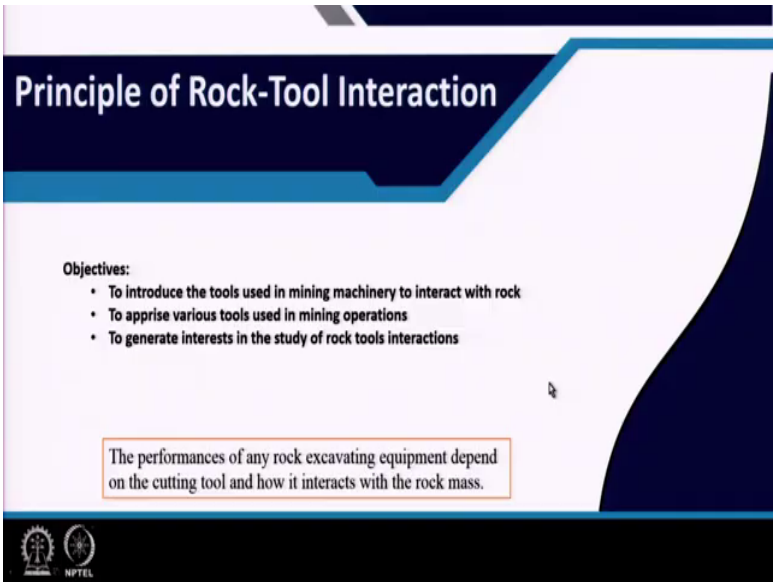
Mining Machinery
Prof. Khanindra Pathak
Department of Mining Engineering
Indian Institute of Technology, Kharagpur

Module – 04
Lecture – 12
Principle of Rock – Tool Interaction

Welcome to our, the journey of studying Mining Machinery. So, far we have studied the basic machine elements, then the basic types of machinery which are used in mining purposes and we have also introduced that how wire ropes are used for mining purposes. Now, we will be going to study about different excavating machinery.

Now, to know that excavating machineries the basic thing is they will have to interact with the rock mass. Now, that is why it is relevant to know little bit of the principle of rock tool interactions. How the working member of the machine will be interacting with the rock mass?

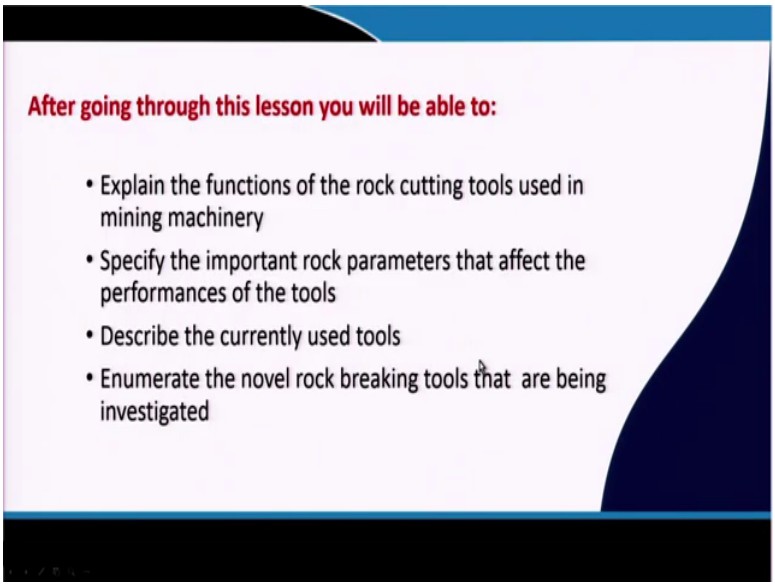
(Refer Slide Time: 01:27)



So, today in this class we will be discussing this Principle of Rock Tool Interactions. We will not go to the detail of the theories, but our objective is to introduce the tools used in the mining machinery to interact with rock and to apprise various types of tools that are used in mining operations.

And so that you can have some interest in the study of rock tool interactions with your knowledge of rock mechanics and mining operations and mining machinery so, that you can initiate some important studies. So, that it can contribute to productive and safe mining operations. Now, the performance of any rock excavating equipment that will be depending on the cutting tool and how it interacts with the rock mass, so that is the basic things.

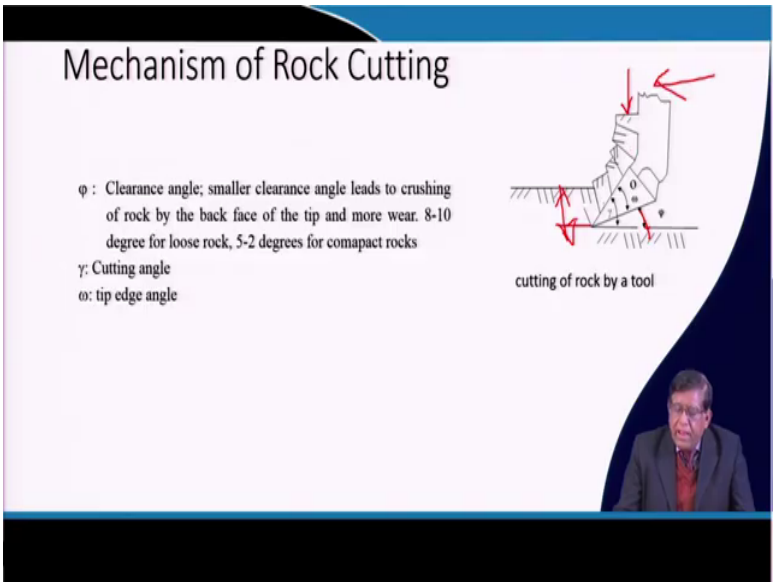
(Refer Slide Time: 02:22)



Now, in that so we hope that after going through this lesson you will be able to explain the functions of this rock cutting tools used in mining machinery. And you will be able to specify the importance of rock parameters that affect the performances of the tools.

And you will be able to describe the currently used tools for different types of machines what are being used. And also we will try to give you a little bit of brief idea about that what are the novel rock breaking tools and the so, that some of you may take up some research work that some new tools for future can be developed.

(Refer Slide Time: 03:12)



So, now coming to the basic things that what is, how a rock is being cut? You might have seen that rock cutting in your villages. You might have seen some of the people working in the rock area that they may be using some peaks to break the rock or you have seen some soil cutting machines say while making a hole for erecting a this any (Refer Time: 03:40) when you are to insert a pole you will have to do dig a hole.

