INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Mechanical Operations
Lecture-14
Size reduction equipment-1

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Welcome to the fourth lecture of third week of mechanical operations course. In this lecture I will cover equipment related to coarse crushing. However, the equipment related to intermediate as well as fine crushing will be covered in next part of this lecture. So let us start the part 1 of this lecture the size reduction equipment.

We are having a number of equipment for size reductions and these are classified based on the particle size they can handle. So first category in this is the crushers.

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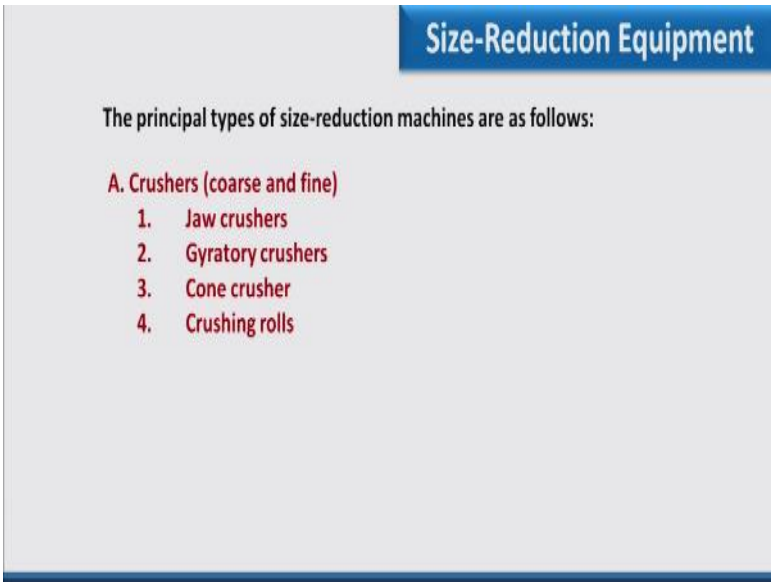

In this crusher we will discuss coarse as well as fine. The first crusher is jaw crushers, second is gyratory crusher, third is cone crusher, and fourth is crushing rolls. All these four equipment are falling in the category of crushers.

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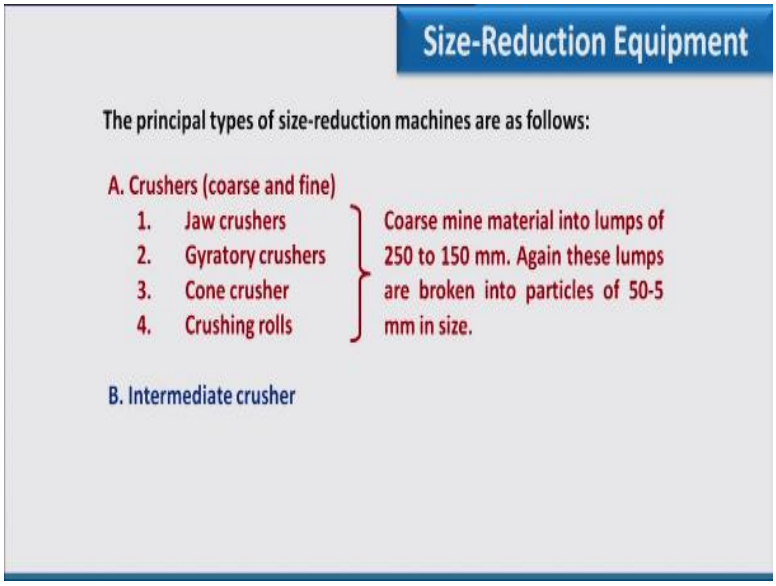

Coarse mine material into lumps of 250 to 150 mm. So what the utility of these crusher, they can convert the coarse mine material from bigger size to 250 to 150 mm. Again these lumps are broken into particles of 50-5 mm in size.

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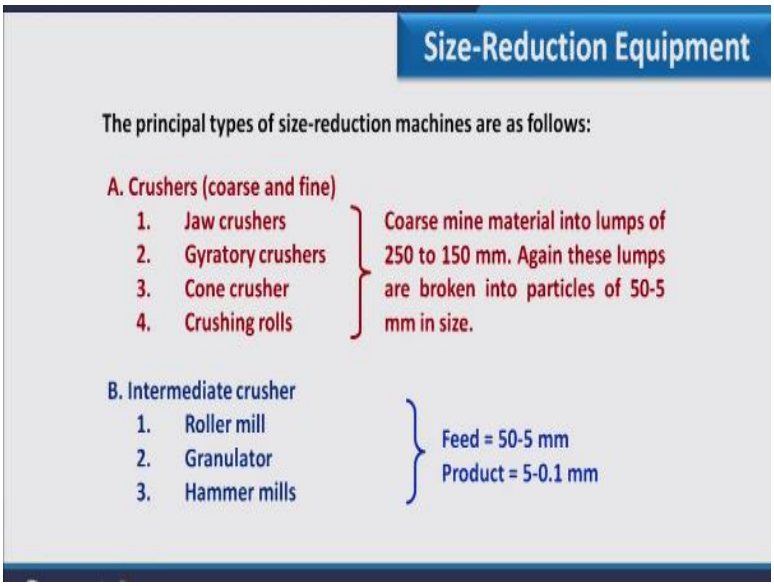

Second category we have is the intermediate crusher. In this crusher we have roller mill, the granulator, and third is hammer mills. All these are a part of intermediate crushers. In these crusher usually feed is having size from 50-5 mm and product we are receiving from this is having size 5-0.1 mm. So these are two category of crushers.

