Introduction to Fluid Machines, and Compressible Flow
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Lecture - 19
Reciprocating Pump

Good morning I welcome you to this session today, where I will discuss reciprocating pumps today's topic is reciprocating pump. We have already described at the beginning of the course, and the two types of fluid machines the fluid rather the fluid machines are classified depending upon their principle of operation into two categories; one is rotodynamic type, another is positive displacement type. Well, while the functioning of rotodynamic types depends on hydrodynamic principles of a continuous flow of fluid through the machine the principle of operation of a reciprocating machine or of a positive displacement type of machine depends on the change of volume of a certain amount of fluid contained within the machine.

So, reciprocating pump is a positive displacement type of machines, where the system boundary changes to cause the change in volume occupied by certain amount of fluid within the machine.

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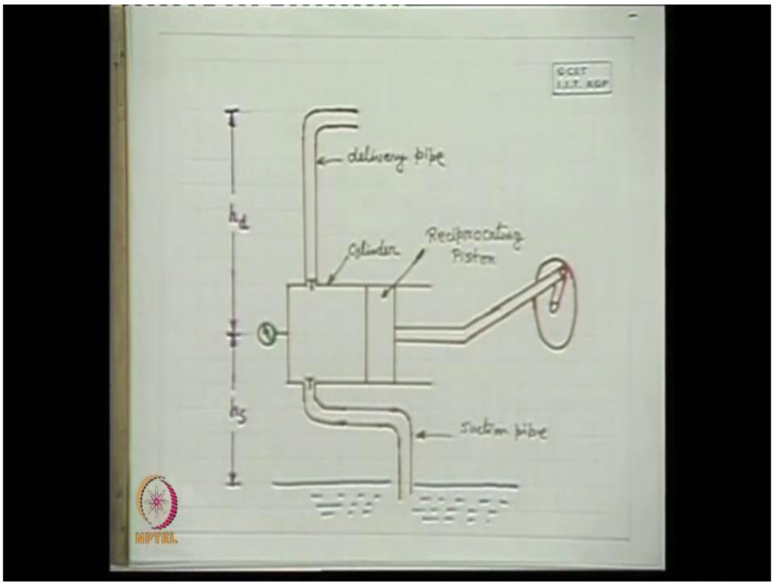

So, let us see what a reciprocating pump is, if you look to the diagram you see the reciprocating pump usually consists of a plunger or piston this is the plunger, and piston which reciprocates or executes reciprocating motion in a closely fitting cylinder; that means, this is the cylinder where a closely fitting plunger or piston executes a reciprocating motion.

Now, the reciprocating motion is executed between two extreme positions known as dead centers between which the plunger or piston executes the reciprocating motion. So, what happens is that due to this reciprocating motion of the piston the fluid within this piston cylinder is either compressed, and expanded both expansion, and compression, and expansion takes place, and the energy transfer takes place, because of this motion of this plunger or piston within the cylinder.

So, therefore, energy is fed from the outside energy is usually fed into the form of a rotation of a shaft here; that means, the shaft work the energy is mainly fed as an input in the form of shaft work with the rotation of the shaft, and this rotary motion is converted to the linear motion the reciprocating motion of the plunger through a very popular connecting rod crank mechanism. So, what happens is that when the plunger or the piston moves for example, it moves onwards; that means, this direction right direction in this figure rightwards, then the fluid inside this expands, and the pressure is reduced, because of which the fluid for example, the liquid here from the supply level or the sump as you know flows through this pipe which is the inlet pipe into the cylinder.

In this case the valve here shown this is the inlet valve this is the inlet valve this is the inlet valve inlet valve opens, because of the pressure differences the inlet valves are designed in such way that it automatically opens, because of the pressure difference created between the cylinder, and the outside the cylinder, and the liquid rushes through this pipe into the cylinder while the cylinder piston moves towards the left, then it pushes this liquid, and is volume is reduced, and ultimately high pressure is generated, because of which this valve opens this is the delivery valve, and the liquid at high pressure is supplied through the delivery pipe to the supply tank. So, this is the delivery pipe this way a reciprocating machine works is very simple principal of operation.

Now, the input energy is put here which is transmitted through the piston to the working fluid now this is the delivery head h d which is the height from the center of the pump to the supply to the overhead reservoir or supply reservoir, and this is the suction head h s which is the height of the supply water level or sump you can tell sump from the center line of the pump. So, the pump has to develop minimum h d plus h s amount which is known as the static lift this is the static lift as you know from your knowledge in centrifugal pump the static lift is h d plus h s; that means, if you neglect the velocity head, and the losses of the fluid; that means, if we consider the fluid to be in visit or liquid to be in visit, then the head the pump has to develop is h d plus h s that is simply the potential total change in the potential head which is the static lift h d plus h s.

