Surface Facilities for Oil and Gas Handling

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Introduction to Compressor

Good morning everybody, today I will start lecture on Compressor and it will be including ah IC engines also or prime movers ok. So, in short I will try to cover in almost 1 hour ah. So, first I will start with compressor. Compressor I already told that pump and compressor almost same function, compressor you are compressing in pump normally you are not target is not to compress. Although liquid if you give very high pressure that also be there will be some compressibility , but we are ignoring in normal application , but in gas if you see some small pressure change the compression will be very high ah. So, in pumping system you have seen reciprocating compressors ah reciprocating pumps centrifugal pumps and other types of some pumps .

Compressor system also same thing we can use ok ah, but some extra study you have to do because it is compressible. So, compressible means that PV gamma and PV cos nRT those formula will be coming here ok. And basically this topic you can check in Arnold and Morris book surface production operation volume 2 and many other document also you can take this is basic. So, you do not need to go too much in depth of of anything ah, just some basic knowledge and some mathematical evaluation we will try to do .

So, compressor why do you use? Compressor when you are considering so, basically like gas compression system you have different well bore and different pressure you have. So, in that case you have to make uniform pressure or same pressure then you can inject actually for example, well 1, well 2, well 3 is there ok. And you have common surface facility you have common surface facility and let us say well 1 is having ah P 1, P 2, P 3 ok. So, P 1 is having very high pressure P 3 is very low pressure. So, if you are not managing this gas pressure properly what will happen P 1 pressure may enter into gas P 2 or P 2 production rate will be lowered because you are not managing pressure high pressure ah will be pushing down this low pressure right.

So, maybe you have to use sometime booster pump. So, that all pressure will be equal then you can have common line and common separate system, but if you have different pressure even pumping system also same if I have one is very low pressure one is very

high high pressure that will be having difficulty in surface production systems. So, you need compression systems or pumping system on the surface production systems. In compressor system ah many cases you work with low pressure its atmospheric pressure in many cases you work with very high pressure for example, you are getting LPG liquid petroleum gas right. So, in that case you have to create liquefaction.

So, pressure should be higher and temperature should be lower. So, that thing criteria should be there, but if you ah consider let us say flaring. So, maybe low pressure compressor other compressor can be using can be used for ah maybe extracting some gas and putting into some other separate system and you can reuse ah. So, there are ample application of compression systems ah in your surface production systems gas lifting system you need to compressor gas ah different available different pressures are there. So, you need to use again ah each separator will have some if you can remember its separator will have some gas outlet line right gas mistakes to get.

So, separator 1 separated 2 maybe another is there ok, separator 1 maybe high pressure ok, separator 2 ah separated 2 may have much lower pressure ok. Because each stage pressure will be going down and you cannot connect directly that pressure other high pressure gas will be entering into your low pressure separator. So, you must manage that one using some ah compression system maybe separated 2 will be requiring some compression system or high pressure creating pressure more pressure system right. So, that way you have to handle system. So, then what are the different options one basically 2 types of compressors will be used reciprocating centrifugal other type of compressor can also be used, but I am not discussing because of time limitation .

So, flash gas compressor possible ok normally characteristic by low throughput rate and high differential pressure ok low throughput or flow rate and high differential pressure will be the flash gas compressor ok ah differential pressure is expressed in terms of overall compression ratio. So, overall compression ratio overall compression ah ratio RT or any symbol you can put ah P discharge pressure P suction pressure. So, what are the unit you have to make same unit ok. So, let us say this one PSIA. So, this must also be PSIA because you have to make unit less because you are saying ratio.

So, I am not talking about unit ok . For ah for a surface production gas compression compression of gas normally RT value will be 5 to 20. So, they say 20 meter cube

volume you take finally, it will be 1 meter cube. So, that ratio ok. So, booster compression system that pressure ratio will be like 2 to 5 lower pressure booster.

So, you are just boosting some pressure ok RT will be 2 to 5 ah ratio. So, this will be unit less fine ah. So, compressor reciprocating compressor pumping system is at least a lower speed, but in compression system normally you can create high pressure also high ah rotational speed and so, high rpm also you can create actually because multiple cylinder will be there. So, you create high rotational speed and total volume flow rate will be higher ok. Pressure range may not be higher, but volume flow rate you are increasing the number of cylinder will be increasing number of cylinder increasing and number of stroke also increasing your volume flow rate will increase because volume flow rate equals ALN right.