So, wherever they are there you are using some rock cutting tools you might have seen some of this equipment, but also you have seen that on the roadside many a times you have seen the dozer. You might have seen also some cutting tools as for example, in the plough in the agricultural form, you might have seen that also you have seen ripper that is at the background of the back of dozer how it is there.

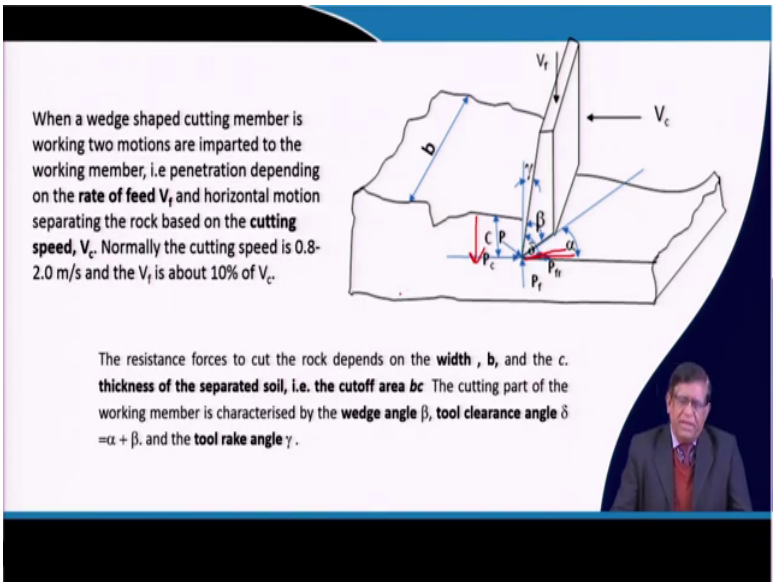
Now, if you just observe that how a say this is you can think of a cross sections of a your, you can think this is the cross section of a dozer blade. So, when it is pushed to the ground you may say that this much this depth tip has penetrated.

Now, when it will be moving in this in the direction of motion suppose your this one is pushed to this direction. So, then what will happen, this thickness of rock mass which was which it has penetrated, this part will be chipped off and when they will be getting exactly broken into.

So, this is the way how a you are just pushing that means, there is a force downward is there by which you are holding it below this ones and this motion is going and at that you are getting some cutting force over here.

So, this exactly will be depending on the geometry of this cutting tool you can see here there is a clearance angle you can see that from the rock surface this is your clearance angle. And then you can see here there is a your tip angle or you can say this is that tool is having this is call your tip angle and then there is this cutting angle.

(Refer Slide Time: 05:54)



So, there are these geometry it will affect the performance of the drilling or the performance of the cutting machinery. So, now, let us see a little bit deeper into it. If your this blade a dozer blade is there, how exactly things are happening? You can see in this figure, that there is you are having a vertical downward force you can see here a. You can see this force is coming over here and this is the speed by which it is going over there these angles.

Now, you can see here another part here this angle is called your rake angle and now the combination of these angles is affecting the direction of these forces. So, what force will be available for stripping of this material that is your if your thickness is this c and that width is b.

So, that means, this much volume of rock that is b c will be cut within a when it will be moving that speed or that quantity of material which will be removed that will be depending on this velocity and this dimensions.

Now, here many things will play if your this angle is small then what will happen that is exactly it is very small or it can be even smaller. Then what will happen when there is no clearance, that means, there will be more rubbing action more friction more heat generated more tip damage will be taking place. So, that means, there are some impact of these angles on the way it will be cutting and the way this tip will be performing.

So, when a wedge shaped cutting member is working two motions are imparted to the working member, that is the penetration depending on the rate of feed which you are giving downwards that is called a feeding or feed force. And the horizontal motion which will be exactly giving the cutting speed at what speed the machine is cutting and normally this cutting speed is 0.8 to 2 meter per second.

And then the that your the feed which is normally it is 10 percent it is of the cutting speed. That is depending on the hardness and the strength of the rock you will have to adjust these things, we will come to that. The resistance forces to cut the rock, depends on the width.

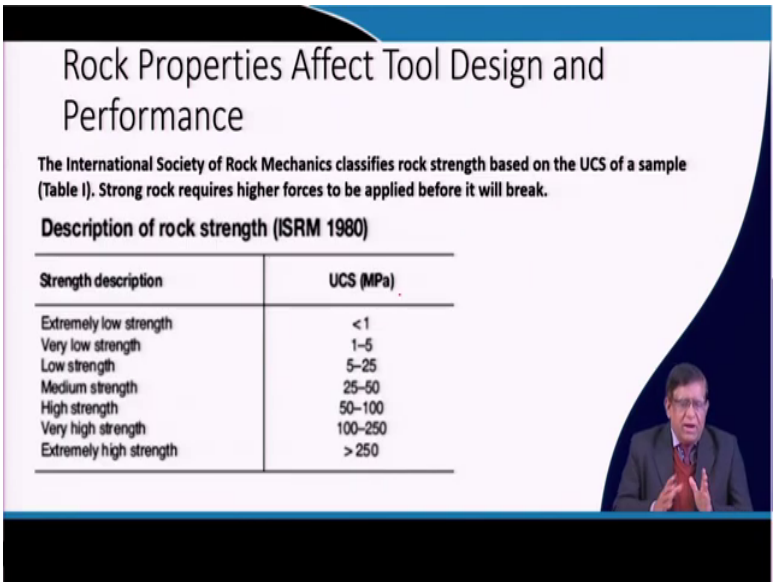
Because the cutting resistance of this rock or soil that will have to be overcome by the power of the or the energy provided by the prime mover of the machine. So, that is why there the whole energy dissipation at this point is very very important.

It will be having two impacts one is how this tip will be or the how that blade life will be there because it will get blunt after some time, how each wear and tear will take place and also how much energy is required. So, there is number of this on the basis of this rock tool interaction the economics of your operations will be dependent.

So, that is why when you want to analyze a particular system of a mining system, your how this energy is dissipated at this point and the how productively you are working it is very

important. So, if you want to do a productivity study of with a particular type of machinery, this rock tool interactions we will have to be going to a we will have to study in detailed, that is where is the part of the research.

(Refer Slide Time: 09:53)



Now, here we need to know I have already said that the interactions will be depending on the type of rock. Say when you are working with the soil or when you are working suppose collecting sand or when you are that is exactly working with a coal or iron ore hematite or you are working with bauxite in all cases that your tools will be performing differently.

