoretical minus Q actual divided by Q actual this is your percentage loss ok. Actually you are not delivering certain amount fluid because of leakage fine clear. In a double acting recipient pump if there are piston area 200 centimeter length of stroke 15 and crank rotation 60. Crank means actually this if I collect directly to one crank ok, you rotate this one continuously rotate.

So, when you are rotating actually the piston will be moving forward backward ok. This is called slider crank mechanism if you remember in mechanical engineering. Slider crank mechanism if you rotate this P I can I should not write P because P I am using some other this is P x just I gave one name. So, P x point if you rotate around O. So, your piston will be moving forward backward ok.

This is called slider crank mechanism this is called slider crank ok. Piston is slider and crank is rotating. So, crank rotating piston is giving reciprocating motion a linear motion. So, one rotary motion creating linear motion this is called slider crank mechanism in a mechanical term. So, this is the same technique is used for your IC engine internal combustion engine bikes motorcycle cars the original engine.

So, same slider crank mechanism they are also using. So, crank rotating their piston also moving up and down, but purpose different we will discuss later ok. So, actual flow rate when you are talking about. So, some energy will be some fluid will be lost 100 percent you are not delivering because of leakage fine. Now, what is the for this problem what will be the q? So, flow rate this is double acting I have written ok.

So, 2 times into length 0.15 stroke length 0.15. So, you are converting in meter then 0.02 is area and 60 is your rpm.

So, total this one 0.35 efficiency 98 percent. So, multiply by 98 0.98 because this one first one is q theoretical ok. So, theoretical whatever you are getting actually you are getting less.

So, you multiply by 0.98. So, you are getting 0.343 and unit you calculate what will be the unit meter q per minute I did not make second if you want to make second then rpm you have to convert into second rps ok. And again you have every time you have to convert units if I give some different unit let us say instead of 200 centimeter if I can give maybe feet square. So, in that case you have to convert you have to make uniform unit then you can calculate ok. Now, another problem you see a single acting this is single acting previously I solved for double acting this single acting reciprocating pump delivering water 0.

01 meter cube. So, q actual is given 0.018 ok and runs at 60 rpm. So, N 60. So, here you see reciprocating pump speed is very low 60 rpm right very low speed pump ok, but centrifugal pump speed will be like 1400, 3000, 3600 that range. The stroke length 500 millimeter stroke length L is given 0.5 meter and piston diameter also given D piston 220 millimeter.

So, 0.220 meter total lift is also given how much fluid is delivering 15 meter height ok. So, you have to calculate theoretical discharge actually is given actually. So, theoretical

how much you are getting. So, q theoretical AL N by 60 if you are converting into second ok, if you are not converting second then it will be meter unit.

So, pi by 4 D square NL by 60. So, it is coming pi by 4 0.22 square 0.5 into 60 divided by 60.

So, this value is coming 0.019 meter cube per second ok. This is theoretical flow rate you are getting, but actual 0.018 if you see already given. So, that means, some amount is lost right. So, slip or how much fluid low fluid you are getting ok.

Slip equals theoretical minus q actual 0.019 minus 0.018 equals 0.001 meter cube per second per second this much of fluid lower fluid will be delivered. So, percentage slip percentage will be q theoretical minus q actual divided by q actual. So, this would be giving if you put all the values it will be giving like 0.

001 already you calculated 0.019 into 100 it will be giving 5.26 percent. So, 5 percent fluid is lost in every time ok. So, see the coefficient of discharge.

So, actual by theoretical q actual by q theoretical 0.018 by 0.019 is giving 947 this is coefficient discharge coefficient. Now, theoretical power ok, p equals rho q theoretical g h ok. So, in neglect losses neglect losses other losses ok.

If something is not given no need to consider. So, in that case you are getting 1000 rho density water right and q theoretical given 0.019 and g value 9.

81 you must not forget and 15. So, ok. So, it is giving 2.8 kilowatt ok. And motor efficiency some extra I am adding here E if motor efficiency 95 percent electric input. So, motor so, electric input electric input equals 2.

8 divided by 0.95 equals 2.95 percent ok. Anything wrong? . Something wrong? q theoretical minus q actual by q actual. q theoretical minus q actual by q actual ok, 0.018 this one ok. Pump series in parallel parallel in series ESP I have shown you like 1 stage, 2 stage, 3 stage these are in series ok.

Normally pumps will be connected in series. So, that total head will be added ok, but if you are saying parallel like 1 pump is here 1 pump is here that is also possible, but normally it will be connected in series ok. So, because when it is parallel there will be issues like 1 pump is working 1 pump is not working then how to control the valve there will be difficulties. So, normally they will be connected in series like ESP. Normally surface application 3 4 stages may be common, but ESP application may be 100 to 100 stages will be common ok. Multiple cylinders when you are talking about reciprocating pump, reciprocating pump single stroke and double stroke whatever pump it is unless a single stroke single stroke will be will be giving pulse like this ok.

So, 1 stroke is giving pulse again when piston is moving down there is no pulse like our heart is beating pulse no pulse, pulse no pulse right. So, if you need continuous flow let us say gas lift application you are applying for or say jet pump application is this pump liquid flow pump. So, jet pump application you need continuous flow, continuous flow if you are giving velocity like this or pressure like this jet pump may not work or it performs will be low. So, actually you have to give pressure like this constant ok, constant pressure you have to give.

