

Mining Machinery
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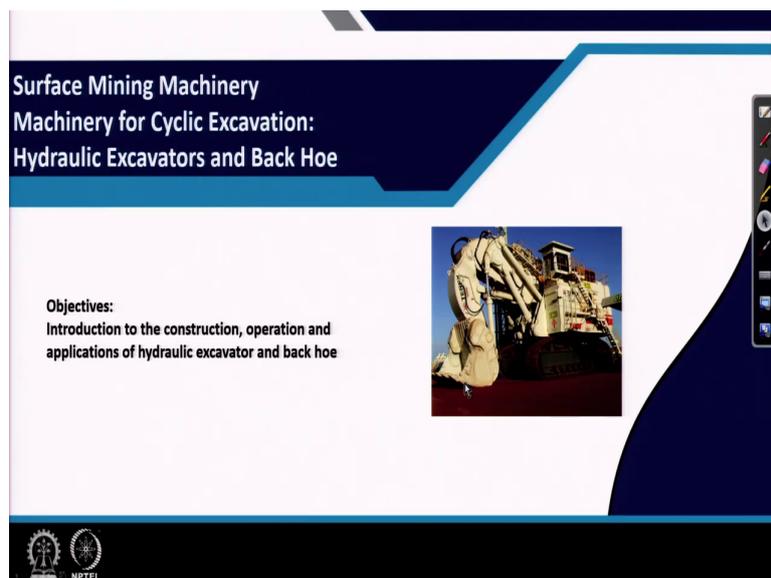
Module – 05

Lecture – 19

Surface Mining Machinery: Machinery for Cyclic Excavation: Hydraulic Excavators and Back Hoe

Welcome back in our discussions on Surface Mining Machinery that we have been talking about this Machinery for Cyclic Excavation. We have introduced you what is electric rope shovel and today we will be discussing on Hydraulic Excavators and Back Hoe. These are the main working force or the primary surface mining machinery today being used.

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Surface Mining Machinery
Machinery for Cyclic Excavation:
Hydraulic Excavators and Back Hoe

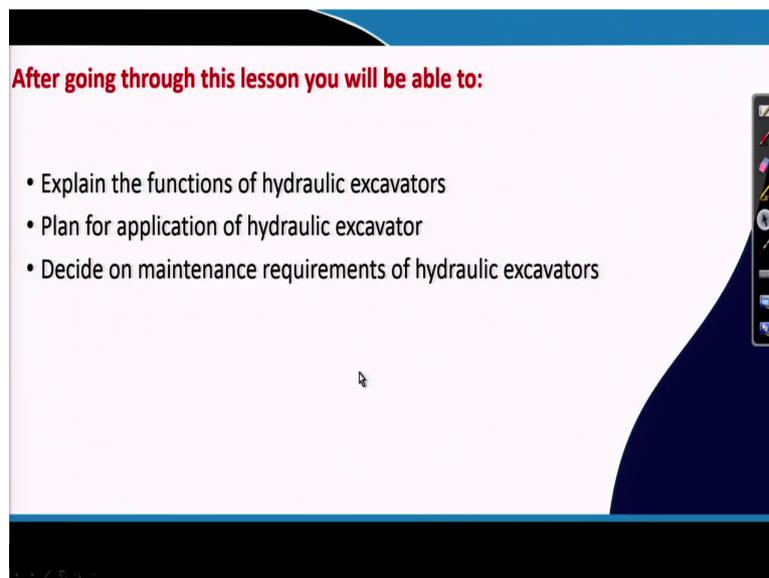
Objectives:
Introduction to the construction, operation and applications of hydraulic excavator and back hoe



NPTEL

In the photograph here you are seeing the world's largest hydraulic excavator that is giant under a gigantic machine which is being used in surface mining, because you know that modern surface mining are for all high capacity. So, there very large capacity machineries are deployed. So, you will be learning about this big machines about their construction operation and a little bit about maintenance.

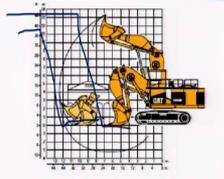
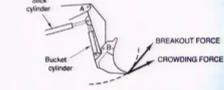
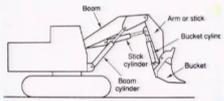
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So, that after this class you should be able to explain the functions of hydraulic excavators, what are the work it does, then you should be able to plan for application of hydraulic excavators. If given a mining situation you should be able to decide on that what type of and which type of hydraulic excavators you will need to use. And also you will have to be able to plan that in how you will be investing for maintenance of these machines in the field.

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Components



Components:

1. Hydraulic System:
 1. Hyd Pump
 2. Hyd Motor
 3. Valves
 4. Actuators
 5. Pipe lines
2. Diesel Engine
3. Hydraulic Control System
4. Brakes
5. Steering System
6. Swing System
7. Travelling System
8. Crowding System

The largest excavator available is the O&K(Orenstein & Koppel) RH400, it weighs in excess of 2,160,510 pounds (979,990 kg), has 4500 hp and has a bucket size of about 52.0 m³.



<http://www.answers.com/topic/excavator#ixzz1VR2F5gFd>

So, let us talk about that this machine as you have seen the world's largest excavator which is a O and K Orenstein, this O and K originally made this machine and it is having total weight of more than 1000 ton such a huge machine which has got this bucket with a capacity of 52 meter cube.

You can imagine how big this is now such a big machines to work there are main components you can see here schematically that how that machine this big machine or this machine is basically what. It is basically you are having a bucket here just schematically it is shown as a bucket, this bucket is operated by a bucket cylinder and there these cylinders is also there is a arm or the stick the movement of this stick is done by the stick cylinder and then there is a boom that boom is moved by a boom cylinder.

So, basically this front part which you are seeing this has got a bucket cylinder, this is stick cylinder and the boom cylinder. So, by this the front attachment of this main your that this undercarriage and there is the super structure which is exactly mounted on a turntable which can give a swinging operation.

Now, as you can see you will have to try to draw you should be able to while we are discussing the functions of this machine, this particular drawing should be very it should be at your hand you practice this just start with giving this line first that then you draw this part, then you give this connecting cylinders then you draw the bucket and then you draw this it is in this sequence if you draw it will not take more than 1 minute to draw such a figure.

Now, why this is here the beauty of this big machine is it has got a wristing action; that means, the front bucket it is just like our wrist it can give a wristing motion which the electric rope shovel bucket cannot give. Now when you give this wristing that is why it is getting another force which is called your breakout force. In case of your electric rope shovel you are giving this crowding actions when you are pushing this to that, but after that you are just hoisting.

But here you can push then by giving this wristing action you can properly fill the bucket that is what is a beauty of this machine and you can see that this diagram which you will find always with the manufacturer leaflet.

It gives this your the zone in which the bucket will be moving or this is the area in which this bucket can work in a designing of this machine and also your designing your face you can take care of that where the bench should be there and how the bench should be oriented. So, that you can use this machine.

So, while deciding for a particular application and then for a particular mine you need to see whether that is exactly if your that bench which you will be creating over here this bench whether you will want to work this bench or you want to work say here if you want to want to

work at this type of bench. That means, which will be the range of its working that can be decided with the help of this diagram which are available with the your manufacturer leaflet.

So, now you must know that what are these components, as we said earlier every machine has got some functional element and there are some power source and there are some control elements. Now the here this machine is basically the whole operation is done by a hydraulically.

You can see there that the machine will be having an engine and that engine will be running number of pumps, that which this pump will be pumping the fluid or giving the pressures the generating pressures on the fluid which will be working different actuators.

So, basically this machine is having the main power source as an engine which can be a diesel engine or can be an electric motor, from there it will be working this hydraulic system where we will be having different type of pumps. There will be hydraulic motor valve actuator and pipeline, this comprises the hydraulic system.

Then there is a hydraulic control system is there by which that is exactly you will be having a joystick type of operations you will be controlling the different valves and then different circuit will get fulfilled, which you have studied in your hydraulics introductions we have talked about.

Now, by that for running of the machines what we will have to have you will have to have a brake, that whenever any machine is there whether you are swinging the machine that time you want to apply a brake. Suppose a big rock is coming you do not want to go in that directions you should brake and then you can reverse, those type of control systems are there for that. There is a steering system as you can see this machine is a crawler mounted machine.

So, whatever we have talked about that steering of a dozer that steering of your electric rope shovel, here also you can change the directions while it is moving you can control the speed of one and you can give a turning to the machine. Similarly it has got a swinging system that

is your hydraulic circuit is arranged in such a way that the swing motor will be rotating and you can make this machine to move about an axis.

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Components

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2. Diesel Engine
3. Hydraulic Control System
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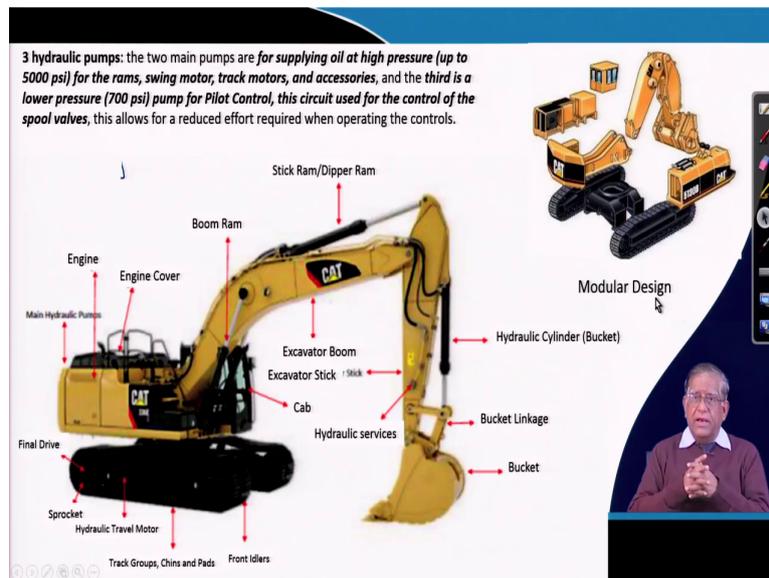
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So, that is exactly about this axis this machine can give a swinging motion or rotations. So, for that this portion is the turntable where we will be having a sun gear and then your this upper portion it can move over here. So, this is your undercarriage this superstructures can swing above that machine.