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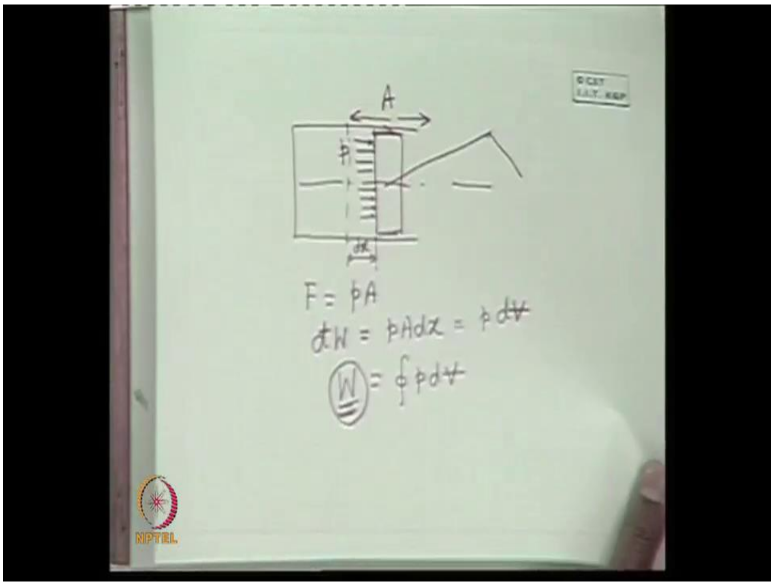

Now, you see that well that if we see that, then how can we find out now the energy transfer now if you see is very simple at any instant let the piston is at a position here let the piston is at this is the connecting rod crank thing let the piston is at a position here where at an instantaneous position the pressure of the liquid is p here in this analysis we will assume everything uniform all hydrodynamic parameters to be uniform within this fluid or within the liquid.

If the pressure is p, and the cross sectional area of the cylinder or piston whatever you say, because these are closely fit in with each other if this is area is a. So, therefore, the force exerted on this piston on the fluid by the piston if you take the free body of the entire fluid mass same thing p into a. So, that is the force exerted by the piston to the fluid in its motion motion may be either in this direction or in this direction. So, this is the force exerted by the piston on the fluid p is equal f is equal to p into a.

So, during a displacement let we consider an infinite small displacement of the piston surface by d x d x, then the work done let we consider the infinite small work done is equal to p a d x here we use d with a cut to distinguish it from the perfect differential as used in mathematics this we have known that from your thermodynamics that whenever we write an infinite small work transfer we give a symbol d with a cut p a d x. So, the total work during a cycle is the this we can write as p into d v. So, where d v is the volume we make a cut v, because earlier we have denoted v as the velocity. So, to distinguish it from the velocity we make it v cut which is the volume. So, dv is the volume served by the piston during its displacement of dx, well.

So, the cyclic integral of p d v; that means, if we make the integral p d v around a cycle of operation that will give the work input to the fluid during that cycle this is the work imparted to the fluid, and because of this work which is being impacted by the piston to the fluid its pressure is increased; that means, this work when it is imparted on the fluid the fluid gains its energy mainly in the form of pressure energy. So, the pressure of the fluid is increased.

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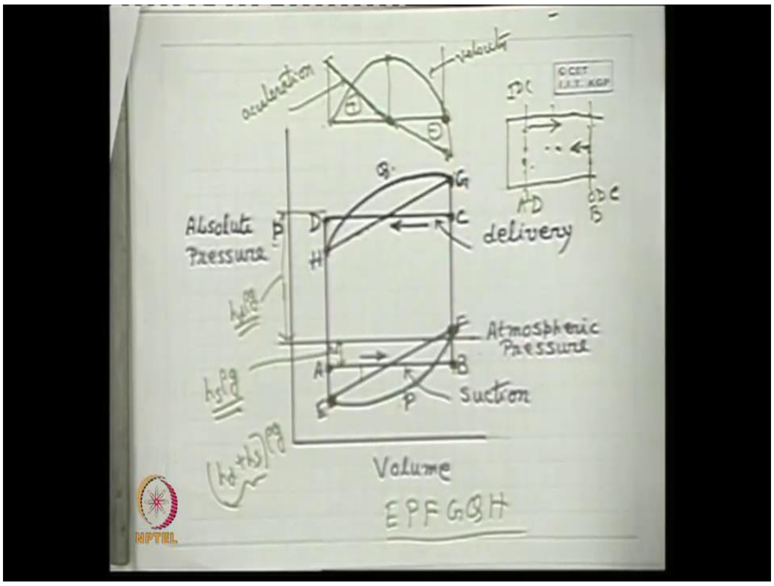

So, therefore, this quantity can be found out from a pressure volume diagram that is this work is the area of a pressure volume diagram. So, pressure volume. So, if we now see what should be a pressure volume diagram over a cycle this type of reciprocating machine we just see this way this is the typical pressure volume diagram.