Then people thought let us make it double acting. So, when piston moving up it is delivering when going down delivering. So, again I got pulse like this. So, it become more smooth ok, but still people thought ok flow rate is not sufficient it still pulses are there. So, they made multiple cylinders how multiple cylinder will be working ok, cylinder like this 2, 3 ok piston piston ok ok. O A let us say O is a center this O is center crank AO crank AO if you are rotating.

So, you see this piston 1, 2, 3 piston be moving 1 by 1 you rotate it point A you rotate it around O ok, point A is rotating around O. So, what will happen this piston rod will be

moving 1 by 1 right. So, 1, 2, 3 piston will be moving not together, 1 will be delivering another be sucking ok. So, let us say piston 1 is giving pressure pulse like this fine, piston 1 reciprocating pump, piston 2 will be little bit lagging ok, it is giving pulse like this piston 3.

So, you get more smooth ok. So, you have multiple cylinder you can create more smooth and total volume also increased instead of let us say you have only 1 cylinder 1 stroke then 1 time delivering. So, total volume ALN now you have 3 cylinders. So, per minute actually 3 into so 3 times you are delivering and your pulses also smooth. Now you want to create much more flow rate. So, you create more piston more piston may be 20, 30, 40 pistons and you get more flow rate and pulse will be almost 0 because you will have pulses like this.

So, average is here and why I am saying this pulses will be 0 this will be connected to 1 single pipe actually all these cylinders will be connected to single pipe. So, that pipe will have smooth almost smooth pressure ok, it is not like this our pulses ok, it is having we have only 1 hertz that is why ok. So, your application succulent pump you are using only 1 stroke this is ok very low flow rate 5 barrel or 2 barrels per day ok, but you have higher flow rate requirement. So, instead of centrifugal pump you can use this one also this will give higher pressure plus higher flow rate.

So, you can create multiple cylinders ok. And if you are using if you have restriction to use multiple cylinders and in that case you can use pulsation dampener. Pulsation dampener what is this? I have one piston cylinder arrangement like this ok and you have flow rate you are getting pulse. So, this will be going to one pulsation dampener ok, pulsation dampener will be like this. So, here you are getting pulse like this left side, but after pulsation dampener pressure will be like this why? Pulsation dampener inside there will be one balloon of nitrogen field when pulses are going the nitrogen balloon will be compressed. So, it will be absorbing all the shocks and when let us say A B when fluid is moving from A to B all the pulses will be absorbed by the nitrogen dome ok and fluid will be exiting smooth pressure ok.

If you have very high very large large size pulsation dampener there will be no pressure pulsation ok after dampener, but if you have smaller maybe there will be some pulses you

can check your allowable pressure pulse ok. This is called pulsation dampener they say some other names are there ok. Pulsation dampener pressure accumulator or hydraulic accumulator they say. So, it will be accumulating little bit fluid and there is already nitrogen dome, nitrogen dome will be compressing and absorbing the shocks or vibrations ok. Then it will give smooth pressure ok, it will not change flow rate it will, but it will have two valves inlet and outlet valve.

So, inlet valve will be operating when certain pressure will be there and it there will be no back flow and outlet valve will be operating when pressure reaches certain pressure. Let us say I need outlet 60 bar pressure and inlet I have 100 bar to 20 bar pressure fluctuations. So, outlet 60 bar if I have to get and inlet I have so much fluctuations. So, already higher pressure is there for example, cycle pumpers cycle pumpers that cycle tube is having certain pressure.

So, you will have one way valve actually. So, when you are putting pushing it up this your cycle cylinder the piston. So, that time air should not enter from tube to your cylinder ok. So, there will be one one way valve. So, that is called valve tube actually ok, the valve tube will that will be one way valve. One way flow will be allowing when it is going pushing up that air will be allowed, but going coming out from tube will not be allowed ok.

So, that is called one way valve. So, there also one way valve will be there. So, two one way valve one B one A one way valve will be working. So, when pressure pulse will be more than this one it will be triggered if less than that one it will not be triggered ok. So, one way valve per function is that it will allow one way flow not other way ok. One more problem also ok. A radial flow impeller A and B has 2 centrifugal A B of 2 centrifugal pumps have information A is having impeller diameter 1 feet, efficiency 70 percent or rotation rpm 1500, B is having 2 feet diameter, efficiency 65, 3000 rpm.

So, what is the head ratio how to calculate? So, head formula you have seen right eta u square by 2 g ok. So, if I have h A by h B eta A by eta B u A square by u B square ok. The ratio simple eta A by eta B u means omega r omega r ok. So, eta A by eta B omega means 2 n pi by 60 into r square n A I can say r A 2 n A pi by 60 into r B square ok

omega equals 2 n pi by 60 I am writing ok. Now, if you remove this 2 2 and pi of this constant terms then it will be coming like this eta A by eta B.

So, n A r A n B r B square now put the values directly eta means 0.7 by 0.65 and n A value 1500 into r A 1 feet by 2 2 feet 3000 2 feet by 2 by 2 I am removing directly like this ok. So, this value will be coming 0.067 ok this ratio. So, simple formula actually ok.

Thank you very much for this today lecture tomorrow we will or the next day we will start a new topic. Thank you.