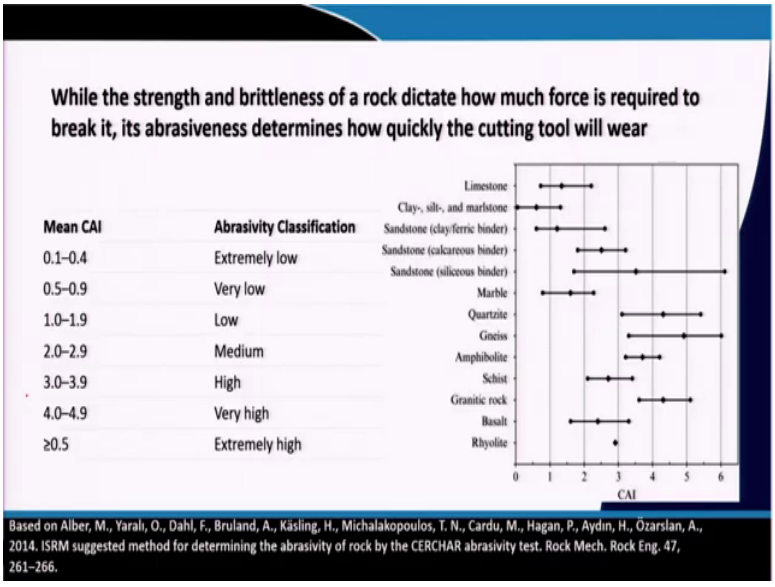
So, that is why that the two things are important that is, how the tool will be getting owned? And exactly, how much that it will be able to cut or not? Now, whether it will be able to cut or not that will be depending on the strength of the rock. Now, this International Society of

Rock Mechanics they have classified the rock strength based on the, that is uniaxial compressive strength, which you might you have already studied in rock mechanics.

Now, you will have to apply those knowledge to correlate with the real operations in the field because if you have found that a particular a coal of a particular seam, may be having the uniaxial compressive strength may be 45 60 mega Pascal. So, in that what will be exactly you will be considering that strength of the rock for the as the giving resistance to cut.

So, that is exactly if it is a 45, 50; that means, it is a high strength. So, that means, when you are designing a machine or that when you are designing the cutting that is your interacting tool. You will have to consider that you will have the material selections will have to be proper otherwise the breaking strength of that tool material should be also higher. So, that is why you will have to see that which way the rock is behaving.

(Refer Slide Time: 12:01)



That this is not only the strength, but also you will find that is that, how it will be varying out. This is another very important thing that is if your tool that which is a cutting tool if it worn out then it will become blunt at that time it will not be able to cut.

I think all of you might have got that experience if you are from the rural area, if you have used a cutter for cutting a bamboo. You know, that if the that your cutter is not properly sharpened then how that, how much time you will be requiring for cutting it.

So, if you have got a direct experience, maybe you are having some experience which your pencil cutter. If you are not having a you have not worked in the village at bamboo, but you might have used your pencil cutter. Then you know that after the blade is becoming blunt because of rusting and all at that time you can how does it cut you, will be requiring more force to be given and then the cut, pencil will never get properly sharpened

So, that means, if the weld takes place on the cutting blade or cutting tool at that time that your things will not be proper. Now, how a particular rock will be affecting the cutting tool to give were depending on the property called abrasivity. And on that exactly that there were CERCHAR abrasivity index rock mechanics you might have search found that this CAI, the CERCHAR abrasivity index that is determined by.

That you are in the laboratory you can taste a rock with a standard that varying surfaces by which you find out, what is that index? And then you will find if the CERCHAR index is going very high. That means, you will have to have a material which will have to be wear resistant material then you cannot use directly a just iron or you cannot use a steel directly.

You will have to go for some alloy steel or sometimes you will find that in the cutting tool you will have to do a surfacing that is your a brazing or hard fishing different, that is in the manufacturing process of the tool will be different.

Similarly, that as you have studied in your while telling about the wire rope we have siad that exactly that during the manufacturing how you are bring the heat treatment that will be giving

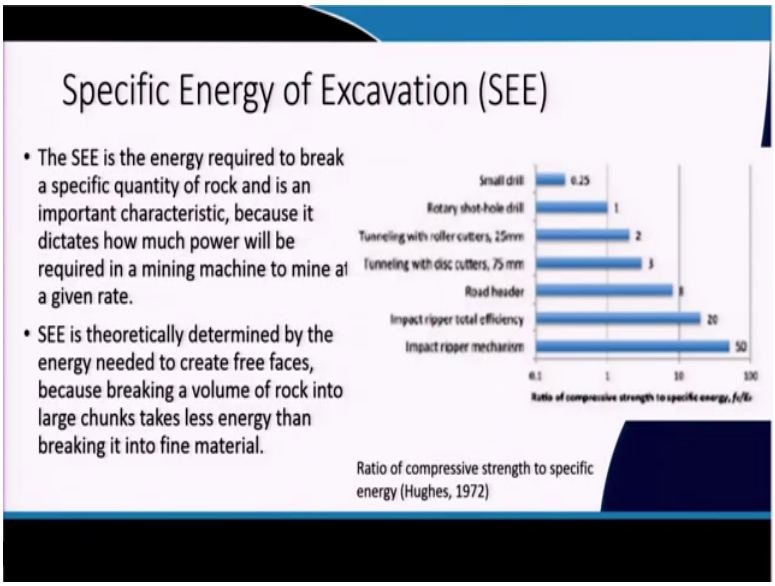
you different strength. Similarly while manufacturing the tools what type of tool will be using. That will be having the material for the tool will have to be selected based on these two property strength and the abrasiveness.

These two are the main and you can see here that in our mining you will be. Whether you are doing a limestone mining there your abrasive index is going up to 2.2 to 2.3, but if we are going to do a granite type of rock, when you are mining that, that it is going more than 5 and there is that amphibolite that is having up to 6.

That is your sandstone it is having a wide range that is because the that sandstone it is a it because it is a sedimentary rock, but it can be having a different type of grain size, it has got different type of bind that is our binding material. And depending on where it occurs if a rock mass is there say below 200 meter of the earth surface or it is there below 30 meter of earth surface.

Depending on the consolidation level of that sandstone the strength or abrasivity may be different. If it is a quartz grain sandstone where high quartz contents are more that will be giving to give very abrasive. So, that is why you can find a very highly abrasive above 6 you can get with the sandstone and that type of rock if you are cutting by ordinary tool, it will get worn out and it will become blunt very easily.