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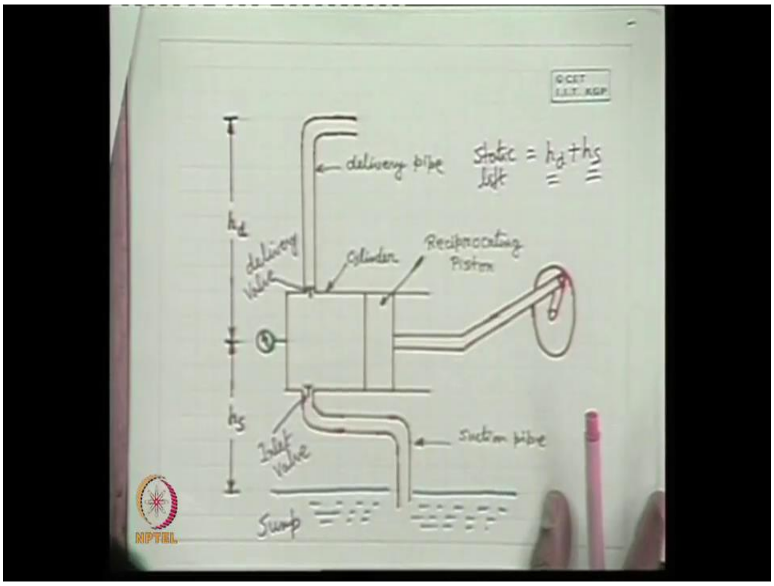

Now we see that If now the piston or if you see this diagram you see that for an incompressible liquid if we consider the fluid to be incompressible; that means, a perfect incompressible an ideal incompressible liquid what happens is that the pressure is filled instantaneously; that means, when the piston for example, from this position well when the piston starts moving rightwards from this position immediately the pressure is reduced to the value that is required by the determent or required by this head h s. So, that during the entire displacement of the piston when the liquid volume changes here the liquid volume increases there is no change in pressure as you know for an incompressible liquid the change in pressure due to change in volume is zero.

So, what happens, because of the energy input from the outside the pressure which is being imparted to the fluid body is sensed immediately similarly when the piston starts from another extreme position or another dead center here inwards; that means, in a left direction. So, immediately it pushes the liquid, if it is an incompressible immediately it will sense the pressure delivery pressure which is required that h d. So, while it will push the piston will push the liquid its volume will be reduced at a constant pressure this is the characteristic feature of a ideally incompressible liquid ideally or ideal incompressible fluid. So, that the pressure is sensed instantaneously, and with the change in the volume there will be no change in the pressure.

So, if you take this for an ideal incompressible liquid, then we see that the ideal form of the diagram will be a b c d this rectangle a b c d; that means, the suction will take place during the reciprocating motion of the piston from one deads say inner dead let us see that these extreme positions inside the cylinder is known as inner dead center position while the extreme position in this side the outside is known as the outside dead center position let us fix these as is this is inner dead center I d c, and let this is o d c.

So, therefore, during the motion from I d c to o d c the suction takes place where the volume of this liquid increases at constant pressure, and this pressure is below the atmospheric pressure, and what will be the magnitude of this pressure if we consider the liquid to be ideal; that means, there is no frictional loss, and also you neglect the velocity head the pressure here will be less from the atmosphere by this amount h s if we apply the bernoulli's equation at this point, and this point we will see the pressure here will be less than the atmospheric pressure by the amount h s; that means, the pressure here will be atmospheric pressure minus h s times the rho g if we simply write this we will get that.

So, therefore, this pressure corresponds to this pressure corresponds to in the pressure unit h s rho g; obviously, if we neglect the frictional losses, and the velocity head. So, it is constant during this suction (( )). So, b point corresponds to the outer dead center position of the piston let me draw this diagram here. So, this is the inner dead center position of the piston this is the outer dead center position this is a this is b. So, from the b point b the piston reverses its direction. So, it initially is initially moves from I d c to o d c now from o d c to inverse direction again to I d c. So, when you reverses the direction immediately the pressure is sensed, and goes upto the point raises upto the point rises upto the point c that is the delivery pressure this is the characteristics of an incompressible liquid or incompressible fluid an ideal incompressible fluid.