So, L increase N increase N increase anything you are increasing Q will be increasing ok. So, volume flow rate if you want to increase then number of strokes or rpm of the system will increase length stroke length may be you can increase total volume will increase or may be piston diameter you can increase that way you can increase total amount of throughput or flow rate and again you have to check unit every time ok. I already told overall compression ratio RT equals P delivery by P suction ok. So, suction pressure will be more delivery pressure will be low.

So, R ah ok. So, overall compression ratio you have seen RT PD by PS. So, delivery pressure is higher than suction pressure. So, it will be like normally I have written already 5 to 20 this within this ratio, but it will be more or less also based on your requirement for normal application 5 to 20 if you if I ask you to use thumb rule. So, you take any value 5 to 20 ok. If I give some value then you have to use that one and in exam if I say ok use some value then you should try to take within this range because common range you should use ok, but you can take 100 ratio also that is also feasible normally you will be expecting the common people are using that one ok.

Now, PV diagram. So, in pumping system you have seen we have cylinder and we have piston ok. And oil and gas industry like sakura pump use the term plunger ok. And this one cylinder same way I am drawing as pump this is plunger or piston this piston rod and there will be valving valve system ok V 1 maybe V 2 maybe ok. So, when piston is

moving left to right TDC, BDC maybe TDC this one because I said like some clearance must be given ok. Otherwise it will be hitting the cylinder.

So, that is not desired because of mechanical reason and this if double acting cylinder is there then there will be some sealing section back side also ok. So, that piston rod will be moving through the seal, seal means it will not allow gas to leak through this one purpose of seal this one. And another purpose is that seal should not get wear out. So, that leaking will start or it will not give so much wearing of piston rod it will break ok. So, purpose will be that you will be giving smooth flow smooth linear motion of the rod piston rod ok or connecting rod.

So, we will have two valves mainly if we have single cylinder, if you have single acting, if you have double acting then I will have more valves V 3 will be there V 4 will be there ok. There is no specific in nomenclature just I am putting my own name V 1, V 2, V 3, V 4 ok. And if there is piston will have certain amount of leakage. So, that leakage also you can consider 1, 2, 3 percent within that range. If you very high amount of leakage is there then you have to change cylinder or piston ok.

For small leakage 3 to 5 percent is ok for Saccadot pumping also normally we assume that much of leakage ok. So, any composition system that much of leakage is that out normally ok. Now, in pumping system your high pressure fluid you are pumping there is no compression, but here compression will be there. So, how this PV diagram pressure and volume diameter diagram will be there? This is pressure ah pressure this is volume ok. So, I am not writing unit unit will be later we will discuss ok.

So, let us say ah it is single acting ok, single acting system I am considering. So, I do not have this ceiling thing fine. I have TDC, BDC. So, TDC I will draw like this here also TDC top dead center if I put vertically then it will be top ok. The bottom desirability tends to be ah vertically down.

So, BDC less here ok BDC ok. Now, piston is moving from BDC to TDC V1 V2 closed ok. V1 V2 closed and piston moves from BDC to TDC ok. So, what what will happen?

The cylinder portion already gas filled. So, actually you are compressing ok. So, compression will be starting let us say compression is starting here ok.

And if you are compressing very slow rate all heat will be dissipated because compression heat will be generated heat will be dissipated. So, in that case it will be PV equals constant pressure and ok. So, PV equals constant if I very slow process ok. If very fast process there is no heat transfer then what will happen? It will happen like this compression. So, normal compression formula ok.

So, here fast process. So, adiabatic adiabatic or entropy constant not 0 entropy constant ok entropy not changing, but when you are changing heat transfer. So, in that case entropy also change ok. Now, you are compressing pushing down pushing down pushing down compressing ah let us say assume your cycle pumper ok how does it work. So, cycle pumper you take manual operation. So, initially what you do you press little bit then nearby end you press you give one jerk ok.

When you are giving jerk that time actually air is pushed into your cycle tube ok. So, that means, you have to reach out to certain pressure then air will be entering ok. So, when air in entering that will be constant pressure process constant pressure process when air entering. So, I compressed it then air will be entering into my cycle tube that is constant pressure ok. So, this is called isobaric bar isobaric ok, isobaric air entry into cylinder or air delivery air delivery ok.

The during compression stroke actually you are not delivering in cycle pumper also you see when you compress actually that will be there will be no delivery, but when you will be giving compress it then give one jerk. So, that time you will get some noise also some noise. So, that time actually air entered into your tube ok pressure increase. So, that will be we are assuming there is constant pressure process ok. Initially you are increasing pressure constant pressure ok.