(Refer Slide Time: 16:17)



So, now we have understood that while selecting the cutting tool you need to see these two properties must be there then another thing is there that how you are using the tool that your different amount of energy will be required. Nowadays, always you must talk about the energy economics and that is why your you will have to properly design the tool. So, that the energy requirement is less.

So, this is what is exactly called specific energy of excavation. That means, whenever you are want to collect the material by a particular bucket with having some teeth. That teeth is interacting with that and then you are collecting over here or when you are doing a drilling and the drilling that how much energy exactly required to make a hole of a particular diameter of a particular depth.

So, when you determine that energy that is called your specific energy. That this specific energy is the energy required to break a specific quantity of rock and is an important

characteristic because it dictates how much power will be required in a mining machine to mine at a given rate.

If the rock it is a, it is a property of the rock tool interactions say in case of the tool you are taking a very sharp rate and then you are making the energy the way you are imparting the energy to the rock by the machine.

And then that is why it is a, it is a property not only with the particular rock, it is not a specific rock property. It is a rock property it's response to a cutting machine and the way the tool is allowed to interact. So, it is a theoretically determined by the energy needed to create a free faces in the rock mass.

So, this has been studied for a long time exactly in the 60s there were a lot of studies. Particularly, it is a specific energy was for drilling purposes when the oil well drilling there a lot of studies. If you see now society of petroleum engineers some of the publications of 60s and 70s you will find this famous name Hughes.

He did a lot of study in those days of 60s and he found out one ratio that is your ratio of the compressive strength to the specific energy and depth, how it respond to different drill. It was found that for a small drill the compressive strength to specific energy ratio is within 0.25, but when there is a impact ripper mechanism when a ripper mechanism with an impactor that is a that.

Nowadays, they are used also for the vertical ripping in hard stone quarries those rippers exactly their ratio of the compressive strength to specific energy is very high. That means, here we are by less amount of energy you can get more strength. So, this is how say for example, in a road header it is going up to 8, but for a rotary shot hole drill it is going up to 1.

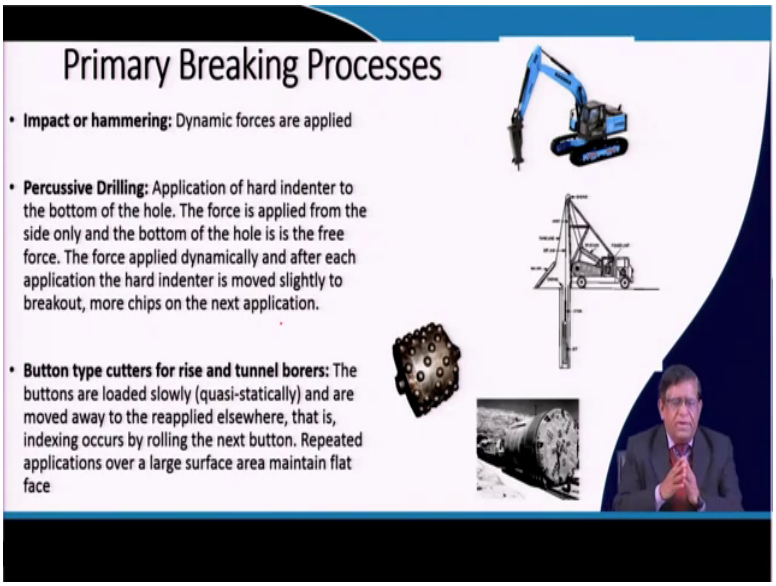
So, that is how this study you can reference of this particular studies you should take out some time and explore because understanding the way it is to work. India also need to develop now its own machinery own material or cutting tools many a times we have got a lot

of imported machines big machines. But there is always a system that is your with the original equipment manufacturer.

They make a contract that they will be selling the teethes and small picks, but now in our make in India move we should be able to manufacture those. And to manufacture those means whatever the imported mining machinery is there in the country there this.

The tool how it is there they are all variable part components, how we can design in our country there we must put our emphasis. And that is why this rock tool interactions should be very carefully studied and the students should do research in it so, that we can develop our tool.

(Refer Slide Time: 20:40)



Now, coming to here what are the primary breaking processes which are exactly there. You can see that impact or hammering there are machines this type of Chinese machines are working in India they are exactly rock breaker, they are called rock breaker.

This is a hydraulic excavators that body here the front end we are allowing a percussive motions with a good impact depending on the whatever the force required or there is what is the resistance of the rock cutting resistance of the rock and there is a tool there and by giving a vibration motion over here with this tool the rock is cut.

That is an impact or hammering type of role, similarly we have the percussive drilling that percussive drilling are of different types. It is a very old type I have shown over here those who are studying drilling technology you may be knowing it this is called a cable tool drilling. Which is nothing, but a version at.

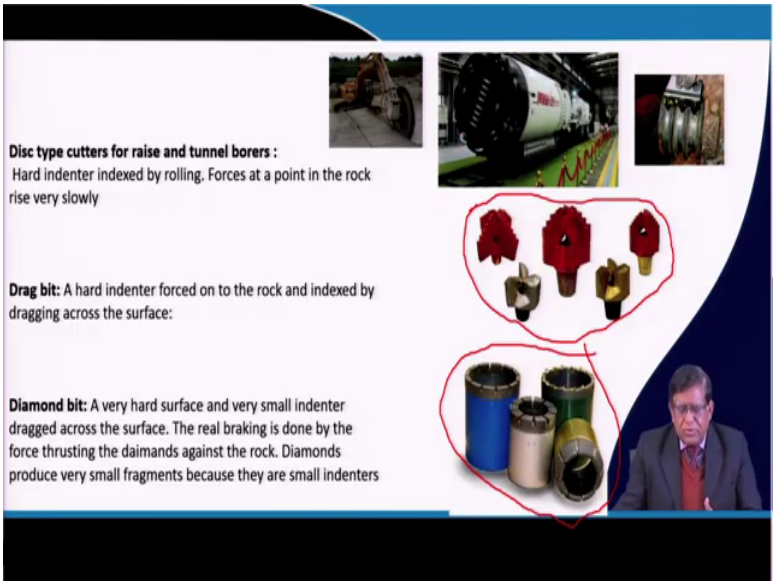
In what in America used of whatever we in India we used to have a ripper stand and the people used to put a big chisel to make a hole in the villages the same principle, when it is done in a mechanized manner it is a they call it a cable tool drilling. You can study later on about these machines, but this percussive drilling you will have to use a very hard rock sometimes. It is a high carbon steel that a bit is used to trot from the top and by that they will be doing the drilling.