Then what happen during its movement from b to a that is o d c to I d c the delivery will take place, because the delivery valve will be open, and the flow will take place through the delivery pipe at a constant pressure while the volume of the liquid will change, and ultimately it will come to a point d again d coincides with this a, so a and d d again. So, this is b, and c b, and c. So, d again when it will again reverse the direction. So, these are the extreme points. So, from d again immediately the pressure will fall. So, these lines are vertical here. So, d, and a are the points at the corresponding to inner dead center positions d is the point that the end of the delivery stroke, and a is the point the beginning of the suction stroke.

Similarly, b is the point at the outer dead center position when the suction stroke is complete, then immediately the piston reverses its direction, and the delivery pressure is immediately sensed by the entire liquid, and c is the starting point of the delivery stroke. So, between b, and c there is no change in volume. So, there is instantaneous change in the pressure, and then c to d is the delivery takes place at constant pressure when the fluid volume is reduced.

So, therefore, we can appreciate that if we considered the fluid or the liquid to be incompressible perfectly incompressible, then the ideal diagram is a rectangle a b c d now this diagram will be change, because of two factors first of all we consider one very important thing that the piston you see this figure while the piston moves the motion of the piston is not uniform there is both acceleration, and deceleration of the piston as it executes the reciprocating motion from I d c to o d c.

So, therefore, what happens the piston at the beginning of a stroke undergoes acceleration, and the end of the stroke it undergoes deceleration for example, when it starts from I d c the suction stroke its velocity increases, and it comes somewhere maximum which is at the middle of the stroke two strokes depending upon certain assumptions, and then again it reduces, and becomes zero at the outer dead center position. So, and one stroke is finish; that means, the suction stroke again when it comes from outer dead center position from a zero velocity its velocity increases, and reaches a maximum in between which is in the mid of the stroke, and then again it falls to zero; that means, it suffers deceleration to I d c.

So, this type of motion is executed by the piston which is purely a simple harmonic motion provided we neglect the effects of solid frictions, and this is valid if the length of the connecting rod is much higher than the length of the crank. So, under these assumptions that you know from your theory of kinematics that we can considered this reciprocating motion to be an simple harmonic motion with zero velocities at the two extreme position dead center positions, and the maximum velocity at the middle; that means, if we draw this velocity diagram. So, this will be zero there will be zero, and this is maximum at the middle this type of trigonometric functions are there is a simple harmonic motion.

Similarly, if we see the accelerations accelerations will be zero here, and this will be maximum at this two point; that means, acceleration will be like this initially there will be accelerations, then accelerations will be zero, and there will be decelerations there will be this is deceleration this is acceleration. So, the acceleration, and this is the velocity this is the velocity curve velocity, and this is the acceleration curve. So, this type of acceleration acceleration curve. So, this type of motion is executed by the piston.

So, therefore, we see at the beginning of its stroke suction stroke the piston has to provide or the machine has to provide an additional head for the acceleration of the liquid; that means, to accelerate the liquid. So, liquid now when the piston executes an acceleration, and deceleration the liquid in contact with the piston within the cylinder also executes acceleration, and deceleration, and not only the liquid in the piston the liquid in that pipes also, because this is a continuous mass. So, acceleration, and deceleration is suffered by the liquid.

So, therefore, at the beginning of the suction stroke the piston has to create more pressure differential to provide for this acceleration of the liquid. So, the pressure difference is between this cylinder, and this supply tank has to be more which means that a suction pressure has to go down. So, the point a further goes down to point e similarly what happens after this mid stroke the piston suffers deceleration; that means, the liquid within the cylinder, and also within the pipe suffers deceleration for which a rise in the pressure is needed a rise in the pressure is needed at the latter part of the suction stroke for which the point b shifts to the point f.

And in an ideal case as I have told that if we consider this as a simple harmonic motion where the acceleration is proportional linearly proportional to the displacement this e f is a linear one; that means, this is a straight line. So, we can join e f by a straight line this will be in a straight line. So, this way the suction stroke a b which was initially parallel to the volume axis will now become like this e f a straight line one. So, this is the first modification that is, because of the acceleration, and deceleration of the piston that is non uniform motion of the piston.

Student: Sir, repeat this once more sir why it comes down.

This one.

Student: Yes sir.