So now, you understand this there is a crowding system, means how you will be pushing this; that means, by movement of this arm or arm stick and the bucket, you can give a motion push motion of the bucket towards the material you are collecting. So, this is what a hydraulic excavator is.

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So, now this you see little bit more about this machine, these machines will be having as I said the engine will be running mainly 3 pumps, that this pump for supplying the oil at a high pressure that will it will go up to 5000 psi that pressure and there will be the that mainly the swing motor for swinging operation track motor for the for movement and then there are number of accessory motions which is there that is given by that pump.

And there is some low pressure pump is there for the control circuits and all for just joystick movement for the brake movement there you do not require a very high pressure pump, so there is a separate pump for that. As you can understand depending on the weight of the machine when you have to move over there really very high energy is required for that to give the momentum to this.

So, now if you see once again that you have seen the components you just again recapitulate what you have learned in the previous slide, I told you about the bucket. Now there is a to get the wringing operation of this bucket we have got a link mechanism here. So that means, by motion of this your this link will be here there is a you can see the three bar link here, then if you have studied in your mechanics that how different exactly the motion of this tip.

This tip will be following what locus that can be determined by this if this is the your pivot point here by movement of this links can give different locus of this tip or the front part of it. So, this is how it is controlled with this hydraulic cylinder.

Now here we are seeing again stick ram or dipper ram, that is exactly ram is when your this your piston is about more than one half time that your cylinder head that is a that hydraulic actuators this is sometimes it is called as a arm cylinder or it is sometime called a stick ram. Or there is a boom ram that is your boom cylinders in sometimes you say here this part is called your boom and this is often referred to as a gooseneck.

You can see here it is just like a gooseneck, because the goose has got this beautiful motion and movement and that from the nature has been designed over here and incorporated. Now this your excavator this stick you can see this is called the stick or arm, then you have got the cabin located over here which is ergonomically designed engine is given over here and their main hydraulic pump is or hydraulic power pack is here.

And then there is the from there this crawler is driven for the crawler final drive is coming to the sprocket over here, this sprocket is rotated. So, that is exactly the rear sprocket is driven, the front sprocket is idler because of this rotation this chain will be making it to rotate it over here. So, that your this hydraulic travel motor is located over here from there the power is coming to the sprocket and it is done.

So, all these components are available the manufacture, manufacture it as a modular design. Normally 8 parts these things will be designed and transported to your site and in the site if you procure a the hydraulic excavator you will have to get in your mine a particular place

earmarked for erection yard, there it does machine these components will be coming you will have to put it over there then you assemble it then you run it over there. So, this is the way how the operations are carried out.

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Schematic Diagram

Hydraulic front shovels with a swiveling (curling) bucket

Back Hoe

1. a boom
2. (rotation axis O1), a stick
3. (rotation axis O2), a bucket
4. (rotation axis O3). Rotation relative to O1, O2, O3 axes is provided by a hydraulic cylinder of hoist and descent boom movement
5. a stick ~~crowd~~ cylinder
6. a bucket swiveling cylinder. The bucket swiveling cylinder can be attached either to the stick or the boom.

(A small inset video of a man speaking is visible in the bottom right corner of the slide.)

Now, coming to the schematic diagram of the figure which you have seen, you can see here where is the rotation taking place. So, this diagram here I am introducing to you this back hoe. Now you have seen the previous diagram this is a back hoe and then this was in excavator; that means, how the bucket is working over here it is giving a forward and then this is the other bucket is giving a backward.

So, this is when it is cutting back it is called your back hoe and the other one is front, that is your shovel. Now in this is the front shovel and this is your back hoe. Now for both the

operations only the portions how the bucket is fitted and the design of the bucket is different rest of the things are similar.

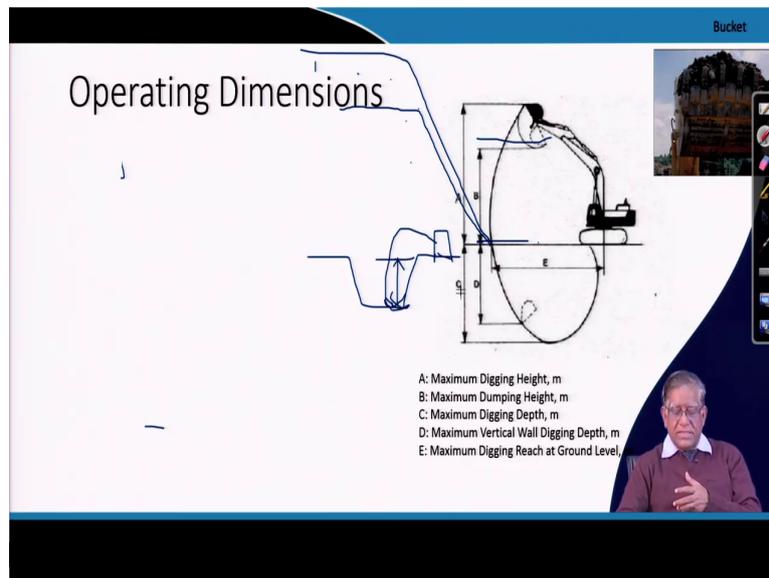
Now, what is here mainly there is a where the rotation is taking place, so that means while designing the machine you will have to get this pivot point about which this motion is there. You can see the boom is moving about this one this is the axis on which it is moving. So, your movement is in the vertical axis, so that means there will be a point on which it will be moving like this.

So, this point how you will be the load will be transferred to this point and what type of system or component will have to be there, so that under that load with there is no much wear and tear of this and it can survive better. So, this is the very critical point where it is moving. Similarly the front arm that is this arm it is exactly moving against this O 2 or in case of here this is the O 2 about which this arm is moving, so then the other that your bucket is moving about this point.

So, you can see here the differences here we are having a gooseneck here we are having a boom which is a straight. So, depending on the design it will be changing. So, mainly now have you understood now there what are the different type of powered motions are there in this machines. If you see that wherever this rotation symbol is shown that these are the powered motions, other powered motion is your this crawler will be moving that is your powered motion and then this will be swinging.

So, you can see that you can make a list of the powered motions or the powered functions and for that those components will have to be designed in such a way that the what will be the power requirement that can be calculated and your total use of energy in this machine can be optimized, when your these components are designed based on their function and then that is where the main analysis work are done.

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So, you can find out here this operating dimensions this is important, as I was telling you that your depending on the that your working site you will have to make this select which machines will be useful for you. Now that machine has got certain operating dimensions, you must know about that what is the digging height; that means, it cannot dig a face that is your this slope or that as your working face cannot be like this.

It is a maximum it can if this is a slope angle you are doing you will be having here. So, up to here it can cut to certain extents, but there is a restrictions here; that means, your this machines will have to be located over here then only your this distance you will be able to reach it over here. So, that is why that what is the maximum height it can cut will be depending on what is the maximum digging height it has got.

Now sometimes of course, depending on the soil type if you can cut it over here sometime if this is loose material it will automatically come down and you can negotiate that is the operational things depending on the site. But you need to know that the machine by design how much maximum digging height is given and what is maximum dumping height; that means, you will be loading it onto a dump truck.

Now, while loading onto the dump truck you will have to see that this dumping height that is the lower point that is your dump truck, if the height is going up to here this will get touching and there will be a bang on the dumper.

So, that is why the dumpers should not be having it is height more than this dumping height of the shovel. So, that way in your real applications you will have to make your dumper compatible with the machine. So, that is why the machine parameters are important that other thing is the maximum digging depth.

So, while standing over here how much you can dig. Suppose you want to make a trench like this your machine is sitting over here. So, by seating this machine over here you can do a cutting over from here, so this means you can make a this type of depth of cut you can make. So, this is possible when this you know that what is the digging depth.

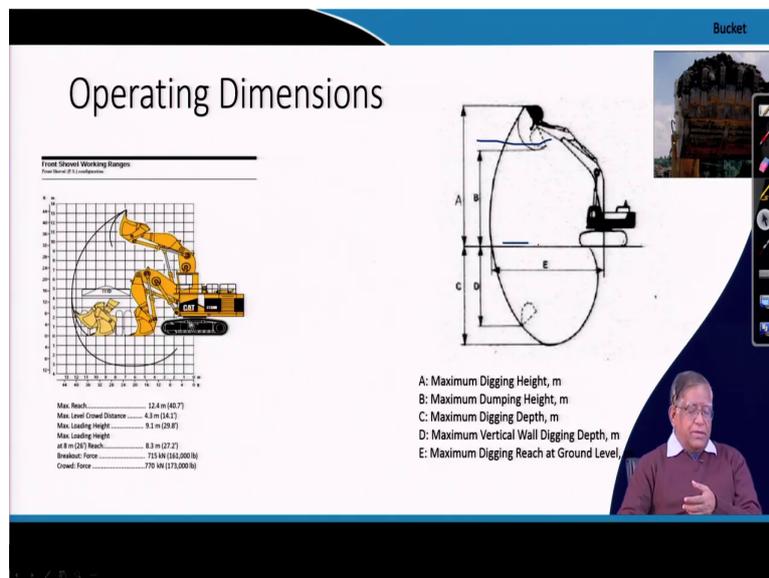
So, if for a particular area you need to get a digging depth of say 5 meter there you will have to see that while selecting the shovel you specify that this is my operational requirement. So, the other one is your digging reach that is your what is the reach of that up to where it can cut.

So that means, while this is standing on a particular position from there the center point up to where the bucket can come, this is exactly that by operation of this different cylinders what is the optimal radius you can get; because this distance E can be a function of the motion of these cylinders.