Then when it compressed again you are moving up piston. So, that time some small amount of a gas will be remaining in the cylinder this clearance area some small amount

of gas will be there because piston is not touching completely ok some gap will be there. So, that gas is that gap is having compressed air you compressed it. So, some small compressed air. So, when piston moving up that will be expanding actually.

So, that will be also same process whatever following like adiabatic is very fast then it is adiabatic ok. So, that gas will be expanding ok. So, that will be gas will be expanding it will be coming to atmospheric pressure ok. So, you press it in entered then small amount of gas will be remaining in your clearance zone piston moving up. So, the gas will be expanding ok gas expanding that will be also adiabatic if it is very fast process if slow process then it is isothermal very fast process will be adiabatic no heat transfer will be assuming.

So, entropy is constant ok. So, if entropy constant then S is constant adiabatic if it is isothermal then it is very different isothermal not possible then that is if you want to create isothermal maybe it will take 2 3 days to move up because you have to maintain constant temperature ok. So, you are not maintaining constant temperature because we are practical engineers. So, we do not think that something is possible in 2 3 days we are moving and in oil and gas industry right. So, we have to see approximate result. So, some heat is transferred fine, but our work must be done.

Now, when P atmospheric compression delivery then again expansion after expansion piston moving up when piston move after certain level then it will be atmospheric pressure and your cylinder pressure will be same outside cylinder the cycle pump or outside pressure atmospheric inside pressure atmospheric same. Again you try to move up. So, that time inside cylinder pressure will be it will be lower because you are trying to move up. So, lower pressure outside higher pressure higher pressure will be enter into your cylinder ok.

So, this portion I will put name 1 2 3 4 ok. So, 4 2 1 air entry ok. So, then then what what happened V 1 V 2 closed piston moves V dc to dc 1 2 2 process ok. Then 2 2 3 what is happening 2 2 3 air exit high pressure ok, gas or air ok. If you say gas is ok you say air is also fine.

Then 3 2 4 what is happening expansion ok. Now, in practical case actually it is not

adiabatic neither adiabatic not isothermal it will be polytrophic. Polytrophic means some heat will get transferred because you are approximating everything right. So, you are not making so, fast so, no heat will be transferred and everything will be insulated not possible cycle pumper also after pumping if you touch the cylinder at the bottom side it will very much heated up ok. That means, some heat is getting dissipated hot atmospheric temperature lower.

So, some heat will be getting dissipated. So, it is not adiabatic ok not isothermal not adiabatic. So, it will be in between it is called polytrophic process ok. So, polytrophic process means my system will be like this ok. Polytrophic process so, adiabatic process p V per gamma equals constant. So, polytrophic also p V per gamma constant, but gamma value will be different ok.

So, adiabatic so, normally gamma value will be 1.4 and polytrophic polytrophic normally p V per n they write n or gamma whatever you write ok. So, n value will be like 1.33 or some value will be given ok, it will be lower than that ok. And if you are making 1 it will be isothermal if you are making higher then it will be adiabatic.

So, it will be in between ok it will be like 1.33, but if you have gas natural gas the molecular weight will be also differing. So, if when molecular weight is different the k value or n value will be differing actually. So, normally air application only we say 1.4 and 1.33, but if you say methane and other gas in this case gamma or specific heat ratio constant value also will be like 1.

28, 1.3, 1.4 that monoatomic, diatomic values also will be different ok. So, if I want to change their value then maybe I will give the value or maybe I will say this is polytrophic process you take this value ok. So, you understood now single acting, reciprocating compressor how it is working ok. It will have one compression stroke, then delivery, then expansion, then suction, air will be fresh air will be entering into cylinder, then compress that fresh air, deliver again some small amount remaining clearance zone ok. So, TDC to BDC piston travelling that is called sweep volume ok this volume is called sweep volume V s or V sw this is called sweep volume ok.

And that small clearance is called clearance volume ok this is called clearance volume. So, I can write V c, V clearance, V sweep volume, V sw and total volume what is the total volume of cylinder actually V 1 at the point V 1 is total volume all right. So, piston is not delivering total volume actually some clearance is there right. Now, issue is that ok I will use. If I have double lifting cylinder then in that case same diagram will be there, but for other side other diagram you can draw, but single side if you can explain that is enough.