So, this is a percussing percussion drilling then there are tunnel boring machines you might have heard this machines and there we can see that the buttons there here this will be a rotary. And then it will be giving impact here in that we have got the tungsten carbide buttons are inserted over here and they will be exactly giving the shearing actions to the rock surface and they make the tunnels.

So, the buttons are loaded slowly and are moved away to the rip applied elsewhere. That means, when it is rotating like this, then what is happening that button it is just only its position is changed and that where it first attacked that point is now attacked by the another one.

So, like that this button when it is rotating at that time the exactly rock is allowed to failed and because these are the tungsten carbide you know is a very hard material. It will not get worn out easily that is why it will be able to make the rock surface to worn out or shear and by that way the cutting actions will take place.

(Refer Slide Time: 23:27)



So, that is different way of cutting the things you can see here that sometimes it can be a disc cutter that is a hard indenter is indexed by rolling forces of that the point of the rock rise very slowly here. It is a rotary motion that is from the this hydraulic excavators. It is a hydraulic force is made here to pilot a hydraulic motor.

We have discussed in our fluid power machines that is a there is a actuator rotary actuator. Now, these rotary motions over here, it is imparted to the this cutting disc and this type of your dimensional stones are cut by like this. And sometimes the disc cutters are in a you can

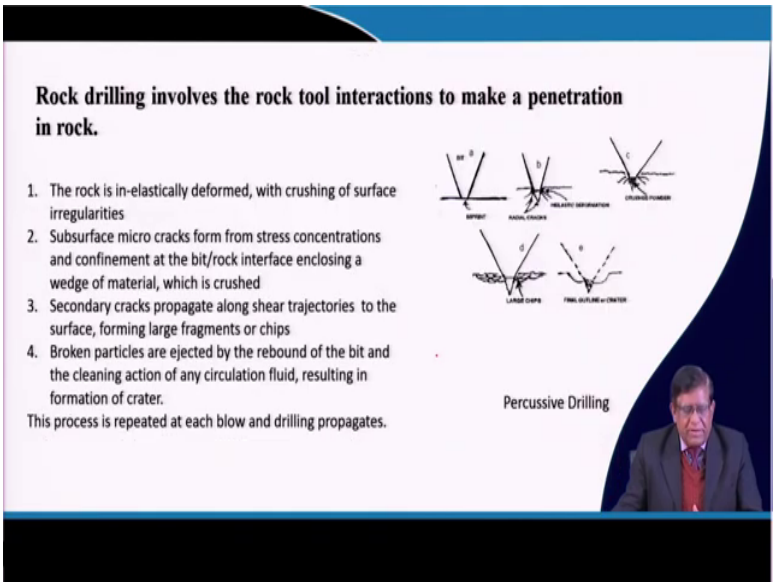
see it is a tunnel boring machine in a tunnel boring machine, you have this disc type of cutters this will be rotating and then that will be making the cutting over here.

So, that is where the disc type cutters are used in different machines. There is a drag bit this is here these type of bits what you are seeing over here these are all our drag bits. That is a hard indenter forced onto the rock and indexed by dragging across the surface.

Now indexing is that is exactly how it rotates at that time its cutting point is changing and that is why it is going to cut. So, this here the teeth of this one when it will be rotating its point it will be just shearing the part of the rock that is the how the drag bit will interact.

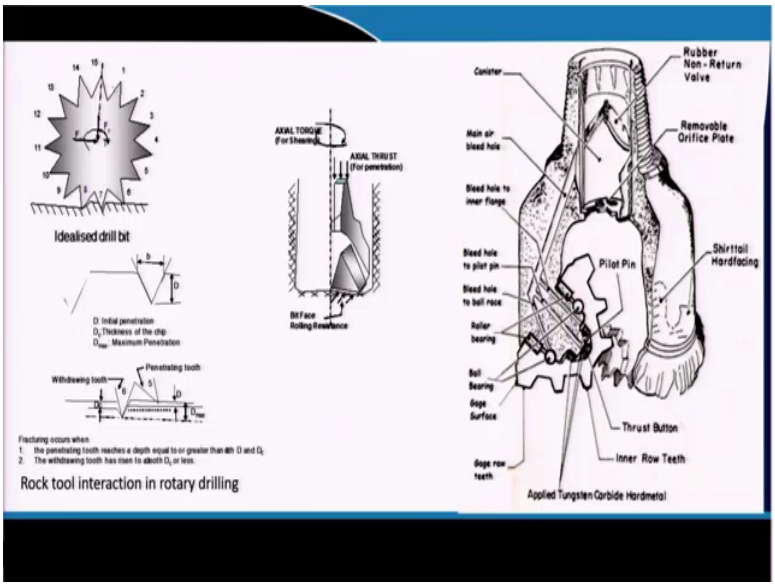
And there is also in your diamond drilling, that is in a exploration part you have said these are your diamond drill bit what is here you need to do before mining need to do the exploration. While you were doing the explorations we need to find out the core say for example, a coal seam maybe there at a deeper that area, then how to get that we will have to do the diamond drilling for doing this type of bits are used for a diamond drilling bit.

(Refer Slide Time: 25:34)



Now, there is a in a percussive drilling how the bit exactly interact the rock is in elastically deformed. First, when your percussion is given this rock starts getting a crack and then the chip formation takes place and then you make your say pneumatic or air blast you throw and these chips have taken out this is the way how diamond drilling that is your percussive drilling take place.

(Refer Slide Time: 25:59)

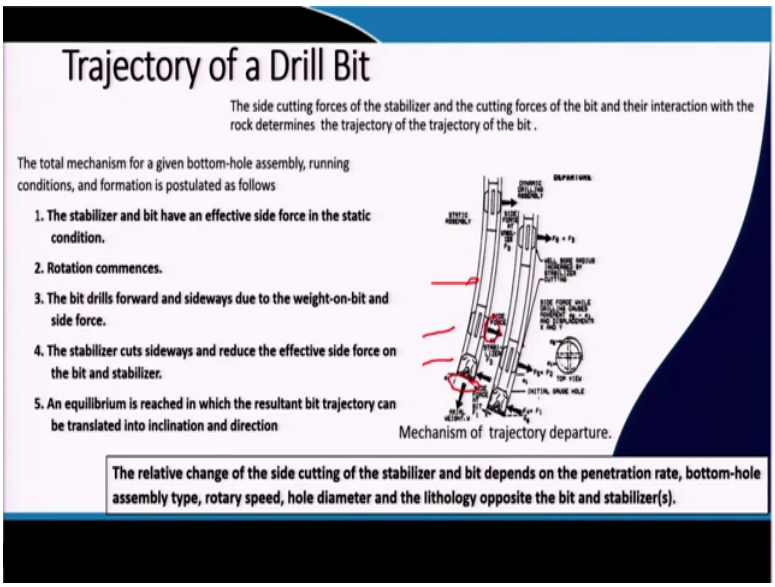


In case of rotary drilling they use a tricone roller bit, you have these bits if you take a cross sections here it is just like a cutting that is your a toothed wheel. Now, if it is forced into you can see that rock in between get trapped over here and now when it will be rotated then this portion will get chipped off and then this is the way how it cuts.