These 3 cylinder there they will be determining this E, you can make a simple equations to find out and that what is E and for if you are given the range of movement how many meters each of them can be moving, then you can find out how with them we can get E.

Or that means to get this E how much of this cylinder will have to be operating, how much this cylinder will be operating and how much this cylinder this they will be exactly making over there. Those simple mechanics and then little bit of that your mathematical expressions you can derive.

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Now, coming to these machines, now these dimensions are put it in this then you can find out exactly how much material it can excavate. You know that this is the potential by sitting in one position how much this area can be cut or that means, then you can see that if you know

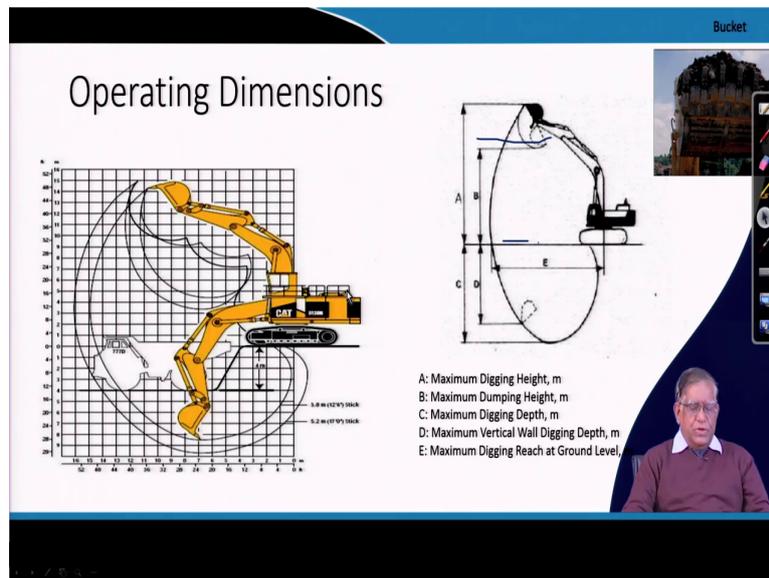
that area you know the bucket lip bucket width, then this much volume of material can be cut by sitting in one position.

Or and now you can sewing it by giving it the next cut by sleeving the machine then you can find out that how much it can cut. So, like that you can find out that how the design of the face will be there and how ultimately the mine will be looking like. So, this is where the machine operating dimensions are important. This vary machine to machine it is say in a particular machines of caterpillar, this is giving as a you can see get yourself familiarized with the type of information you get the operation manual.

So, here I ask you to do 1 exercise find out that who are the different manufacturers of hydraulic excavator, like you may find out nowadays lot of acquisition and merging is there one company by other company and their machines become their machines like that.

But thing is that the major designer like Liebherr O and K P and H Kamacho Hitachi all these are there. So, these machines manufacturer website you go and there you download the leaflets and from there you find out and then you know that at present what is the range of operating equipment available make a tabular form get an information's fill the machines from those information.

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So, you can see that the operating dimensions in a back hoe, your this back hoe by you can see here by controlling these pistons it is either this can be placed over here or it can be placed over here. Now while it is placing like that it is cutting the material and then it is loading. So, how this machine operates in fill you can understand from here and then you can find out the 3 dimensionally how much material it will be taking and then while taking it over there and then positioning the dumper.

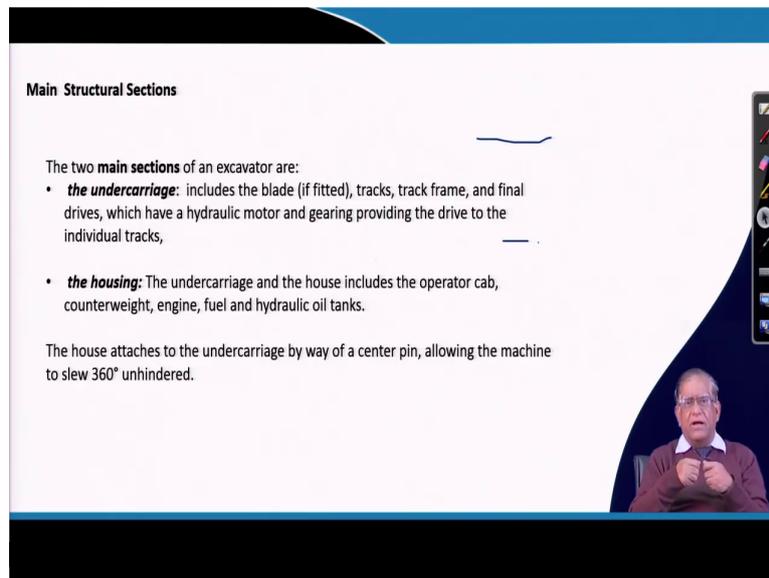
This motion total distance of movement total coverage of movement that is related with the number of that is how many seconds a particular motor will have to operate and how many seconds that how the fluid will be under pressurized conditions and how much energy will be required. Those type of analysis exactly gives you a confidence and how you can improve the operation of the machines, how you can exactly design optimal phase.

So, when you go to the field you see the machine is being operating and a particular phase of the mining phase has been created. There is always a question is that phase an optimal that will be depending on what is the rock properties, what is the fissures and all whether you can loosen instead of raising up to the top.

You can just leave the first 1 meter you can take it out over there that will automatically slide down, if that that thing is coming then why should we come up to collecting the top of it. Because even every 1 meter of or 1 centimeter of movement is a you are using the power.

So by that when you are getting it like that you are not raising up to the total bench height, because the top portion will slide down at that time what you are doing exactly you are reducing the cycle time of the machine. So, like that the productivity can be enhanced. So, those type of analysis you will be doing, but before that try to understand that how this machine is.

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Main Structural Sections

The two **main sections** of an excavator are:

- **the undercarriage:** includes the blade (if fitted), tracks, track frame, and final drives, which have a hydraulic motor and gearing providing the drive to the individual tracks,
- **the housing:** The undercarriage and the house includes the operator cab, counterweight, engine, fuel and hydraulic oil tanks.

The house attaches to the undercarriage by way of a center pin, allowing the machine to slew 360° unhindered.

So, that machines has got some structural component, as I said already what are those are undercarriage and the housing the lower portion and the upper portion. And the housing it has got the front that is a pivot point I have said on which your front attachments are collected.

Now that front attachments which you have seen which may be having arm stick and the bucket or we may having a boom that is a gooseneck boom or a straight boom with that. That front attachments can be managing it is exactly when you have seen that whether you are using a rock breaker you can make a reaper you can make a front end loader anything can be brought over the other prime.

Sometimes it is possible that in the mines you do not buy all these machines, because sometimes a same machine that in instead of having 1 rock breaker and 1 this one. Sometimes one you write the superstructure and undercarriage you create and then the front attachment

can be changed after the blasting, you find that there are lot of big boulders have come you can use that remove the front attachment bring a breaker you break the things.

And then you collect you connect the front attachment with a loader you can load the things over there or there is a if the necessity of to make it an excavator you can make an excavator. We will be learning about what is the difference of an excavator and loader later on.

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Configurations of the boom

- The main boom attaches to the house

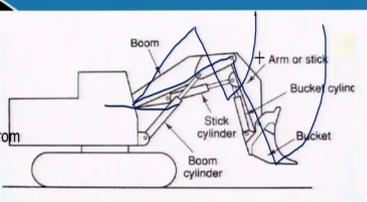
Mono booms: these have no movement apart from straight up and down

Triple Articulated Boom:

Knuckle boom: which can also move left and right in line with the machine.

, The other option is a hinge at the base of the boom allowing it to hydraulically pivot up to 180° independent to the house, however this is generally available only to compact excavators. Attached to the end of the boom is the stick (or dipper arm). The stick provides the digging force needed to pull the bucket through the ground. The stick length is optional depending whether reach (longer stick) or break-out power (shorter stick) is required.

On the end of the stick is usually a bucket. A wide range



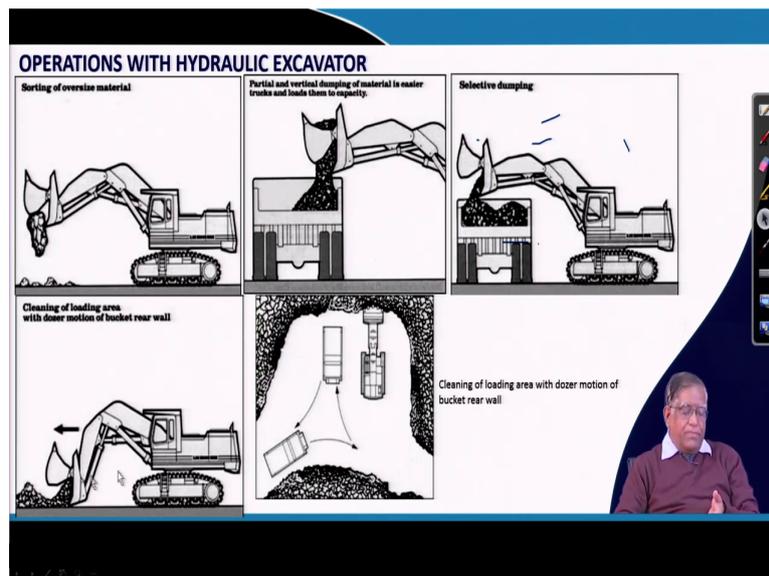
The diagram illustrates the mechanical components of an excavator's boom system. It shows a side view of the excavator's house and boom. Labels include: 'Boom' pointing to the main arm; 'Arm or stick' pointing to the dipper arm; 'Bucket cylinder' pointing to the hydraulic cylinder at the bucket's pivot; 'Stick cylinder' pointing to the hydraulic cylinder at the boom's pivot; and 'Boom cylinder' pointing to the hydraulic cylinder at the boom's base. A small inset image shows a man in a brown sweater speaking.