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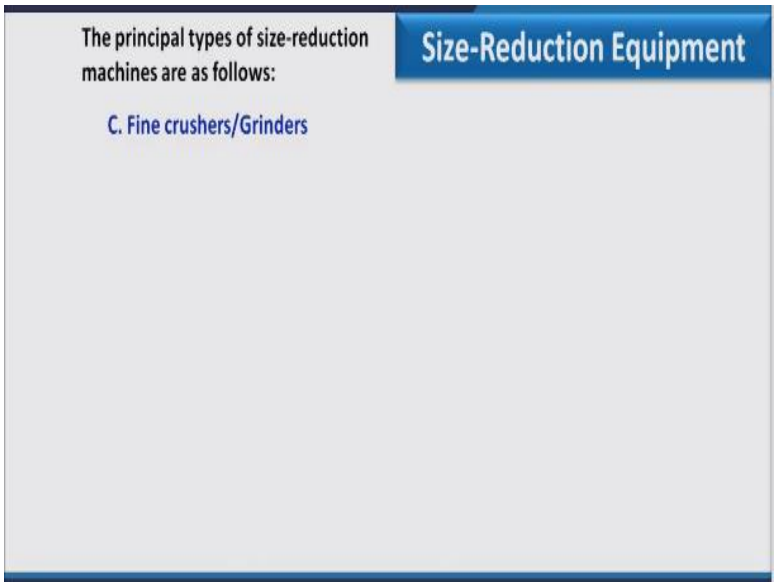

Now in third category we have fine crushers, we also call these as grinders.

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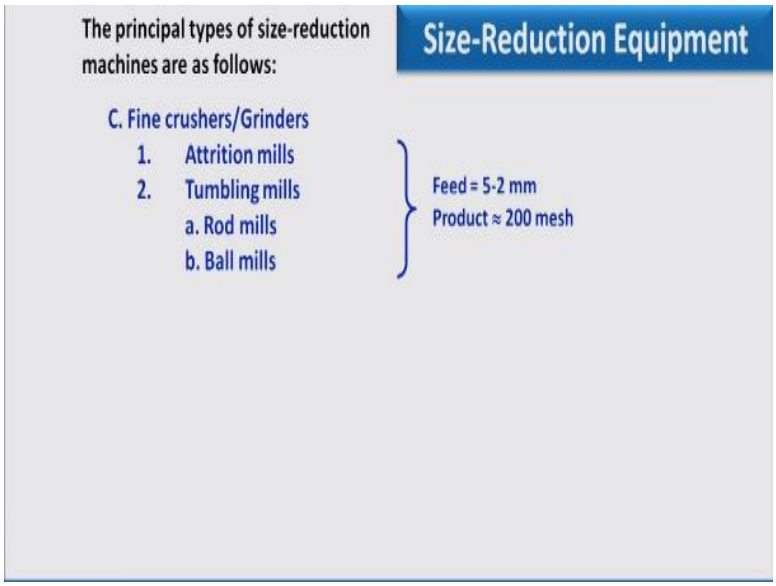

In this fine crusher the first is attrition mills, second is tumbling mills and in tumbling mills again we have rod mills as well as ball mills. So when we see the feed as well as product size in this fine grinders or fine crushers, the feed include 5-2 mm size and product is approximately 200 mesh size.

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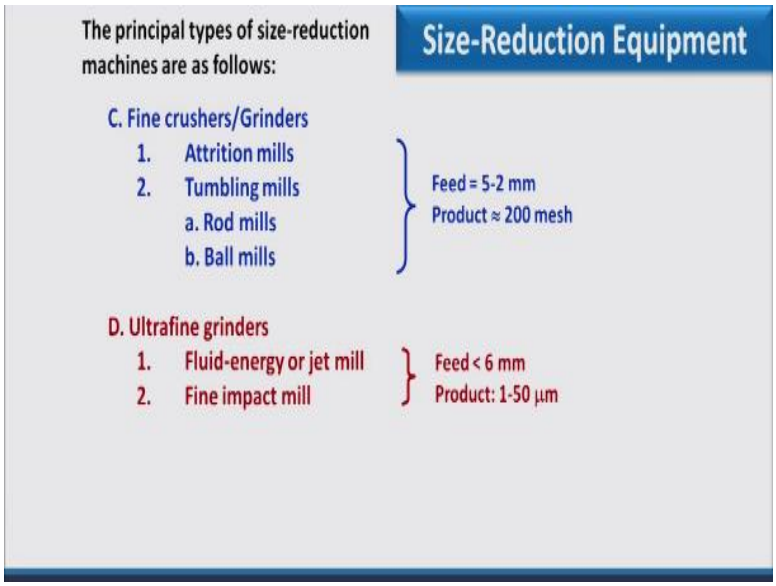

In category D we have ultrafine grinders. In these grinders the first is fluid energy or jet mill, and second we have fine impact mill. In this category the feed is usually accepted lesser than 6 mm size and product which is coming out from these grinders is having size 1-50 micrometer.

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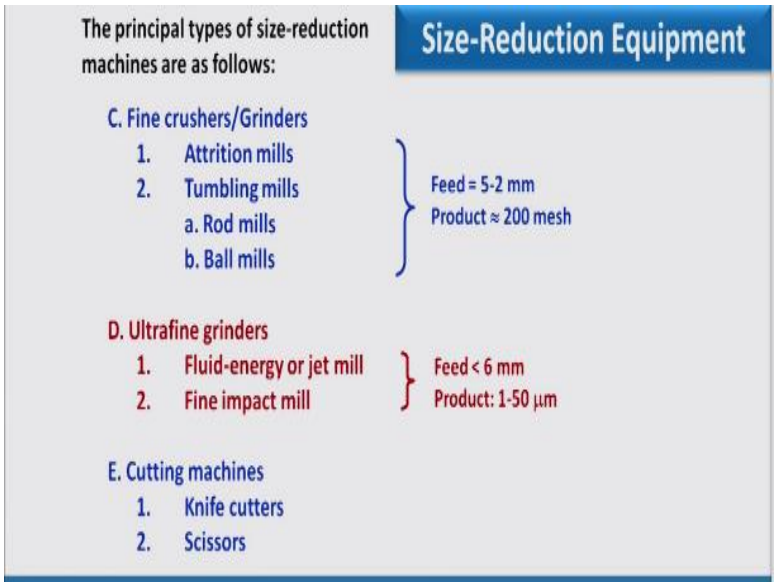

And finally we have cutting machines, in cutting machines first knife cutters is there and second equipment is the scissors. All these knives and scissors we will discuss in terms of industrial equipment.