That is what there is a crack on this type of cone is there three cones are kept over there. That is why it is called tricone roller and that your buttons or teethes are placed over here as a roll and then this will be giving. And then the cut and their air is flown through this and then it will.

So, that is the while cutting here a lot of heat generated. So, the drilling mud or drilling fluid will be going through here it will be cooling and that the rock will be cut by distance. So, we will be discussing this in our drilling bits.

(Refer Slide Time: 27:02)



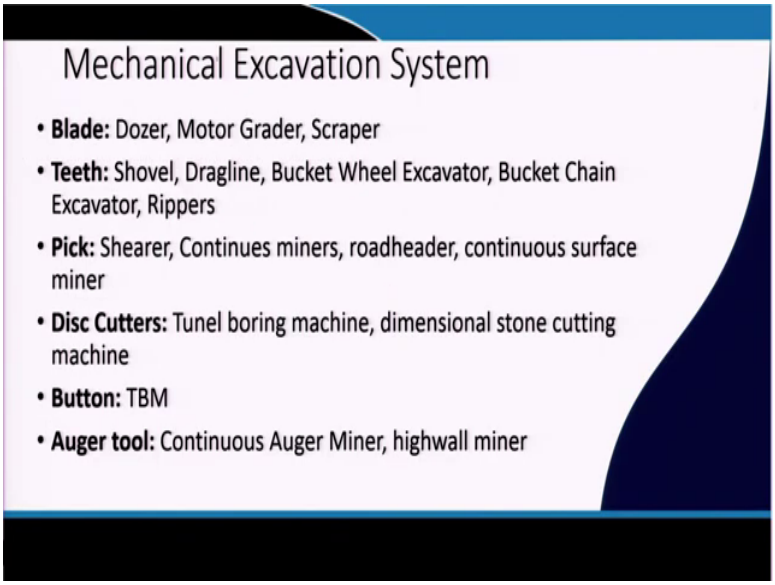
Now, you can find out that in a deep drilling in that your in the oil field. When we want to do a deeper oil well drilling sometimes the direction get changed because that whenever there is a drill rod on that we have got one your stabilizer and then there is a bit. Now, when the, that stabilizer is widening this hole that there is a bit is here. So, there is a side force is coming on this now depending on what is the that this rock is being cut over here.

And what is that rock being cut or that is your by the stabilizer streaming it depending on that a dynamics of force is taking place this will divide design the trajectory by which this will go.

So, that is a very interesting study one can study about that then if you develop it then you can find out if the strata if the strata is of different type then how that trajectory will go.

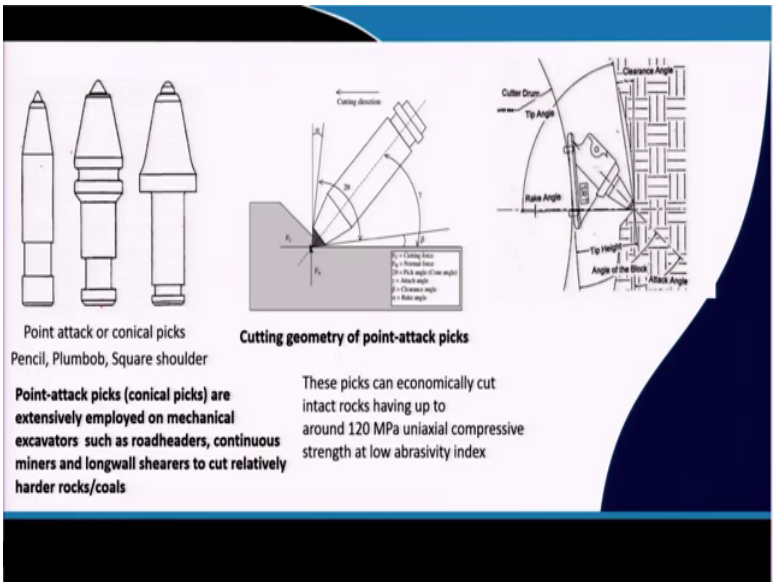
Then depending on this exactly in a directional drilling you decide that decide that in which way we will have to be engineered the drill hole. So, that is the drilling technology is a very interesting subject, but you need to know that the interactions which is taking place with the rock with the bit and with the stabilizer they will be making the trajectory.

(Refer Slide Time: 28:31)



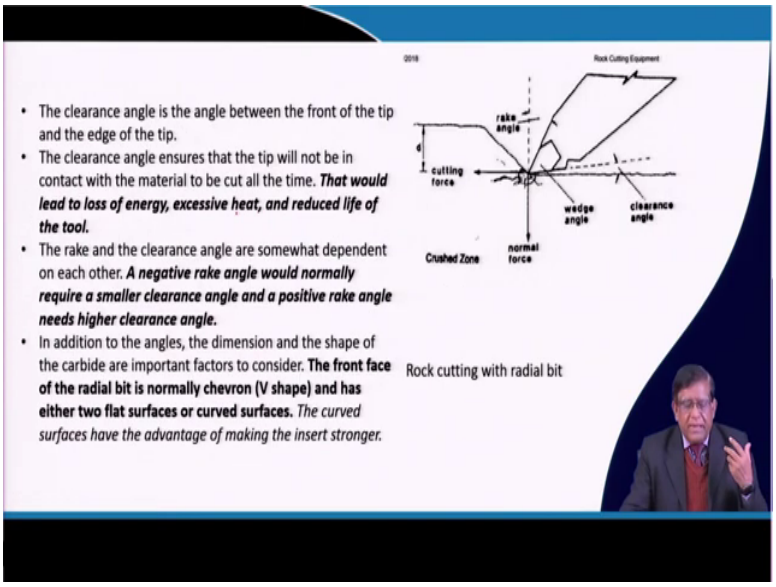
So, similarly your the total excavations can be done by different type of your interacting tool; it can be blade, it can be teeth, it can be pick, it can be disc cutter, button or other tool.