Now this what is the most important thing I told you about the dimensions is how you configure the boom. Configuring the boom means exactly controlling that your working envelope, what you have seen in the manufacturer leaflet it gives an that is your working envelope.

Now, that working envelope can be controlled by configuring the boom with its different attachments. So, that is why there all the parts are articulated it can be separately controlled, your movement you can keep this is fixed. If you are keeping this portion fixed and then you are having this only then your movement will be only a arc like this.

Now, if this point you raise these things that is your this point, if you are keeping it the boom is now raised then your this arm will be having a working envelope here. So that means, working envelope can be from this position to this positions and during this you can do the cutting of it. So now you have understood this basic operation different type of booms different type of sticks are available you will have to study about this.

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Now, that in the operations you can find that this it can load on the dumper, it can sometimes handle a big boulder. Because, here the bucket is open or operated by just having your one

you are having an unloading of the bucket by motion of this backside this material is loaded over here. So, you can separate out a big boulder and do not load it on there. So, that the crusher will be overloaded or you can separate this type of selective operations can be done you can load the truck uniformly.

So, that wherever it goes because you by you have got the control on the extending this in electric rope shovel it will be just dumping as a it will develop as a one cone and then it is coming. But here you can spread uniformly the material over there. Then while that this exactly loading in the fill you can clean this, sometimes this front excavators it can also work as a just dozer you can dress your face your that cleaning of the face to make it properly collected this type of operations can be done.

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Mining Backhoe



Strong horsepower, efficient engines, comfortable cabs, advanced hydraulics, tough frames, powerful arm- and bucket-digging forces, and easily accessible inspection points and more make these machines stand out a class apart.



So, this back hoe operation is a very very important thing, you know one thing the back hoe is working by sitting over the bench and the excavator if this bucket was not a back hoe bucket if it was an excavator [FL] this side bucket then your the machine would have been sitting over here; that means, the dumper and the machines will be at the same level. But as it is a back hoe it can exactly dig from the bottom and it can load like this. So, this diagram explains how a mining back hoe works.

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Back Hoe

Performance Variables:

1. Hydraulic system
2. Pressure
3. Flows
4. Cylinder size
5. Pin location
6. Operator's line of sight to the back hoe's working area

Overcentre Back Hoe

The backhoe arrangement is proved where the boom comprises a pair of spaced apart hollow boom sections and a single boom cylinder and piston rod assembly is positioned between the sections. The backhoe arrangement accommodates overcentre movement of the boom cylinder when the boom sections are swung to the transport position in which the boom sections are held vertically and slightly forwardly. The boom sections are held locked in position by the boom cylinder assembly when in the overcentre. When the boom is in the transport position and the boom is swung overcentre, the backhoe is positioned in front of the vehicle, the

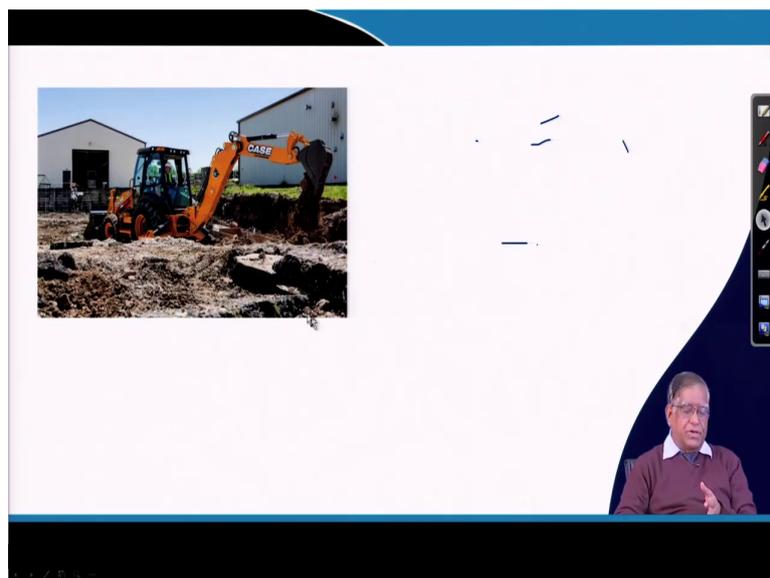
So, you can see here that in a back hoe also. What are the things that as a system variables, which you can study control and design and develop your performance. So, there is a; there is a hydraulic system pressure flow cylinder size pin. Now you can see one thing this operation of the that front attachments or the excavator you can see here the background the tractor part

is same here is a front end loader collecting over there at the back side you are bringing an attachments.

This attachment you can see from here that is a back hoe has a attachment it is fixed over here, it has got a separate mounting you put it over there and then as because it can swing a particular range you can work over there.

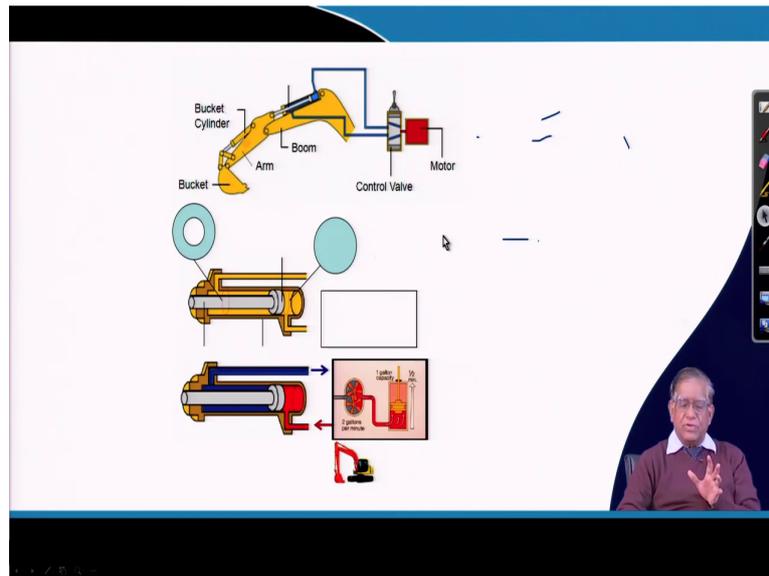
So that means, you are having the other machine in which you change a front end and you can do the back hoe excavation purpose, if you want to draw cut a trench like this is there. So, this is a over center back hoe it is said this is the modern development only last 5 10 years such type of machines such type of modularity has come because of the economic uses.

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So, you can see here the machine backside is a different machines; but only the front attachment is corrected for making a back hoe operation you can do the excavations and do the work.

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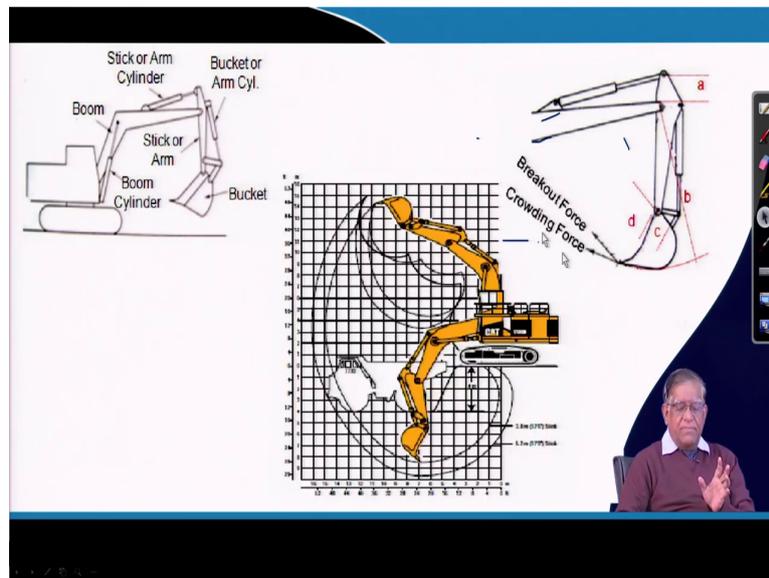


So, case is a company which make this type of things. Now if you see here the how the hydraulic system work over there from the motor you are running and that the pump is getting to the fluid you are controlling which is joystick, you are giving the pressurized fluid to the different cylinders.

So, mainly these hoses pipes which is bringing they will giving the control. So, main operating component of this machine is that pump, that hydraulic pump we told you about that gear

pump and vane pump which is to be there to get the pressurized fluid and the piston operations will be there.

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So, such type of things are available as we recapitulate again that what are the main component your that how this will be operating over here. Now if this bucket is to move you can analyze that is how much braking force will be coming, depending on how much force are coming at this point. So, it is just a draw a free body diagram and then you find out and calculate how much force will be coming over here.

So, this is an exercise you please try that what is how will you express this breakout force in terms of this different forces at that pistons and then on the how this will be different, if the dimensions of this machines are different. So, this type of exercise you can do.

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Force Application Scenario

90-90-90 condition:

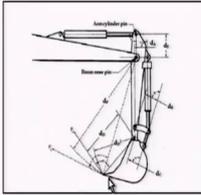


Figure 2: 90-90-90 condition

The 90-90-90 condition is considered for the worst case scenario for force application. This arrangement is explained below [1]:

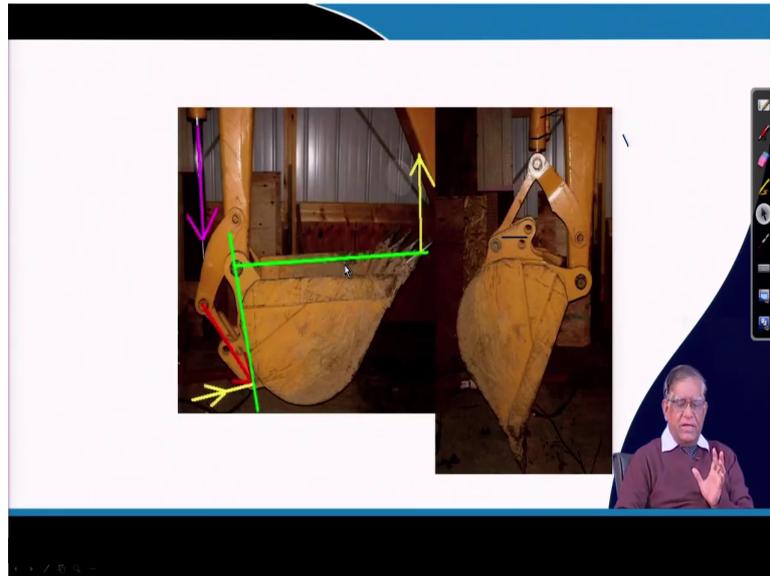
- The angle between boom cylinder and the line joining the boom foot and boom cylinder pivot should be 90deg.
- The angle between arm cylinder and the line joining the arm pivot and the arm cylinder pivot should be 90deg.
- The angle between bucket cylinder and the line joining the bucket pivot and bucket cylinder pivot should be 90deg.

https://www.ijirset.com/upload/2018/september/62_Optimisation.pdf

And then the different force application scenario; that means the worst condition that is highest force which will be coming over there the maximum stress will be coming on to this when this is a 90 degree 90 degree 90 degree conditions.