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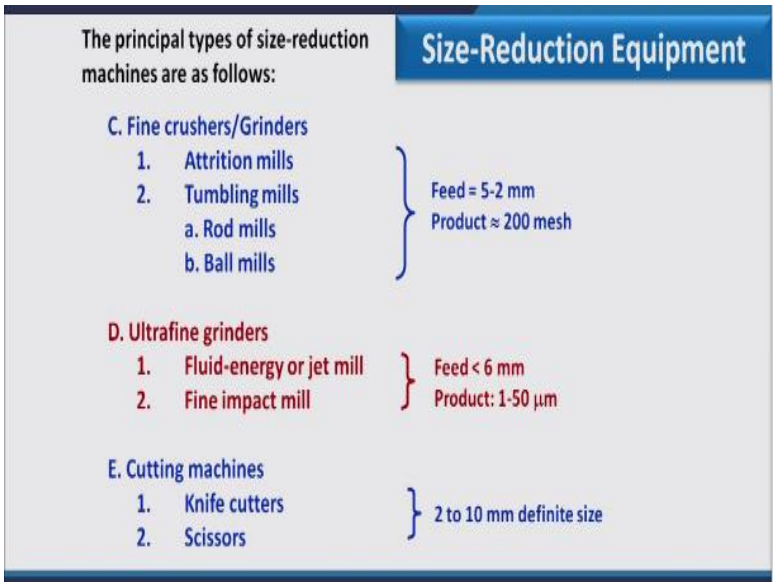

Basically in cutting mills we have a definite size product which is 2-10 mm in size. So these are different categories of size reduction equipment, in subsequent slides we will discuss the working behavior of these equipment one by one. Now before doing this we will discuss what is the selection criteria for equipment and there are number of criteria.

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The first is produced material of desired size and shape, we will obviously select the material which gives me the proper product size that I want. So first is the machine, the equipment should produce materials of desired size and shape, second it should accept maximum input size expected, have large capacity, it should not be choked.

Pass unbreaking materials without causing damage to itself, small power per unit weight of the product. So it should consume a small power, resist abrasive wear, have prolonged service life, easy and safe to operate, easy access to internal parts for maintenance. So here we are having a number of criteria based on which the required equipment or the suitable equipment should be selected.

Breakage pattern we will discuss here and this we have already discussed during the introduction of size reduction, but these equipment will utilize these patterns so therefore we are revising these patterns here also.

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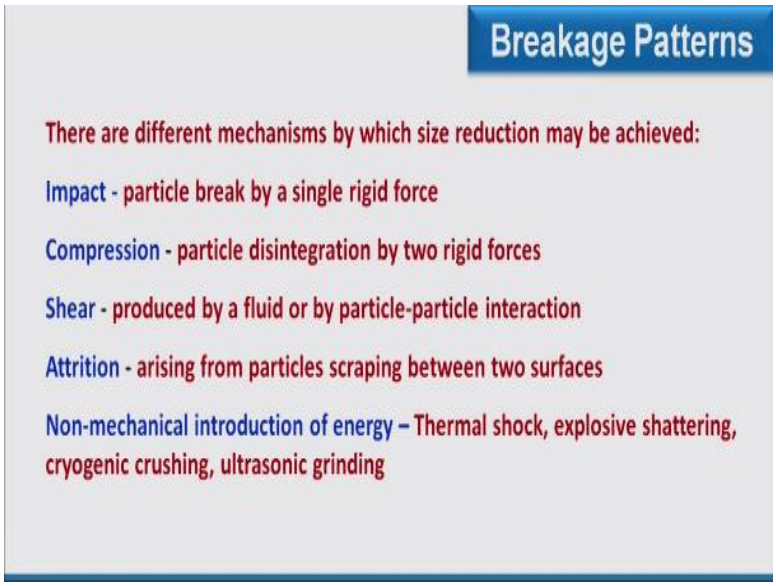

The first is impact, you understand this very well that particle break by a single rigid force, second is compression particle disintegration by two rigid forces, third is shear produced by a fluid or by particle-particle interaction, fourth attrition, arising from particles scraping between two surfaces or rubbing between two surfaces. And another we have non-mechanical introduction of energy in which thermal shock, explosive shattering, cryogenic crushing, and ultrasonic grindings are used to crush the material.

Now as far as these breaking patterns are concerned, here we are having a number of main equipment for size reduction.