Yes this is, because the piston initially what we thought that this line was done this line was made by considering the piston wheel has to provide only a constant suction head determined by h s this h s is fixed. So, therefore, if we neglect the velocity head or the losses, then the suction head has to be provide h s rho g a constant suction head; that means, the pressure within the cylinder will be below the atmospheric pressure by this amount h s rho g it is clear.

Now, when the acceleration has took take place now you consider the motion of the liquid liquid column liquid within the suction pipe, and the cylinder now what happens at the initial part of the motion of the piston in the suction stroke the liquid in this part has to be accelerated; that means, to provide this additional acceleration; that means, this inertia force associated with this acceleration the pressure difference between this cylinder, and this has to be more than that h s rho g; that means, piston has to provide more suction head; that means, a point has to go down.

Similar is the case at the end when deceleration takes place you understand which needs that the cylinder pressures must rise cylinder pressure must rise. So, it shifted from b to f. So, the suction head will vary from during the suction stroke from e to f it is minimum at this e starting point, and goes on increasing, and is a maximum at f this is, because of the non uniform motion executed by the piston as it is shown it is acceleration at the first part of the stroke, and the latter part of the stroke the two equal half this is the middle of the stroke under ideal assumptions. So, you consider a simple harmonic motion, and the latter part is deceleration, and this is positive acceleration this is the negative acceleration.

Student: Sir

Well

Student: (( )) be greater than the atmospheric.

O that may be that may be that may not be that may be that may not be, but that depends, because the flow takes place, because of the energy difference sometimes that depends upon the speed of the machine type of operations depending upon the total head the static lift it may or may not be. So, this changes from e to f it may or may not be mainly depends upon the very good question mainly depends upon the speed of the well speed of the pump speed of the machine.

Now, again if we consider the velocity head, and the losses now we modify this diagram considering the velocity head, and the losses. So, you will see that at any point the suction pressure has to fall much more; that means, the pressure differences has to be more to provide for the velocity head that is the kinetic energy of the fluid, and also the frictional losses it has to overcome the losses while it flows through that which consists of both the major, and minor losses; that means, the frictional loss, and the losses due to change in the flow in the pipe that is pipe bins. So, to take care of this hydrodynamic losses, and the velocity heads this is again modified like this why we get this qualitative train, because it is zero at these two points, because at these two dead center points; that means, this two points or this two points the velocities are zero.

So, therefore, the contribution of velocity head, and the losses the hydrodynamic losses are zero. So, therefore, this is zero, and this also increases when the velocity increases, and this decreases when the velocity decreases when the velocity decreases in this part of the stroke he velocity head also; obviously, decreases, because velocity decreases means the velocity head decreases, and similarly the frictional losses also decreases. So, therefore, this curve takes the increasing, and decreasing pattern with zero at these two dead center positions.

So, you finally, see that in consideration of the non uniform motion of the piston, and due to that the non uniform motion of the fluid in the cylinder, and the pipelines the a b this the ideal suction line is shifted to e f, and finally, in consideration of the velocity head, and he frictional losses it changes to e p f. So, e p f is the real suction stroke suction stroke in real field; that means, in practice e p f is the suction stroke represent the suction stroke.

Similarly, the delivery stroke is also modified similarly the delivery stroke is also modified from c d to g q h similar thing is that at the start of the delivery stroke again if you see it is just the reverse the acceleration takes place. So, when the delivery stroke starts from the point b now this is changed to point f. So, it starts acceleration to provide the acceleration of the liquid the piston has to provide an additional head which means again if you see this the pressure difference between the piston, and the outside; that means, has to be more than that given by this head earlier, we consider only this head h d rho g; that means, earlier this pressure was earlier this pressure was determined by h d. So, this was h d p a this is the atmospheric pressure. So, this was h d rho g in consideration of without consideration of velocity head, and any losses. So, simply h d rho; that means, if you write the bernoulli's equation between this point, and any point outside we will see that the pressure here has to be more than the atmosphere by this amount h d; that means, h d rho g.

So, this this height is h d rho g this was h s rho g; that means, this height of the rectangle was h d plus h s rho g that is the static lift of the pump now this if this pressure has to be more, because the pressure differential has to be more to provide the acceleration in the first part of the delivery stroke n the similar fashion as we did for suction stroke the delivery point c will be shifted to give more pressure to indicate more pressure within the cylinder to g again this will fall gradually, because the acceleration is decreasing similarly in the first part the acceleration is decreased; that means, the it comes to zero, and then again it is deceleration; that means, the deceleration; that means, the final point will be shifted like that; that means, the pressure within the cylinder will be lower than that of the ideal point this is, because of the deceleration of the liquid the similar way as it was done in case of suction.