So, this what is that exactly in this machine in this machines when I say that the front attachment configurations can be changed you take out different possibilities and under different possibilities you find out how much force is coming over there or how much stress is developed and that is the way how that exactly an excavator operation is analyzed.

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So, then while in applications your main importance is that how much exactly we are producing, that will be depending on the dimension and the capacity of the bucket. The bucket capacity is depending on that how what are exactly different forces coming on to this bucket and there you can find out how it will be used.

when you take the material out and then you measure it, then you find out that this capacity is much less than the struck capacity.

That means the bucket fill factor is now less it can go as less as 60 percent that is 0.6 that is the whole capacity if the material is getting sticky over there then you cannot fill. Moreover while in operating you will have to control the breakout force, if you are not doing it properly then also bucket does not get filled.

And then sometimes if you take a lot of time to fill it fully by that time exactly you will be losing the cycle time. If you are in 30 second you are supposed to load a truck, if you are taking more than 50 second to load the truck; that means, number of trips will be less. So, ultimately the mine will be producing less.

That is why sometimes the operator he will not bother about that whether it is filling 100 or 110 percents you will do and try to manage the time within that time that is why it does not get fully filled and you get about 70 percent 80 percent of bucket fill factor. So, this is what is very important to know that the bucket fill factor it exactly your hourly production capacity of the machine can be affected by that. So, you need to be careful about how it is done.

So, then this is exactly how the back hoe is operating, the truck it can do that operationally in some phases your say you can load 2 trucks 1 is coming over 1 is coming over there that whether you will be using this or not. There you can simulate that the simulations of the operations over there, that truck will be travelling some distance to dump the material and come back that distance is called your lid distance.

Depending on the lid distance and depending on the velocity of the truck on load full load and without load they will be requiring some time. And during that time your this truck is loaded and it has gone by that time that truck must be coming over there and ready. So, that there is no queue and there is no obstructions on the operations.

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Average Work Cycles in sec

Material	Easy	Conditions		Explanation of conditions
		Average	Heavy	
Granite, diorit, gabro, basalt, diabas	23 - 26	26 - 29	29 - 32	Heavy: Poorly shot material, very hard to penetrate, big percentage of boulders over 5 ft
Dolomite, limestone, sandstone, coral rock	19 - 22	22 - 25	25 - 27	Medium: Well shot material, rock boulders up to 3.5 feet, few oversized material
Rock-earth mixture, clay	16 - 18	18 - 21	21 - 23	Easy: Very well shot material, average rock size up to 3 feet, no oversized material



So, like that your face need to be simulated and then the operation cycle depending on the different material, because in a easy digging cases there could be within 23 26 second you can do it. And sometimes say some of the sandstones and all which are very difficult conditions to operate there your that time requirement will be more.

So, that is where how the cycle time get very material to material, whenever you are doing designing and whenever you are doing your blasting in surface mining you will have to see the how the fragmentation is there. If the fragmentation is not proper then your cycle time for loading it by shovel will be more and then it will be exactly your productivity will be going less.

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1.	Bucket with hook	Hoisting operations for water supply and drainage pipe system.
2.	Dweep digging bucket	For turning over the soil in agricultural field work
3.	Hydraulic power auger	Digging/boring holes for telephone poles, piles etc.
4.	Concrete block grab	For grabbing, hoisting and moving concrete block
5.	Semi long arm	Extension of work reach
6.	Long arm	Extension of work reach
7.	Extension arm	Extension of work reach
8.	Ripper bucket	Digging of hard soil and rocky terrain
9.	Asphalt cutter	For cutting out asphalt pavement.
10.	Sieve bucket	To separate sand and pebbles from crushed concrete in building-breaking work.
11.	Rock bucket	Reinforced small sized bucket for rock breaking and digging.
12.	Hydraulic breaker	Breaking and crushing of concrete and rock.
13.	Rotator	Rotates the grabber of clam-shell.
14.	Gathering Rock	For collecting and taking scraps, chips and large garbage
15.	Clam shell bucket	Digging of ditches
16.	Extra long boom	Excavation work at a height from the starting level
17.	Wide width bucket	Light digging and loading
18.	Shallow bucket	Digging of clayey soil

So, all are related that is why while learning surface mining you will have to know how different fragmented material will be loaded over there. And then this different material that they may that is that when you are having using a bucket for the excavator. But you can remove that front attachment and you can collect different type of front bucket different type of operating things that is called in a hydraulic excavator; by changing the front attachments you can make multiple use of this machine.

So, this is also very important thing in hydraulic excavator that 1 machine can serve you different things, maybe sometimes the same bucket excavator you can have a grab bucket type of loader or sometimes you can have a say depending on the material you can change the bucket so that the operational efficiency increases.

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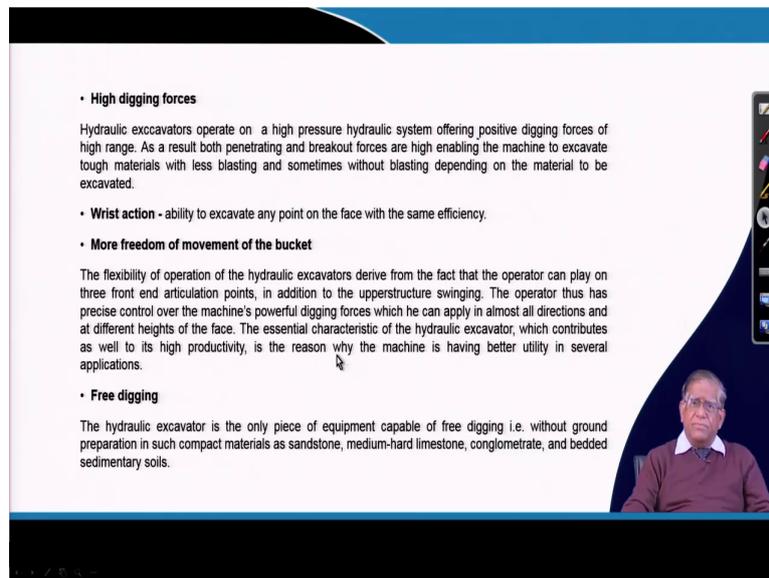
The most commonly used attachment for surface mining are:

- Front shovel attachment for excavation at vertical face above ground level.
- Backhoe attachment for excavation, both on above ground level and below ground level.
- Rock-breaker for handling large size boulder.

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So, there are the front shovel attachments backhoe attachments and the rock breaker these 3 are mainly used in surface mining.

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- **High digging forces**
Hydraulic excavators operate on a high pressure hydraulic system offering positive digging forces of high range. As a result both penetrating and breakout forces are high enabling the machine to excavate tough materials with less blasting and sometimes without blasting depending on the material to be excavated.
- **Wrist action** - ability to excavate any point on the face with the same efficiency.
- **More freedom of movement of the bucket**
The flexibility of operation of the hydraulic excavators derive from the fact that the operator can play on three front end articulation points, in addition to the upperstructure swinging. The operator thus has precise control over the machine's powerful digging forces which he can apply in almost all directions and at different heights of the face. The essential characteristic of the hydraulic excavator, which contributes as well to its high productivity, is the reason why the machine is having better utility in several applications.
- **Free digging**
The hydraulic excavator is the only piece of equipment capable of free digging i.e. without ground preparation in such compact materials as sandstone, medium-hard limestone, conglomerate, and bedded sedimentary soils.

And then the advantage of this machine is it can give a high digging force, it has got the wringing actions, it is a more freedom of movement of the bucket, it gives a free digging.

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•Clearing the face and handling oversize blocks

On this operation the rope shovel is forced to remove the boulder by digging around it. Getting a hold of the boulder is difficult because of the shape of the bucket and its lack of wrist action. The bucket hoist yoke and cables also risk getting damaged. The wheel loader's design means it can only load at ground level; face clearance is therefore an impossibility. Travel under heavy loads also puts considerable strain on the machine and requires a well-maintained ground surface. The hydraulic excavator has no difficulty in rolling back heavy oversize blocks into its cut-away bucket and can do this at any height of the face.