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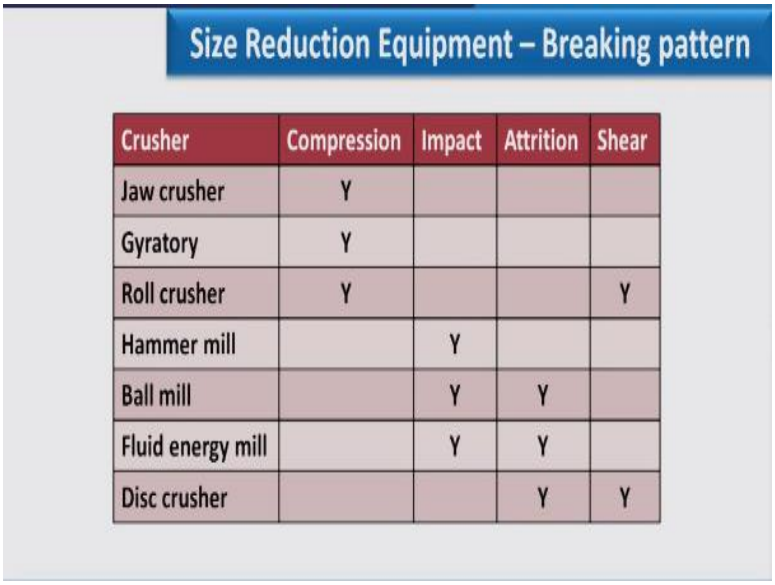

And this table shows the particular equipment and what type of pattern that equipment follow that we can see from this table. So if we consider jaw crusher, basically jaw crusher utilizes the compression so if I am having gyratory crusher it will again have compression. If I consider roll crusher it considers compression as well as shear. Hammer mill it works on impact, ball mill here we have impact as well as attrition pattern, fluid energy mill here impact as well as attrition both are used and disk crusher here we have attrition as well as shear, so you can understand the breaking pattern followed by each equipment.

Now I start with the very first equipment we have discussed which is falling in first category that is category A and these are crushers, so what is the crusher?

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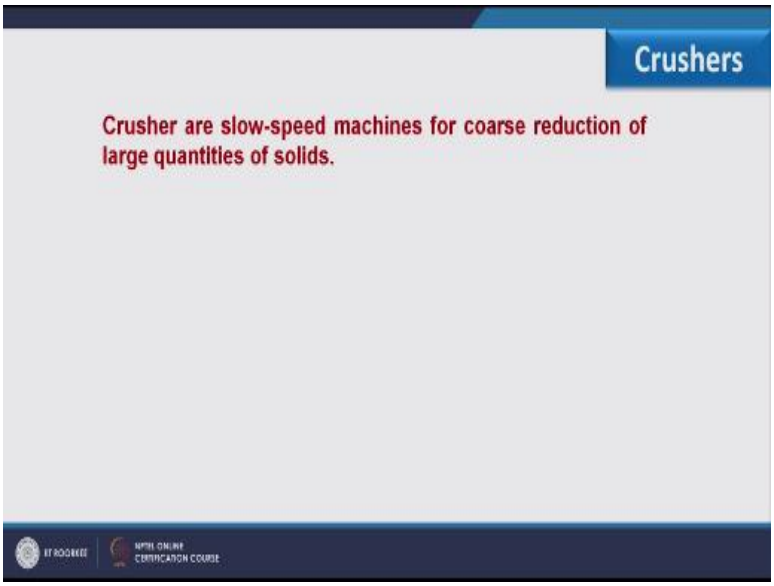

Crusher is slow speed machines for coarse reduction of large quantities of solids, so you can understand coarse reduction we can carry out using the crushers, there are main types of crusher.

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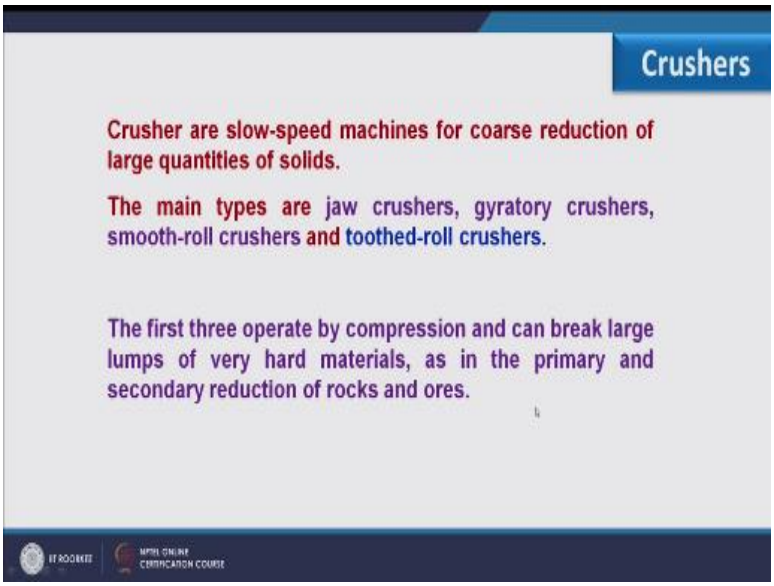

And in this category we have jaw crushers, gyratory crushers, smooth- roll crushers and toothed-roll crushers. When we consider the first three equipment that is jaw crushers, gyratory crushers and smooth- roll crusher these operate by compression and can break large lumps of very hard material as in the primary and secondary reduction of rocks and ores, so from here you can have the idea that crushers are basically used as primary and secondary reducer of rock as well as ores. On the other hand toothed-roll crushers.