So, this curves become g h which can be thought of a straight line in case of an simple harmonic motion executed by the cylinder, then taking care of the frictional losses, and the velocity head of the fluid flowing through the delivery pipe this curve is again modified as g q h. So, therefore, we see the final curve becomes e p f g q h. So, e p f g q h is the final pressure volume diagram considering the fluid to be incompressible that part is still there; that means, the pressure is sensed immediately the any pressure pulse generated in an incompressible fluid you can take it is a action of fluid flow that the incompressible fluid any pressure pulse is sensed instatneously by entire fluid body similarly here also this instantaneous fall from h to e here the instantaneous rise from f to g. So, therefore, finally, we get e p f g q h as the pressure volume diagram well all right.

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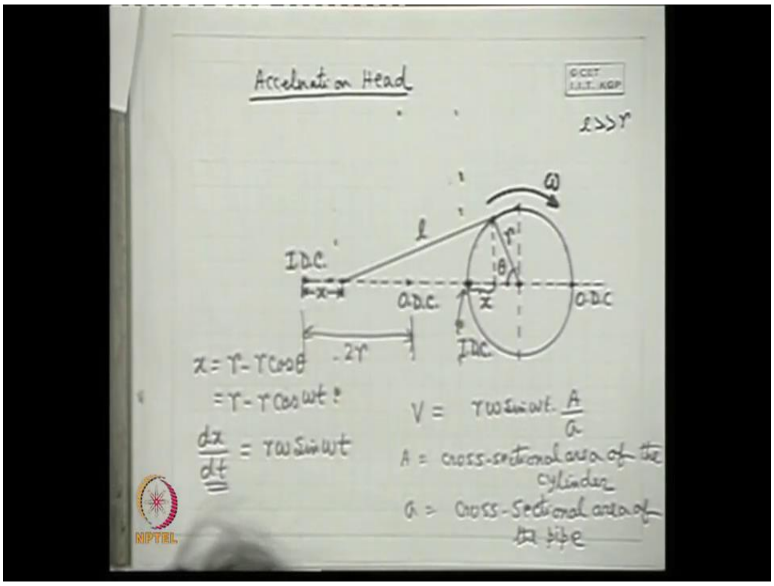

Now, next you see the most o o, this has become like this most important thing now how to find out these accelerations now we have come to know that the due to this accelerating motion of this piston from I d c to o d c, and o d c to I d c some additional head has to be generated by the piston during the suction, and delivery stroke these are the additional head. So, you seen the delivery stroke this is the additional head which is more than the, then piston has to deliver it to deliver a head which is more than that of the that determent from this static lift; that means, h d similarly at the end of the delivery stroke this is negative. So, piston has to generate a less head. So, continuously we see considering this plus, and minus we can tell that additional head piston has to generate due to the non uniform motion or acceleration or deceleration of the piston over, and above the head determent from the staid lift.

Similarly, in case of suction also the additional head has to be generated due to acceleration of the piston or deceleration of the piston this head is known as acceleration heads now we will find out the expression of this acceleration head this is known as acceleration head head means you know the energy per unit weight. So, piston has to generate an additional acceleration head even if the fluid is in vats this is true even if the fluid is in visit; that means, if the piston could have executed a uniform motion for which the liquid in the pipeline, and in the cylinder flow with uniform velocity, then if we consider the liquid to be in visit without any loss, then the head to be developed at the delivery stroke is determined simply by h d, and the head to be created during the suction that is the below the atmospheric pressure was determine by h s only if we neglect the flow velocity.

But due to the acceleration, and deceleration of the piston the additional head; that means, additional energy has to be given or created o provide the inertia force, because of this acceleration. So, this acceleration, and declaration has to be considered providing in providing an additional heads even if the fluid is in visit that is more important concept. So, even if the fluid is in visit. So, therefore, this acceleration head we understand has to be provided by the pump in both suction, and delivery strokes.

Let us find out an analytical expression of this acceleration head here we see that this is the angular velocity of the crank which is executing a rotary motion this is the shaft as you know that crankshaft where the mechanical energy is put in the form of shaft work now you consider a crank a sorry connecting rod whose length is l, and the length of the crank is r the radius. So, if l is very greater than r, then this simple harmonic motion we can consider from I d c to o d c what is I d c this is inner dead center position; that means, when this crank is at this position this corresponding corresponds to inner dead center position where the piston is here.

Similarly, when this crank moves one eighty degree goes here is a complete stroke two r the piston is here at outer dead center; that means, the distance from inner dead to outer dead center in the piston is automatically the two r, and is associated with one eighty degree movement of the crank this is the half the revolution. So, the next half is again from o d c to I d c. So, therefore, one revolution of the crank completes one cycle its very simple; that means, two reciprocating motions one is suction another is delivery.