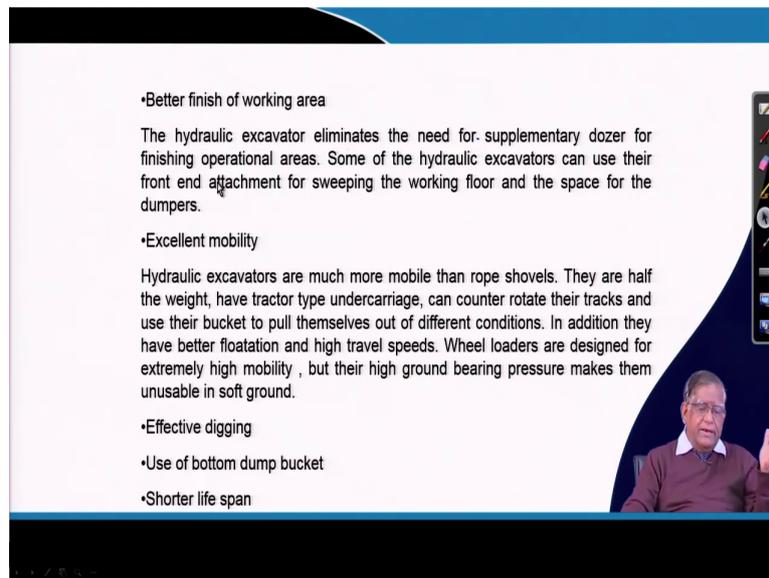
•Precise loading

The bucket trajectory of both the cable shovel and the wheeled loader only allows for minimal adaptation to the configuration of the material being dug. The hydraulic excavator's precise control of height and angle of attack enables operator to selectively mine deposits without dilution.



It gives a clearing of the face also can be done by it, it can do a very precise loading.

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•Better finish of working area

The hydraulic excavator eliminates the need for supplementary dozer for finishing operational areas. Some of the hydraulic excavators can use their front end attachment for sweeping the working floor and the space for the dumpers.

•Excellent mobility

Hydraulic excavators are much more mobile than rope shovels. They are half the weight, have tractor type undercarriage, can counter rotate their tracks and use their bucket to pull themselves out of different conditions. In addition they have better floatation and high travel speeds. Wheel loaders are designed for extremely high mobility, but their high ground bearing pressure makes them unusable in soft ground.

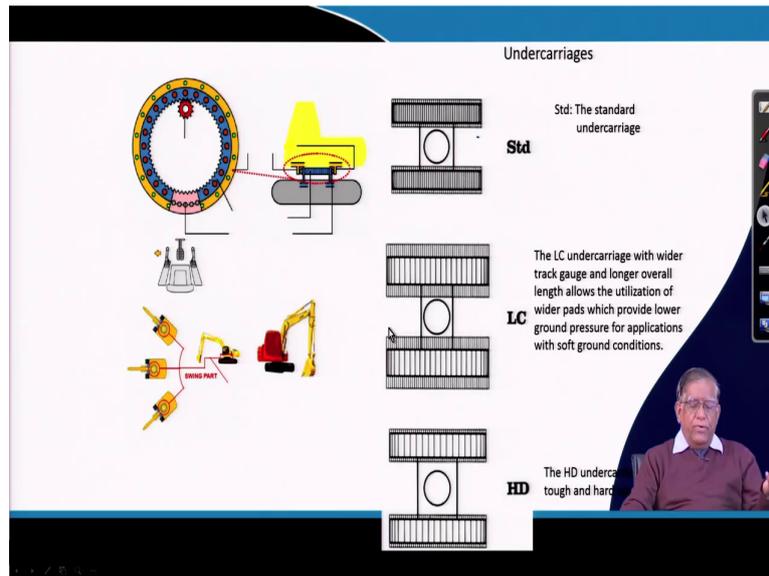
•Effective digging

•Use of bottom dump bucket

•Shorter life span

And then it has a very better finishing of the space can be done, it has got excellent mobility, it has got effective digging efficiency is high and use of bottom dump can bucket can it will easily you can change the design of it and it is a that only thing is that its life span is shorter.

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So, now you can find out that how exactly the undercarriage is rotated, you can see that in the undercarriage there is a turntable in the turntable inside there is a sun gear. So, this is a swing gear, if your motor is rotated over there this outer this platform will be rotating. And that is how that exactly the shovel can be this your front attachment can work that is swinging operations is done.

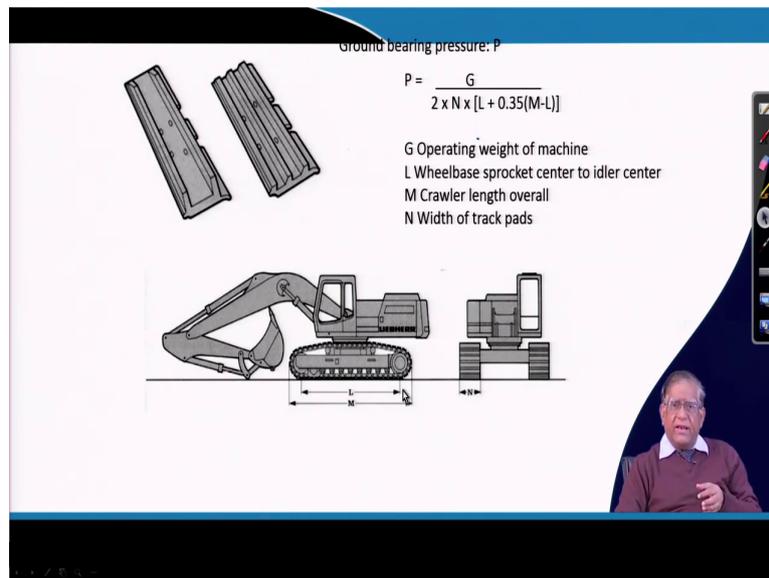
And this operations by just adjusting the control of this swing motor, the swing gear running in this sun gear this can be rotated and then the supporting undercarriage is these 2 crawlers are there each of them will be having a separate drive. So, by controlling 1 drive you can steer these things.

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Ground bearing pressure: P

$$P = \frac{G}{2 \times N \times [L + 0.35(M-L)]}$$

G Operating weight of machine
L Wheelbase sprocket center to idler center
M Crawler length overall
N Width of track pads



The diagram illustrates the components and dimensions for calculating ground bearing pressure. It shows two individual track pads, a side view of a crawler machine with dimensions L (wheelbase sprocket center to idler center), M (crawler length overall), and N (width of track pads), and a top view of the machine's track system.

So, these are the you can see that this how the crawlers pads are there, these pads make the crawler chain and they do it. So, this exactly because of the weight of the machines there will be pressure on the ground, that ground pressure is very very important. If the soil on which you are working the rock on which working it should be able to bear this load and that is called your ground bearing pressure.

That ground bearing pressure depends on the total weight of the machines with load and then the dimension of this chain crawler chain. So, this is the exactly see this whole crawler length it is not supported only this L part is getting supported over here. So, this is the equations you can note it down that for the ground bearing pressure depends on the operating weight, with the wheelbase sprocket to sprocket length and the crawler length and also the width of the track pad this exactly is very very important parameter.

Depending on if your geo mining conditions during the rainy season what is the ground bearing pressures, if it is very low then this machines will sink over here and then the operation will be difficult.

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Digging Force (RK): The digging force is the available force at the tip of the bucket teeth created by the stick cylinder(s). Maximum digging force is calculated with dimension "a" at its maximum and with the bucket in a position calculated for max. breakout force

$$R_k = \frac{F_s \times a}{b}$$

F_s : Stick cylinder force
 a : Perpendicular distance stick cylinder axis - stick pivot
 b : Pivot Distance stick pivot - tooth tip

Breakout Force (L): The breakout force is the available force at the tip of the teeth created by the bucket cylinder. Max. breakout force is reached when the available tooth force reaches its maximum.

$$L = \frac{c \times e \times F_l}{d \times r}$$

F_l Bucket cylinder force
 c Perpendicular distance bucket cylinder axis - lever pivot
 d Perpendicular distance connecting link axis - lever pivot
 e Perpendicular distance connecting link axis - bucket pivot

Similarly, the digging force here how much digging force will be coming it depends on the dimensions of this arm and this forces. So, this is depending on the what is the stick cylinder force that exactly and the distance between this perpendicular distance from the stick cylinder to the axis.

And the pivot distance of the stick power, that is by this simply balancing of the forces you can use the couple and then there is you can easily find out this equations of forces. So, this is

why you will have to do that what is the breaking force what is the digging force you can calculate out.

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Definition of used symbols

A = BUCKET OPENING, measured from cutting edge to end of bucket rear plate
 B = CUTTING WIDTH, measured over the teeth or side cutters
 b = BUCKET WIDTH, measured over sides of bucket at the lower lip without teeth of side cutters attached
 b1 = INSIDE WIDTH FRONT, measured at cutting edge
 b2 = INSIDE WIDTH REAR, measured at narrowest part in the back of the bucket
 F = SIDE PROFILE AREA OF BUCKET, bounded by the inside contour and the strike plane of the bucket. Angular or curved indentation of the side leading edge from the strike plane is not being considered if less than A/12.

Capacity calculation of backhoe buckets according to SAE (Society of Automotive Engineers) and PCSA (Power Crane & Shovel Association) — see figure 1

Angle of repose 1:1

$$V_{saec/pcsa} = F \frac{b_1 + b_2 + A \times b_1 - b_2}{2 \times 4 \times 12}$$

Capacity calculation of backhoe buckets according to CECE (Committee for European Construction Equipment) — see figure 2

Angle of repose 2:1

$$V_{cece} = F \frac{b_1 + b_2 + A \times b_1 - b_2}{2 \times 8 \times 24}$$

And as I said that how the capacity of the bucket is determined, there are different type of bucket this profile that bucket bottom profile why you make it such curve. Because the material will have to get filled into the bucket and also get evacuation easily now when you push into the bucket the material first will go and then there will be a friction coefficient of friction of the this surface and the material that will make in what speed it will be moving over there.

And then when some material is over there then depending on the cohesion of the material there will be a different type of movement of the loose material inside the bucket. So, to facilitate that you design a curve, so this that this particular curve why it is? So, it has been

taken under certain conditions has been taken that this type of material will be very easily get filled into it.

So, the capacity calculations of the backhoe bucket you can find it out, it will be depending on the capacity is the dimension of the buckets from there it is there certain formula this society of. This in say SAE they gives lot of these automotive engineers there are standards there, you can find out that how this calculations are done.