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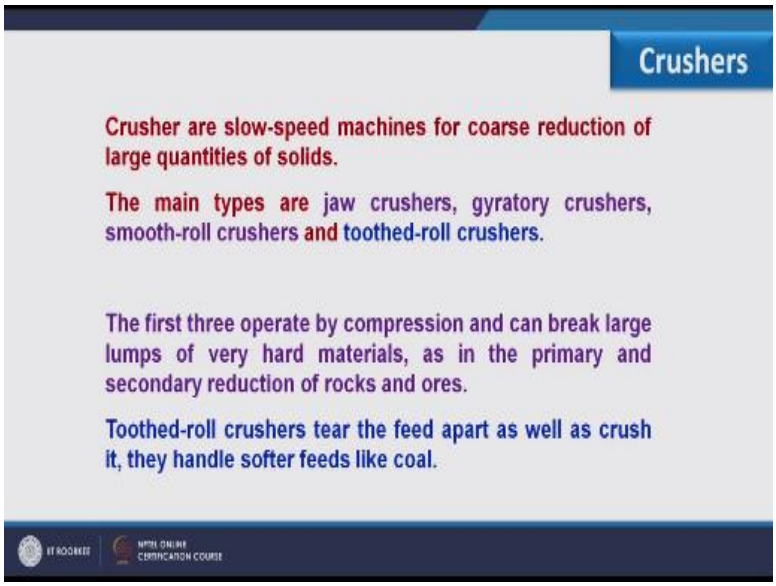

Tear the feed apart as well as crush it, they handle softer feeds like coal, now if you see the tooth which are available on the crusher they can get wear very easily therefore they are utilizing softer material in comparison to jaw, gyratory or smooth roll crushers. Now in subsequent slides we will discuss all these crushers one by one, let us start with the jaw crushers.

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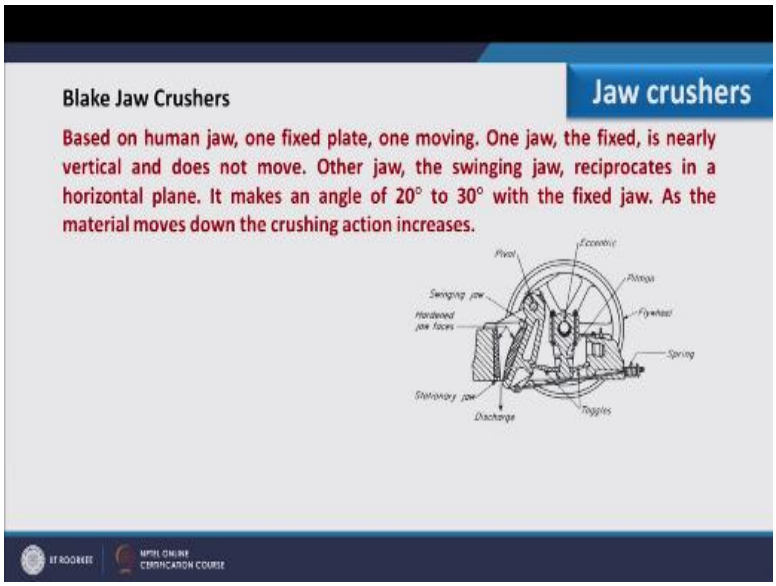

First of all we are having Blake jaw crushers, what is the structure of it, it is basically works on the human jaw, so based on human jaw one fixed plate and one moving plate we are using as jaw. So if you see this schematic, in this schematic this section basically we call it stationary jaw which fixed at its position and this section is the swingimg or we call it hanging jaw which moves forward as well as backward to crush the material.

So one jaw the fixed is nearly vertical and does not move, other jaw the swinging jaw reciprocates in horizontal plane, it makes an angle of 20º to 30º with the fixed jaw so usually this angle is 20 to 30º, as the material moves down the crushing action increases so here you can understand from this side we have the feed and when feed comes over here continuously this swinging jaw strikes this or put the compression on the feed and due to that compression material breaks and the reduced size material discharge from here.

So if you see this it is a photographic view.

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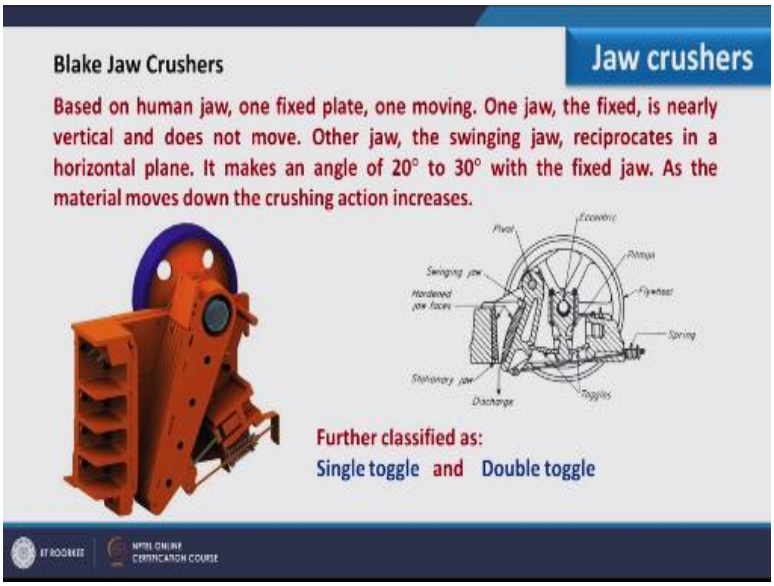

Here you can have better idea of this like this is the fixed jaw and this is the moving jaw which moves forward as well as backward and here it is attached with an is eccentric or we can say that it is pivoted at the top, so feed comes from this side and it continually compress the feed so when feed is broken it gets out from this section. Further Blake jaw crushers are classified as single toggle or double toggle.

What is single toggle and what is double toggle, that we will discuss, so single toggle is an eccentric shaft is positioned.