Now, let us consider during this suction stroke the piston has moved a distance from I d c by an amount of time during which the crank has rotted from this position when it was at I d c it was here. So, with respect to this line the crank has rotated by an angle theta. So, therefore, we can see from simple geometry this if this be the x that is a displacement of the crank along this line this is same as this x. So, this x therefore, can be written as from here this is r. So, r minus r cos theta r minus r cos theta well. So, this theta is can be expressed in terms of the angular speed omega t where t is the time take for piston to move the distance x or the crank to rotate by an angle theta.

So, therefore, if we want to find out the velocity of the piston; that means, differentiate x with t it is very simple school level thing. So, we take this r omega sine omega t well derivative of cos omega t is minus sine omega t. So, this is the velocity of the piston now here we assume again, because of the incompressible fluid that the entire liquid volume within the cylinder as a as a mass as a solid mass assumes the piston velocity just like a solid body motion; that means, this liquid within the cylinder assumes the motion of the or velocity of the piston.

So, therefore, we can ascribe this velocity as the velocity of the liquid within the cylinder. So, if this be the velocity of the liquid within the cylinder what will be the velocity of the liquid in the pipelines. So, velocity of the liquid in the pipelines let us consider this as v any pipe delivery pipe or suction pipe from the continuity we can write r omega sine omega t into a by a where a is the cross sectional area of cross sectional area of cylinder of the cylinder cross sectional area of the cylinder, and a is the cross sectional area sectional area cross sectional area of the pipe it may be any pipe suction or delivery pipe.

So, if the area of the pipe is a, then from the continuity we can find out that this is the velocity f the liquid in the pipeline why we are interested why we are interested in the velocity in the pipeline this is, because the velocity head or the acceleration head n the pipeline is much more than in the cylinder this is, because the cylinder area is much much higher than the area cross sectional area of this pipe. So, velocity, and the subsequent accelerations are much more in these pipes as compared to the that in the cylinder.

So, therefore, we are finding out the acceleration head, because of the acceleration of the fluid in the pipes. Now this is the velocity now next task is very simple to find out the acceleration.

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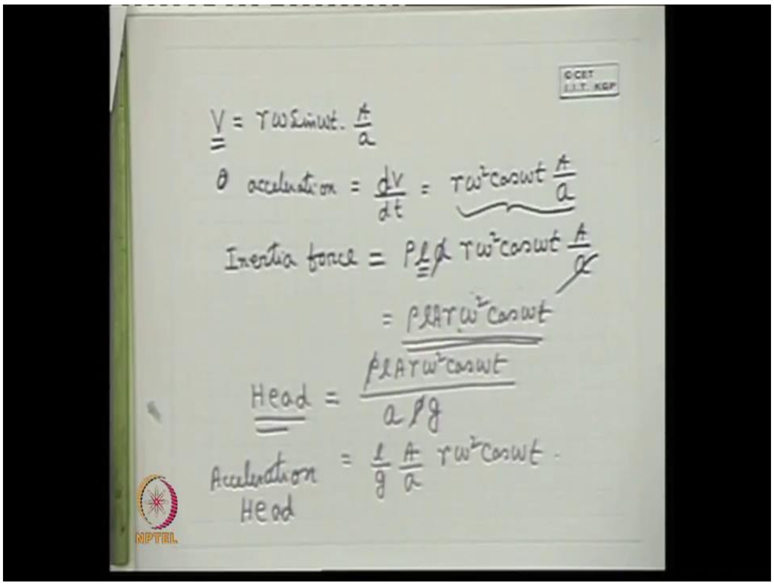

So, again I write velocity is equal to the velocity r omega sine omega t into this is the velocity in the pipeline this v is the velocity in the pipeline r omega sine omega t a by a. So, what is acceleration in the pipeline o. So, this is a 8is the cross sectional area. So, acceleration in the pipeline right acceleration without nomenclature acceleration is equal to again differentiate it; that means, d v d t r omega square again it becomes the cosine function cos omega t a by a. So, this is the acceleration of the liquid as a whole the entire liquid mass entire liquid mass in the pipes.

So, what is the inertia force; that means, if the liquid mass has to be accelerated by this acceleration what should be the inertia force that is equal to mass times this acceleration. So, mass of the liquid column is rho l a where l is the length of the liquid column; that means, the total length of the suction or delivery pipe a is the corresponding cross sectional area r omega square cos a very simple analysis here a by a. So, a a cancels; that means, this is the force rho l r omega square cos omega t I take a here rho l a r omega square cos omega t.