(Refer Slide Time: 28:44)

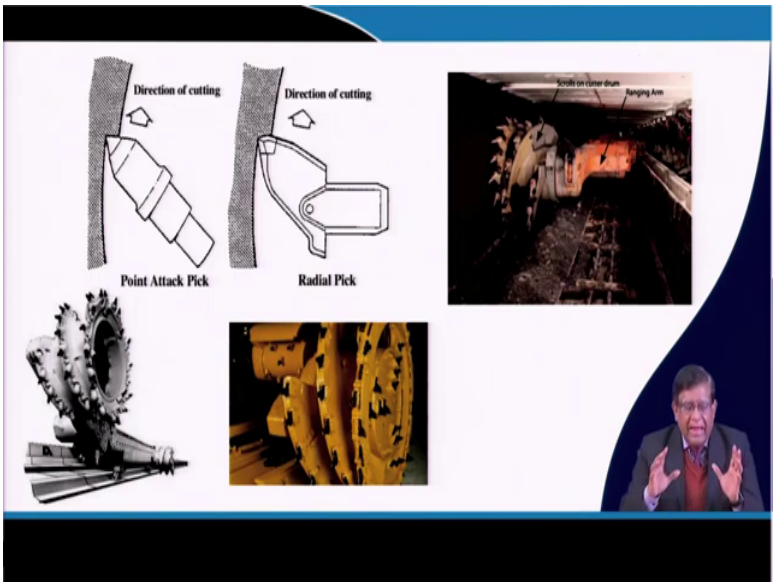


Now, this the cutting pick or tool it can be differently we have got a point cutters or we have got another called radial cutter. Now this point cutter and radial cutter while cutting in the rock they also just as I said earlier the main thing is the rake angle clearance angle and cutting angle. And with that how it is energy is dissipated over here, what is that cutting force will be available on that basis the cutting rate or the production rate will be coming.

(Refer Slide Time: 29:15)

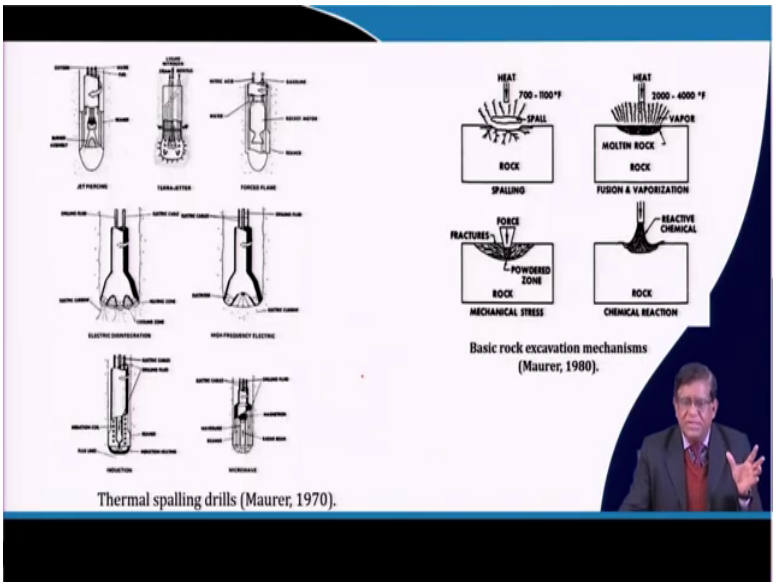


(Refer Slide Time: 29:26)



So, you can see here in a radial bit there also the same thing your that rake angle cutting angle and all their relationships will be behaving with a different type of rock differently and these are exactly deployed in different mining machinery. In a shearer, we can have a this type of your conical bit point at a conical bit or we can have the same shearer in some places we may have with the radial pick. So, how it will be behaving and then how they are exactly done we will be discussing in our detail machinery study.

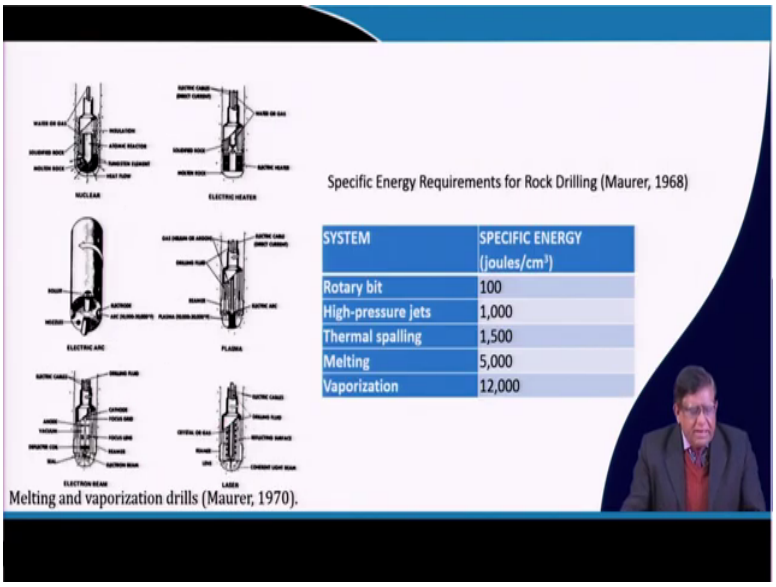
(Refer Slide Time: 29:49)



But as I told that there are many studies were there that what could be the alternative new method of cutting the rock tools. And there this Maurer Allen Maurer is the persons whose reading who wrote a book I think in the 70s or not in or 80s he wrote a book called novel drilling technique.

Please go through that book where in those days in the 80s they initiated so many researchers or on this different way of cutting. Here there are thermal spalling of drill. That means, rock can be brought by making a tool which will be exactly not interacting directly with the rock, but generating heat by that heat the rock will be allowed to spall.