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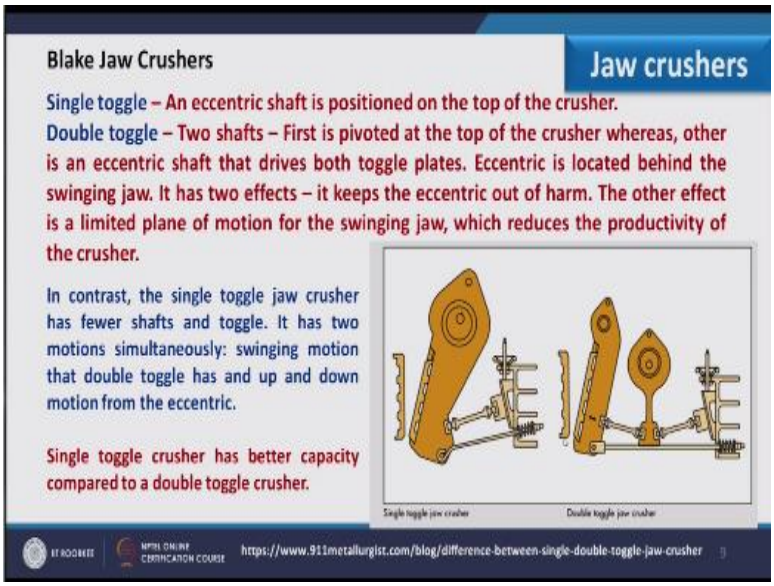

On the top of the crusher, so if you see this image here we have this is the fixed jaw and this is moving jaw so this is pivoted at the top and here we have this a single toggle so this is called single toggle jaw crusher and in double toggle two shafts are basically used, first is pivoted at the top of the crusher, like if we consider this image this is basically of double toggle jaw crusher, here the first toggle or we say the first shaft is pivoted at the top of the crusher whereas the eccentric shaft that drives both toggle plates.

So eccentric is located behind the swinging jaw so you can see here we have two toggle, first is pivoted at the top and here we have the eccentric which is behind this toggled shaft. However here jaw is pivoted at the top and eccentric is also attached over here, when we consider the double toggle jaw it has two effects it keeps the eccentric out of harm so what happens over here, here we have this eccentric which is obviously away from this pivoted jaw.

So when jaw moves backward and forward it does not affect this, the other effect is a limited plane of motion for swinging jaw which reduces the productivity of crusher so what happens in double toggle, like here we have the pivoted jaw so due to the placement of eccentric jaw just behind this it has least less position opportunity to move forward as well backward so it is less

productive, on the other hand the single jaw crusher has fewer shafts and toggle, it has two motions simultaneously swinging motion that double toggle has and upper and downward motion from the eccentric, so you see here we have this forward and backward motion from this side from this toggle and due to this eccentric we have upward and downward motion in the single toggle . So the single toggle crusher has better capacity compared to double toggle crusher, here I have already shown the link if you want to study about this.

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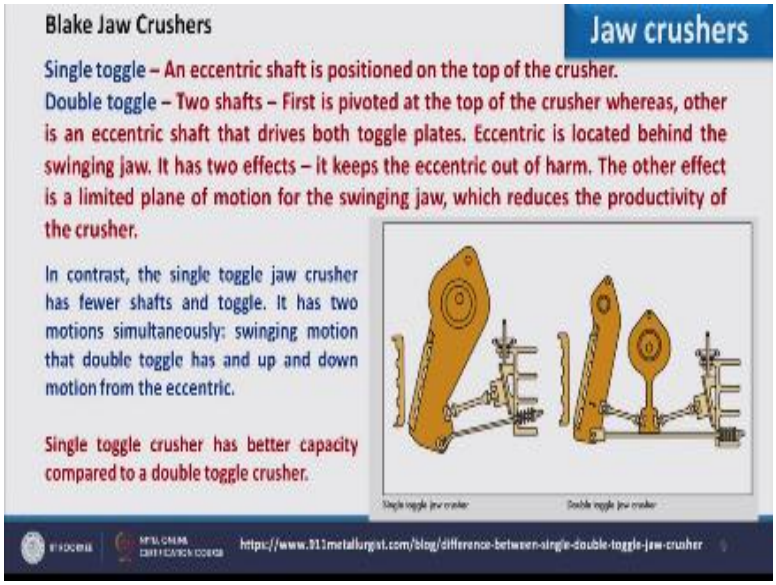

You can go through this link, so Blake Jaw crusher here I have shown the animation of this, here.

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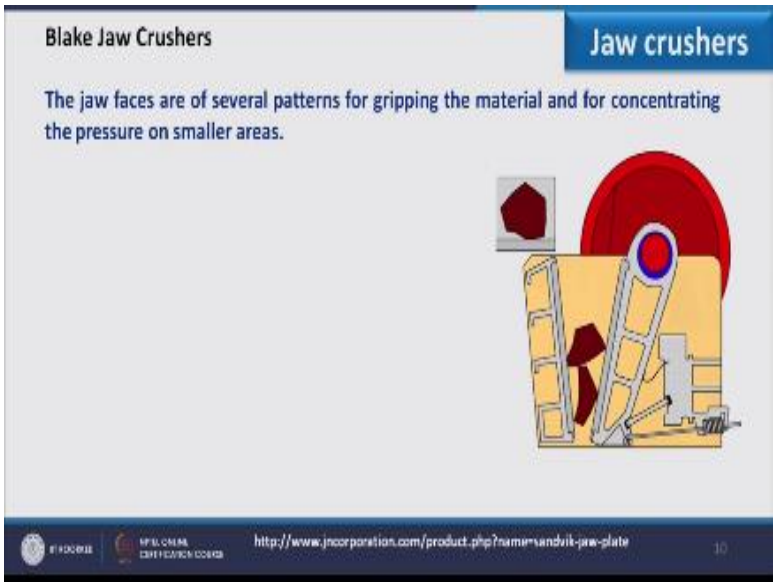

You can see the material comes in between and continuously it compresses the material between this fixed jaw as well as this movable jaw and then the material is reduced in size. Now what happens, due to this toggle it moves forward as well as backward and due to this eccentric it moves up and down, that you can very well see from this animation and more you can study in this link so the jaw faces are of several patterns for gripping the material and for concentrating the pressure on smaller area.