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Engine	
Engine Model	Cat C3 with ACERT™ Technology
Net Flywheel Power	200 kW 268 hp
Net Power – ISO 5249	200 kW 268 hp
Net Power – SAE J1349	198 kW 266 hp
Net Power – EEC 80/1269	200 kW 268 hp
Bore	112 mm 4.4 in
Stroke	149 mm 5.87 in
Displacement	8.8 L 537 in³
Weights	
Operating Weight	36 498 kg 80,464 lb
• HD Reach boom, R3.50B (12 ft 6 in) Stick, 1.19 m³ (1.56 yd³) GP Bucket, 800 mm (32 in) Shoe	
Swing Mechanism	
Swing Speed	10 RPM
Swing Torque	108.7 kNm 80,142 lb ft
Drive	
Maximum Drawbar Pull	300 kN 67,443 lb
Maximum Travel Speed	5 km/h 3.1 mph

Hydraulic System	
Main Implement System – Maximum Flow (2x)	280 L/min 74 gal/min
Max. pressure – Equipment	35 000 kPa 5 076 psi
Max. pressure – Equipment – Heavy	38 000 kPa 5 221 psi
Max. pressure – Travel	35 000 kPa 5 076 psi
Max. pressure – Swing	28 000 kPa 4 061 psi
Pilot System – Maximum flow	43 L/min 11.4 gal/min
Pilot System – Maximum pressure	4 000 kPa 585.7 psi
Boom Cylinder – Bore	150 mm 5.9 in
Boom Cylinder – Stroke	1 440 mm 56.7 in
Stick Cylinder – Bore	170 mm 6.7 in
Stick Cylinder – Stroke	1 738 mm 68.4 in

Bucket Specifications	
Bucket Type	Capacity*
	m³ yd³
General Purpose	2.00 2.62

Bucket and Stick Forces	
General Purpose	kN lb
Bucket Digging Force (SAE)	191.1 42,961
Stick Digging Force (SAE)	145.9 32,800

Now, you make a study of the different leaflets of machines and calculate and find out what is the range of.

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Boom Options

	Boom Option 6.5 m (21'4")	
Stick Options	R120B (12'9")	R120B (10'7")
1 Shipping height*	3,630 mm (11'11")	3,350 mm (11'0")
2 Shipping length	11,200 mm (36'7")	11,150 mm (36'7")
3 Tail swing radius	3,500 mm (11'5")	3,500 mm (11'5")
4 Length to center of rollers	4,000 mm (13'1")	4,000 mm (13'1")
5 Track length	5,025 mm (16'6")	5,025 mm (16'6")
6 Ground clearance**	450 mm (1'6")	450 mm (1'6")
7 Track gauge	2,500 mm (8'2")	2,500 mm (8'2")
8 Transport width	100 mm (3.9") above (optional)	3,300 mm (10'10")
9 Cab height	3,100 mm (10'1")	3,100 mm (10'1")
10 Counterweight clearance*	1,220 mm (4'0")	1,220 mm (4'0")

	Boom Option R120B (12'9")
Bucket Options	6.1 m (20'0") (4.3 m (14'1"))
1 Maximum digging depth	8,187 mm (26'9")
2 Maximum reach at ground level	11,714 mm (38'5")
3 Maximum cutting height	10,749 mm (35'3")
4 Maximum loading height	7,542 mm (24'8")
5 Maximum loading height	7,911 mm (26'0")
6 Maximum depth cut for 2,000 mm (6'7") level boom	8,052 mm (26'5")
7 Maximum vertical wall excavation depth	7,152 mm (23'5")

This exactly the different forces and different parameters you must study the leaflets of the machine.

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The figure shows a hydraulic excavator doing a level crowding operation where the bucket has been moved along the surface. Explain the how the actuators of boom, arm and bucket will have to be controlled for such a bucket movement?

Level crowding of an excavator and frame model of an excavator.

The diagram consists of two parts. The top part is a perspective view of a hydraulic excavator with labels for 'arm' and 'boom'. The bottom part is a 2D frame model of the excavator's arm and boom. The boom is the lower link, pivoted at the base with angle θ_1 . The arm is the upper link, pivoted to the boom with angle θ_2 . The bucket is attached to the end of the arm with angle θ_3 . The horizontal distance from the base to the bucket is labeled Z . A text box on the right asks for an explanation of the control for such a bucket movement.

And then you can find out what is that how different configuration of the boom can be there to which distance it can cut this is also an exercise you can do over here.

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And then your the front attachments as I said it can be it is a grab bucket, it can be rock breaker, it can be a this is your vertical ripper, it is a different type of grab bucket. This type of material can be ends by just changing the front attachment of the hydraulic excavator.

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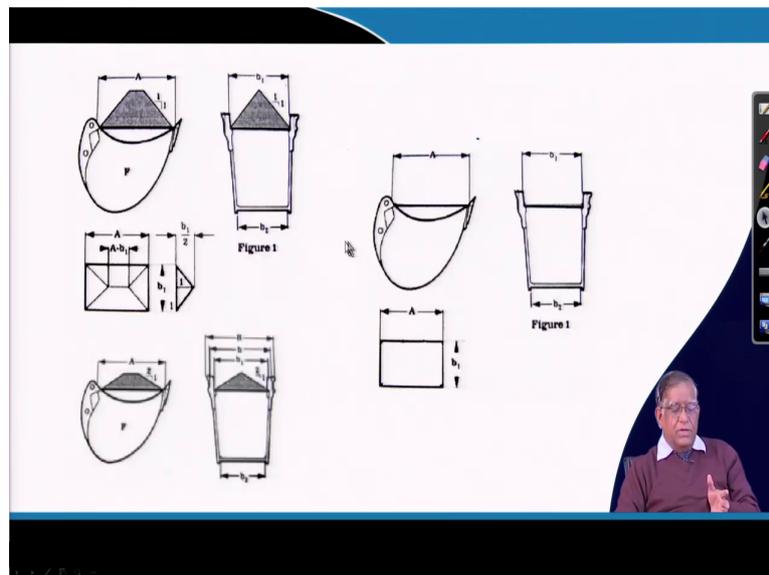
Table 1 Salient features of various shovels.

Model	Bucket Capacity (m ³)	Working Weight (T)	Max. Height (m)	Cut Radius at floor (m)	Digging Depth (m)	Power (KW)
4.6	4.6	170	10.3	9.3		250
195B	10	342	12.7	11.8		600
191A	10	438	13.8	12.8		800
Hydraulic Shovel						
300CK	3.2	58	10	8.15	2.4	308
1000CK	8.3	170	13.9	11.25	2.8	903
PC-650	3.8		10.6		3.5	410
PC-1500-1	8.5		13.6	13	4.1	820



You can do a lot of other work.

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Fill Factors for Front Shovel Buckets (Caterpillar Inc.)

Material	Fill Factor (%)
Bank clay: earth	100 to 110
Rock-earth mixture	105 to 115
Rock-poorly blasted	85 to 100
Rock-well blasted	100 to 110
Shale: sandstone-standing bank	85 to 100

* Percent of heaped bucket capacity



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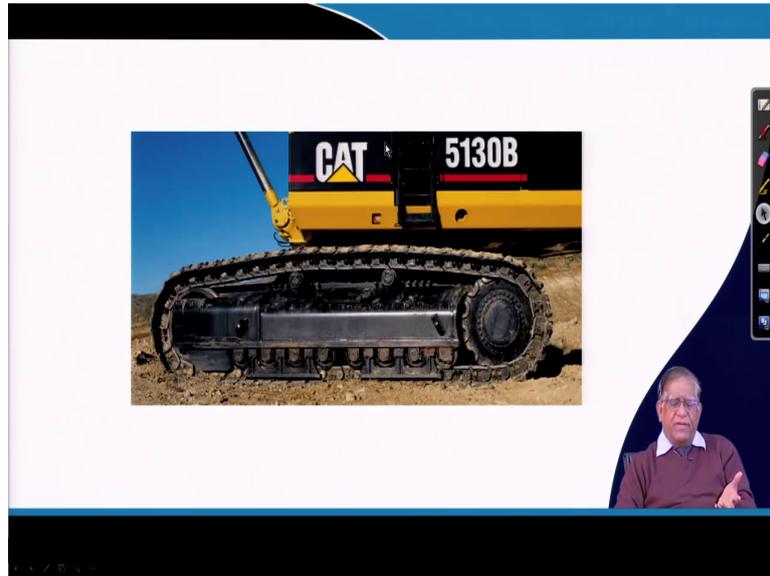
Model C tooth	Model L tooth	Model R tooth	Model p tooth	Model CR tooth
Features:				
The conical design of this tooth, which becomes narrower towards the tip, ensures excellent penetration in cohesive materials.	Spade shape, sharpening edge for easier penetration in tough materials.	Narrow point and high wear volume for high penetrating forces in abrasive material.	Pointed tooth with good penetration in hard material, even rock. Due to its shape this tooth is self-sharpening.	Long shaped tooth with good penetration in blasted rock. The large and thick tooth point guarantees a long lifetime in abrasive material. Especially designed to bottom dump buckets.
Application:				
Easy soils, not difficult to dig Fig.: sand, clay and gravel	Medium heavy, cohesive materials Fig.: hard loamy sand soft coal hard gravel	Hard abrasive materials and deteriorated rock Fig.: limestone shale coal	Very hard material Fig.: rock hard shale laminated rock fragmental heavy ore steelmill slag	Especially abrasive material rock Fig.: granite basalt sand stone

Model S2 tooth	Model S11 tooth	Model S12 tooth	Model S4 tooth

So, this is the teeth of the bucket they can be also of different because the teeth will get wear out and then you will have to maintain it properly, that when operating with these basins that teeth their wear is a very very important things. This is one area where you can study for the getting a new innovative material and then the how the teeth will be fitted over there.