Now, again I will draw this reciprocating compressor piston is here, piston or plunger, plunger rod is here and I will have valve also I am not drawing I am making simplified diagram ok. Now, what happens let us say you have drawn PV diagram, you have no clearance then the curve will be like this ok. There is no clearance whatever air you are taking the same amount of delivering ok, but practically there will be some clearance. So, if you are creating very high pressure let us say this is no clearance. So, there is no clearance here ok, but when you have clearance what will happen piston will move up to this one because of this one ok.

You are delivering certain fluid then you are compressing and this one will get like this and you are getting like this 1, 2, 3, 4 ok this cycle will be like this. Now, if you want to get very high pressure, high pressure means P will be going up up up ok. So, when P is going up let us say I make like this ok. So, you see this I will do another figure this overlapping ok, I will do another figure.

So, initially I take air like this ok. Now, you want to get more pressure say initially you are taking 5 is to 5 ratio R T. Now, someone say no sir you take 20 R T value ratio value ok. So, ratio value means compressing compressing compressing compressing compressing ok. Now, this clearance volume also very high compressed gas small volume, but very high compressed. So, when you are expanding 1, 2, 3, 4 it was initially for low pressure case, but some other student says assist says ok no sir I will take 20 is to 1 or R T value 20.

So, what will happen you compress 1 to 2 dash then deliver 3 dash then 3 dash when

you are expanding it will come to here 4 dash. So, V so, V you see V changed. So, intake total amount is changed ok. Initially you had air 1 to 4 that volume you are sucking right, but because of very high compression ratio you are sucking small amount that means, total amount of fluid delivery will be low ok.

So, if you increase further air pressure. So, that compressed gas part will be expanding further. So, intake will be very low amount. So, that means, your finally, if you increase as a very 100 psi. So, in that case intake will be so low it will not be effective then what is the solution for that for that scientist found some solution.

Solution is that they will put intercool multiple cylinders ok. How they will put multiple cylinders? Let us say one cylinder is air ok, air will be taken air will be going through this again there will be another cylinder ok. So, cylinder 1 or pump 1 stage 1 stage 2 ok. Stage 1 you are getting certain fluid that fluid or air or natural gas because of compression temperature very high ok. So, very high temperature is there high temperature high volume if I reduce temperature volume will be going down ok.

So, performance will be increasing if I reduce temperature actually ok. Isothermal is better ok, if you can reach isothermal it is better, but we cannot do practically. So, that is why they will they will be putting multiple cylinders. So, first cylinder you compress certain amount then cool it down. So, then again you compress again cool it down again compress again cool again compress. So, that way they will be working like if you see cycle pumpers they are in hosters most probably they will have one cylinder ok.

If you watch properly ok cylinder there will be one pumping system here ok electrical connection will be there and there will lots of fins will be there compression system fins. Actually there will be multiple cylinder 2 or 3 cylinders will be there. So, one cylinder compressing intercooler will be there intercooler means cooling the air again put that same compressed air to another cylinder again compress. So, 1 to 5 bar you increase pressure reduce temperature again 5 bar to 10 bar maybe ok instead of going to single compression system. Single compression means it will be taking more energy and performance will be lower.

So, this will be they will be putting intercooler. So, here one stage two stage this is intercooler ok. So, whenever there will be any compression system it is a focusing centrifugal also there will be certain intercooler or reducing temperature ok. If you are not reducing your performance will be down ok. Now, how to represent this one in your PV diagram ok. So, in single stage case ok single stage case PV diagram was like this this is V this is P with intercooler right.

So, initially curve will be like this let us say I do not have any clearance volume initially as well ok. Now single stage this much of pressure P 1 P 2 we are raising, but some engineers came and they said put one intercooler. Intercooler means after first stage 1 2 you reduce temperature this much of energy will be saved actually again compress ok. So, PV diagram P into V P into V actually this is this area is called energy actually P d V you can remember the work formula P d V that much of work you are giving, but if you have intercooler.

So, this shaded portion actually is saving energy ok. So, your system performance will be increasing ok. So, if I draw this will be adiabatic adiabatic and isothermal will be like this because at certain point you are making the temperature almost normal. So, isothermal will be going like this adiabatic this is polytrophic ok. So, you understood? So, isobaric entry compression will be polytrophic exit will be isobaric isobar means same pressure ok. And what will be the in between pressure? So, in between pressure formula will be like this if I have this one P 3 if I have P 2.

So, P 2 will be P 1 by P 3 if I have two stage. So, normally this is formula you can use ok inlet pressure exit pressure multiplication square root. So, that will be in intermediate pressure the first stage and second stage in between what will be the pressure. So, this will be the formula ok for this performance you can use different pressure also, but for better performance you can use this formula.