(Refer Slide Time: 30:30)

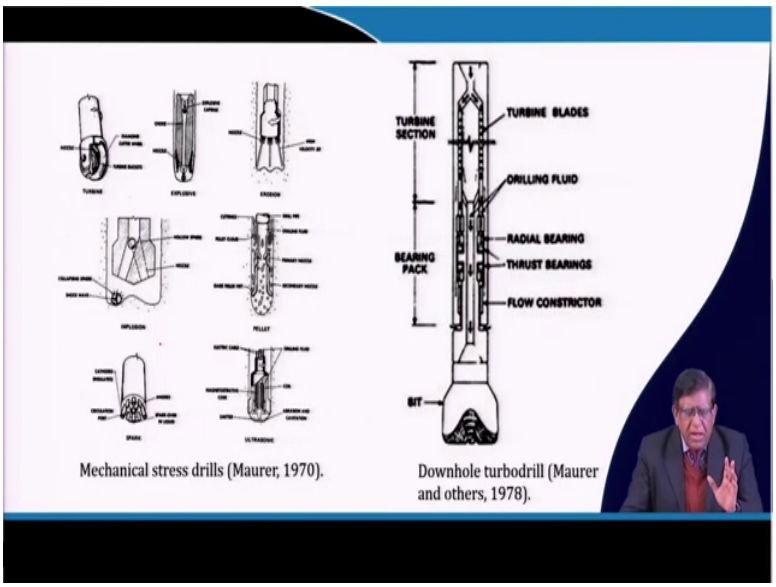


That similarly there were that different chemical reactions can be taken up, then there will be vaporizations nuclear electronics sometimes they have just generating very high arc. Say for example, you cannot make a very good decisions drilling, when there are a lot of chips are there in a alluvium there you will have to use a different way of taking out the material and doing it.

Say if you are going to do a drop cutting or drilling in Antarctica there in the that permafrost that what could be done that on ice they are very hard, how to do it? It can be done by electric arc, you give a very high voltage arc there and that heat that water that your the that permafrost they will get into water and you can take out the water to make the drill hole.

Similarly, when you are to do some exploration in the glaciers in say Himalaya there how you will do it there? Those different type of situations we can have some novel drilling technique you can study about that.

(Refer Slide Time: 31:36)



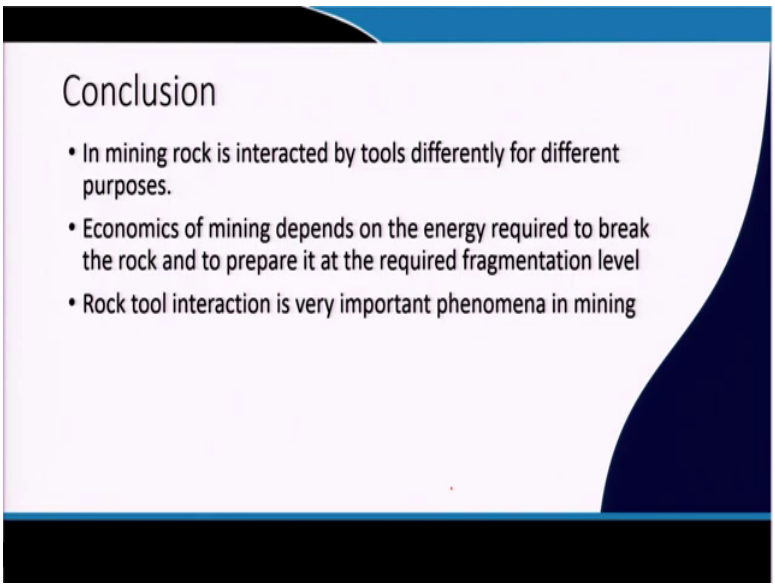
And there are also this mechanics stress drills, they are the spark drilling can be done then there is a jet spear some sometimes to generate that heat you can use a fuel then carry. Maybe a oxygen and the fuel is allowed to down the hole and then you make it just like a welding arc they will be burning over there, they will make the rock to spall and then you take it.

So, that bit can be that interaction with the rock can be done differently depending on the different purposes. There is another thing which is very common in petroleum industry also is called turbo drill in which the bit above the bit. There will be because the drill hole cleaning

fluid when it is passing at a high pressure there is a turbine blades are there. So, it will start rotating.

So; that means, the above this the rod is not rotating, but below here this portions will be rotating at a very high speed and you will getting a high penetration rate those type of drills are also there as a different way of interacting with rock.

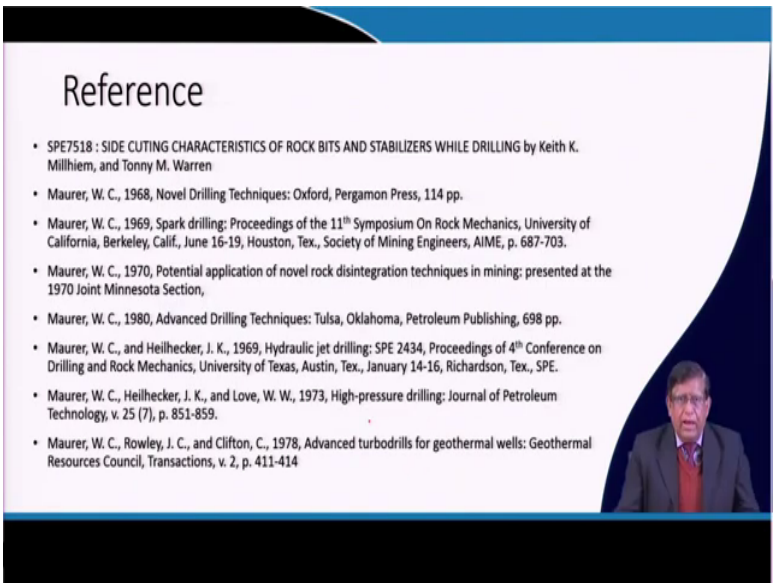
(Refer Slide Time: 32:41)



So, in mining rock is interacted by tools differently for different purposes, whether you want to do it drilling whether you want to do it cutting or for excavating. In a bucket teeth their interactions will be different those interactions while studying the particular machine there we will be studying about how you will be fitting those teeth in the lip of the bucket and how that will be interacting.

Then if you want to do research in this area there is a ample scope for it. Economics of mining depends on the energy required to break the rock and prepare it at a required fragmentation level rock tool interaction is very important phenomena in mining.

(Refer Slide Time: 33:26)



And you should do a little bit study and then make a report on the rock tool interactions maybe the for a very hard rock. If you can study that how in the Finland the Finnish hard rock mining they are doing a lot of research on that tool or you can study in a coal mining country like China they have done a lot of development of machinery and tools there or you can study in the oil well drilling how the different types of bits have come.

So, one thing is the materials selected are one of the very important area you can think of how polycrystalline diamond drilling bit PCD bits are being used for our exploratory drilling for interacting with the rock and increasing the penetration rate lot of things can be studied.

Thank you, very much I think your time is up.