Now we will discuss what is the jaw plate and how these plates.

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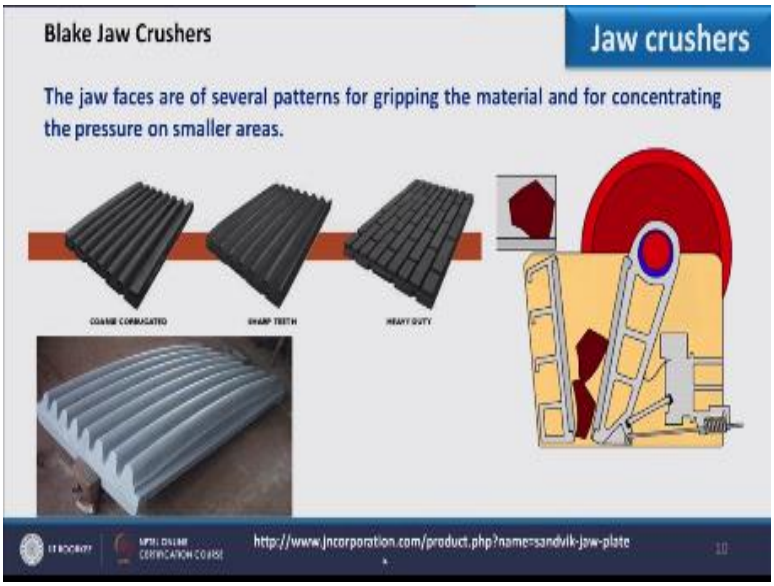

Look like, if we see this these are the number of jaw faces or jaw plates, you see first one is coarse corrugated, second is sharp teeth and finally we have the heavy duty plate or heavy duty face, so these are the faces of which are placed over here, if you see this strip this is nothing but these faces. This is another example of this for more you can go through the link which is available on the slide. So here as far as Blake jaw is concerned the product size is adjusted by adjusting the gap size, what is the gap size, that gap between two jaws and second the jaws open and close.

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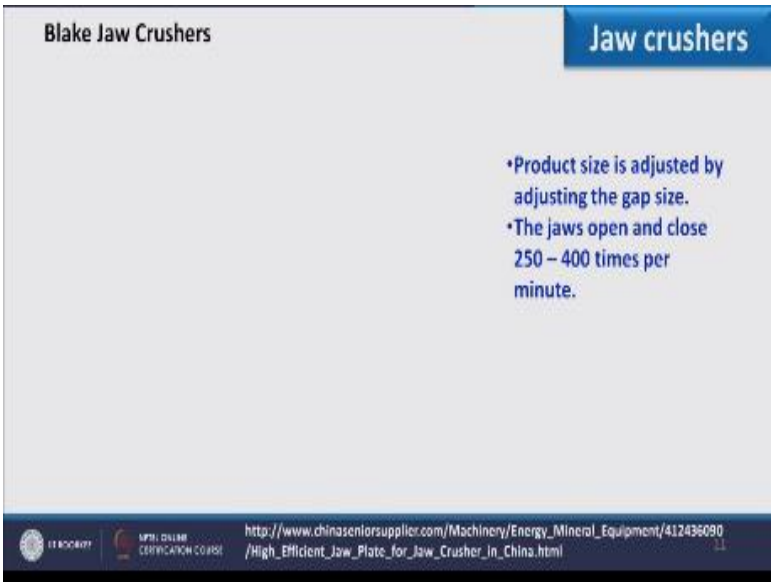

By 250 to 400 times per minute, so this is the rate by which jaw opens and closes and once it opens and closes it puts the compression and then material is being crushed.

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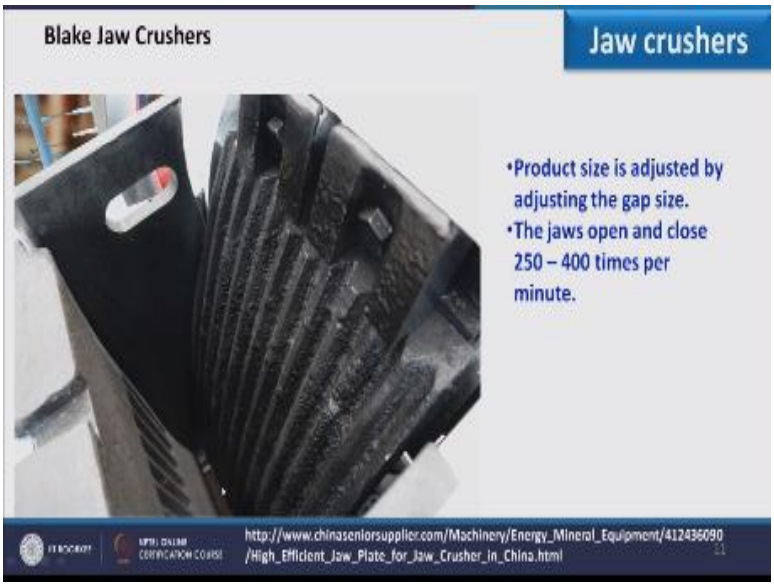

So here again I have shown one close view of jaw, here this is the fixed jaw, this is the movable jaw and gap by adjusting this gap between the two we can adjust the product size we want, and more about this if.