So, this is the inertia force, then additional force that has to be generated for acceleration of the fluid. So, this force creates say head. So, due to this force the head that is created is what from this force which is being acted on the fluid or which has to be acted which has is necessary for the fluid to cause its acceleration corresponds to a head, what is that head is force how to find out the corresponding head from the force force by area is the pressure in the.

Capital A.

Capital A divided by a that is the pressure what is wrong in it pressure time divided by rho g. So, that is the head that is the pressure energy. So, this is the. So, therefore, rho rho cancels. So, we can write l by g a by a r omega square cos omega t. So, this is the acceleration head acceleration head acceleration head. So, therefore, we see the acceleration head is l by g a by a r omega square cos omega t if any problem you just ask me please any problem you can ask me. So, this is the acceleration head that is developed in the pipes well ok.

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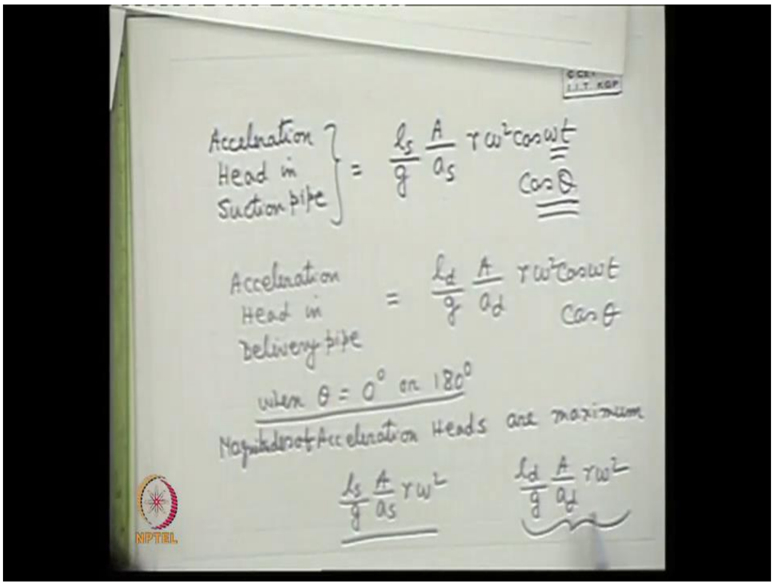

Now, therefore, if we replace by the suction line dimensions hen the acceleration head in suction pipe we can write acceleration acceleration head in suction pipe is equal to l s l s is the length of this, this a is the cylinder area a s length of the suction pipe a is the cross sectional area of the suction pipe other thing remaining the same similarly the acceleration head in delivery pipe in delivery pipe that is equal to l d the corresponding dimensions of the delivery pipe a by a d r omega square.

Now, from this mathematical expression it is clear that this will be zero these acceleration heads these acceleration heads will be zero at the dead center positions, then will be maximum in the middle. So, at the both dead center position when this will be theta rather cos theta from theta you can write. So, when better you replace theta it will be better. So, if you want to find out the acceleration head variation with crank angle theta. So, theta is zero, and theta is one eighty degree you see this is maximum, and then it is zero at the middle.

So, therefore, we see the acceleration is maximum at the two dead center positions. So, when theta is zero or one eighty degree the acceleration heads are maximum acceleration heads are maximum or minimum maximum the magnitude of acceleration heads are maximum rather I write magnitude magnitudes of acceleration heads are maximum. So, therefore, at the beginning of suction stroke the acceleration head is l s by g a by a s r omega square similarly at the beginning of the delivery stroke this is l d by g a by a d r omega square this is the acceleration head.

So, this acceleration head goes on decreasing as the theta is increased from zero degree to one eighty degree similarly in the delivery stroke starting from theta is equal to one eighty degree the acceleration head is maximum by this amount, and then it goes on reducing; that means, if you now see this figure we see that this a e this is the this value l s by g sorry a by a s into r omega r omega square similarly this one here also this is the maximum this one is l d y g a by a d r omega square similarly this is this similarly at the end also this is equal to this this is the negative one. So, it increases the pressure similarly here it is positive one. So, delivery pressure is increased from that at c d level which is determined only by the h d, and then again it becomes negative. So, that it is decreased. So, the d h is also equal to this amount; that means, this is less than that of the h d rho g.

So, this way we can find out the acceleration head this is the additional head over, and above the determent from this static lift that has to be provided by the machine or the pump for the pumping action to be maintained well. So, this is please any question. No sir.

Thank you.