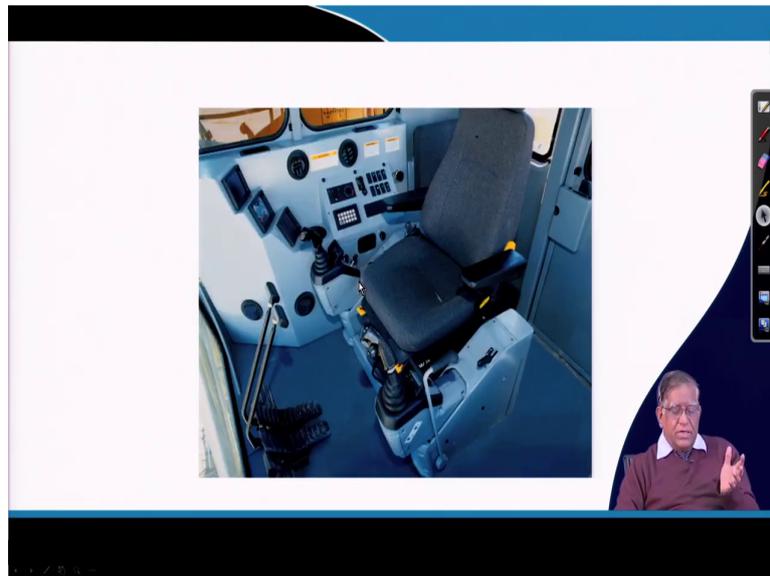
That also is a very important things because that to maintaining the teeth; that means, the old on teeth will have to be taken out and the new teeth will have to be fitted. So, you should design in such a way that the time of your removing and fitting should be very less.

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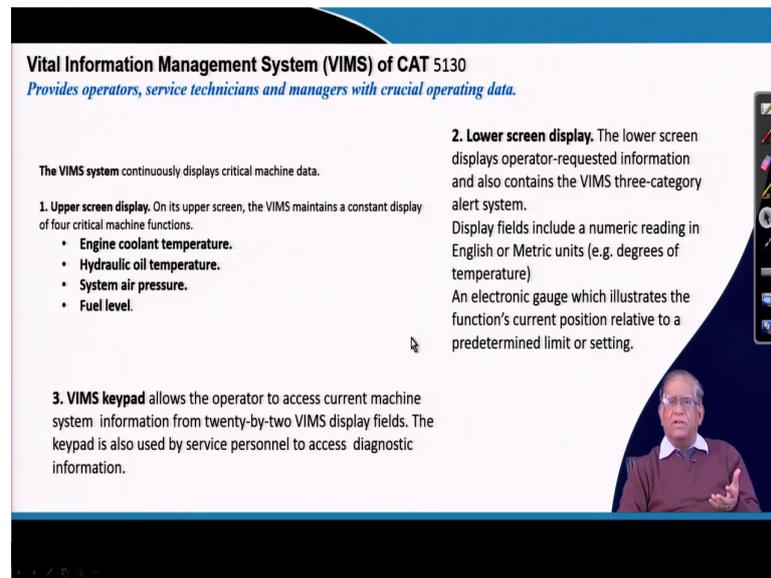
So, that is the way it is done.

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So, there is a main crawlers and you can see the ergonomic design of the operators cabin, that is now it is modern this hydraulic excavator has got a such sophisticated operations. And you know that the in Australia many of the this your machine operators they are all graduate engineers earning about 12500 dollar Australian dollar a year. So, this is highly of sophisticated operations many of the engineers can aspire to become a very good operator, because they will be changing the productivity of the mines.

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Vital Information Management System (VIMS) of CAT 5130
Provides operators, service technicians and managers with crucial operating data.

The VIMS system continuously displays critical machine data.

1. Upper screen display. On its upper screen, the VIMS maintains a constant display of four critical machine functions.

- **Engine coolant temperature.**
- **Hydraulic oil temperature.**
- **System air pressure.**
- **Fuel level.**

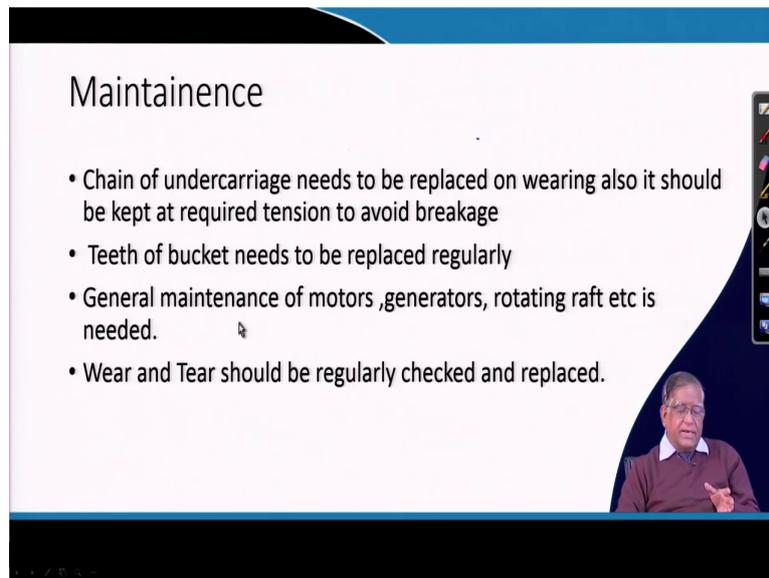
2. Lower screen display. The lower screen displays operator-requested information and also contains the VIMS three-category alert system. Display fields include a numeric reading in English or Metric units (e.g. degrees of temperature) An electronic gauge which illustrates the function's current position relative to a predetermined limit or setting.

3. VIMS keypad allows the operator to access current machine system information from twenty-by-two VIMS display fields. The keypad is also used by service personnel to access diagnostic information.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

So, there is a in the modern machines because of the mechatronics development with the sensor technology and all now all these things are data driven. To take a data driven decisions these are that machine information systems have been developed.

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Maintainence

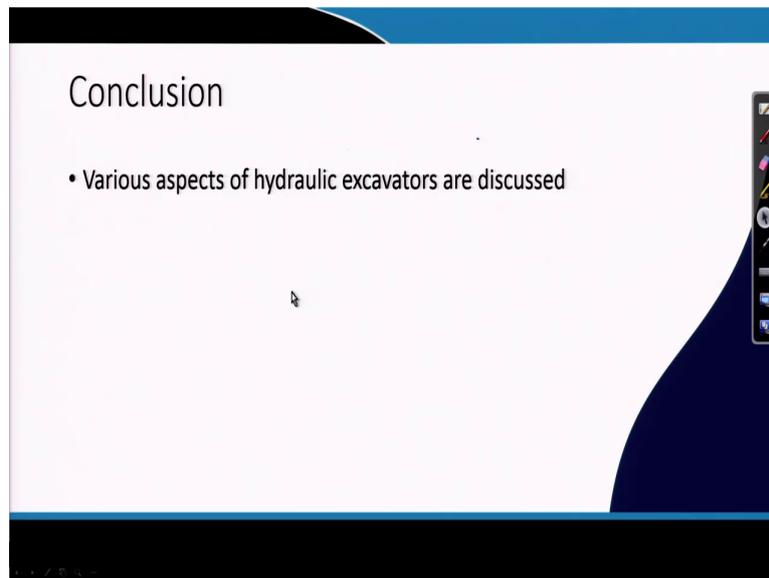
- Chain of undercarriage needs to be replaced on wearing also it should be kept at required tension to avoid breakage
- Teeth of bucket needs to be replaced regularly
- General maintenance of motors ,generators, rotating raft etc is needed.
- Wear and Tear should be regularly checked and replaced.

The slide is titled "Maintainence" and contains a bulleted list of four maintenance tasks. A small video inset in the bottom right corner shows a man in a brown sweater speaking. The slide has a blue header and footer.

The different parameters are collected and from that parameter it is exactly you take a decisions for the operations maintenance and management of this. So, that ultimately the productivity is reached and you get a very good financial aspects. And of course the maintenance the every machines will be giving a maintenance schedule of the preventive maintenance schedule will have to be there, but the most care should be taken about the undercarriage because if any leak breaks then it will take a long time.

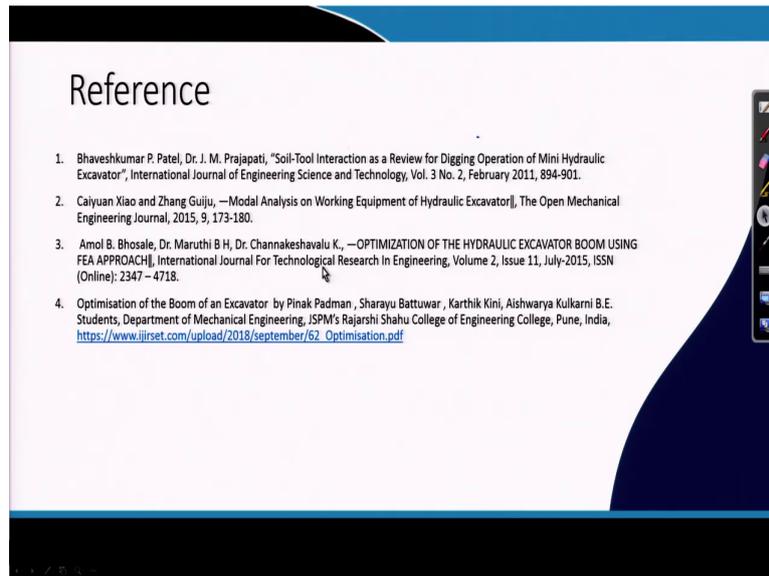
That the other general equipment and the teeth maintenance and the wear and tear that is other, other than that there will be some problems and troubleshooting you will have to learn for the hydraulic systems, because many a time the hydraulic systems can give a problem.

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So, in a nutshell you have learnt today what is exactly a hydraulic excavator and how it is to be selected for. And then I think after this discussions we have discussed 2 machines electric rope shovel.

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And hydraulic excavator please prepare a comparative table of these 2 machines what can be done by electric rope shovel and what can be done by your hydraulic rope shovel. And then you study different material from the nets and then you can come forward, so that you try to explain with your own words what are the differences between these 2 machines.

Thank you very much.