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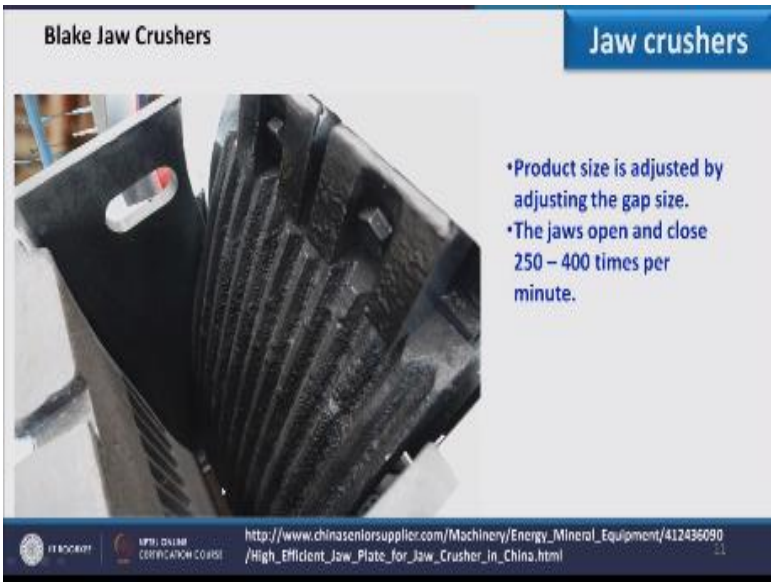

You want to study you can go through this link so this uncrushed raw can be passed through, yes that is the drawback of jaw crusher, sometimes what happen when material is not compressed properly it can pass through the crusher uncrushed or let us say size, if we have not decided the size between the gap between the jaws properly then uncrushed raw can also be passed through this.

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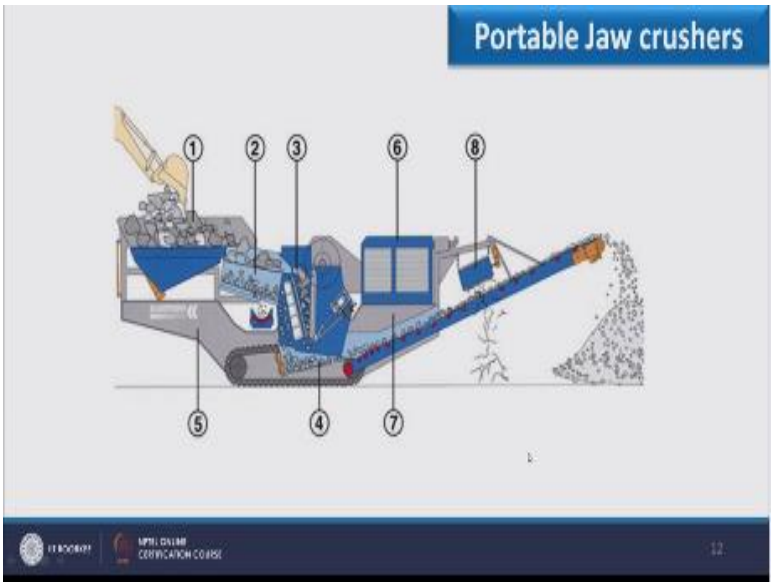

Here I have put this image to show the portable jaw crusher and this crusher consist of feeder, screen, crusher, and conveyer. How it works, if you see this is the, here we have the wheel in this portable jaw crusher so that can be taken out at any position where we want this so if you consider this particular section over here, here we put the feed of large size, once this feed is coming over here it can pass through this so here we have the screen where we have to separate the coarse material as well as the fine material.

The fine material can be collected over here and coarse material is retained on the screen, once this coarse material are available on the screen it can come to the jaw crusher, here the jaw crusher is placed so continuously the large particle is the large or we say the lump comes in the jaw crusher and due to compression its size is reduced and then it mix with the fine particle which are already collected through screening previously so this mixture continuously convey to the desired.

Site through this belt conveyer so this complete assembly we call portable jaw crusher where we have feeder, screen, crusher, and conveyer. So in jaw crusher the, another crusher we are having is dodge jaw crusher, in this dodge Jaw crusher the movable jaw is pivoted.

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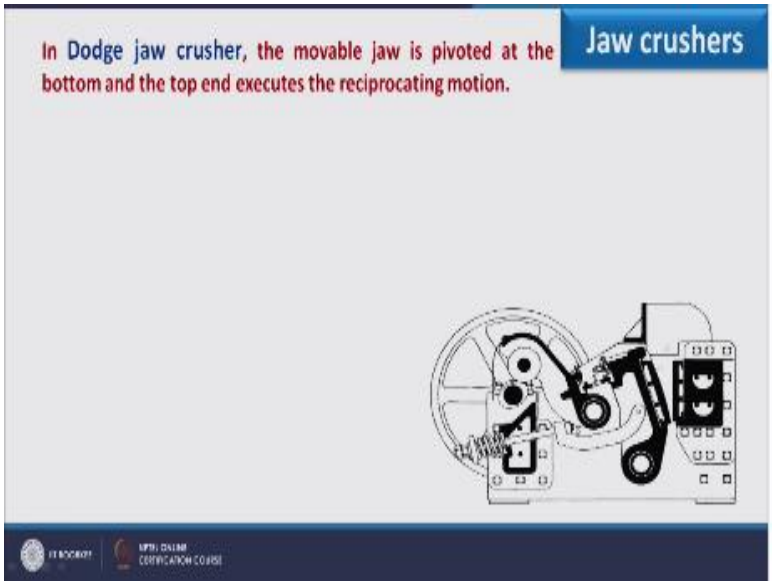

At the bottom and the top end executes the reciprocating motion, so what happens in Blake jaw in Blake jaw we do the pivoting of swinging jaw at the top but here we have the we have done the pivoting at bottom, so this particular section.

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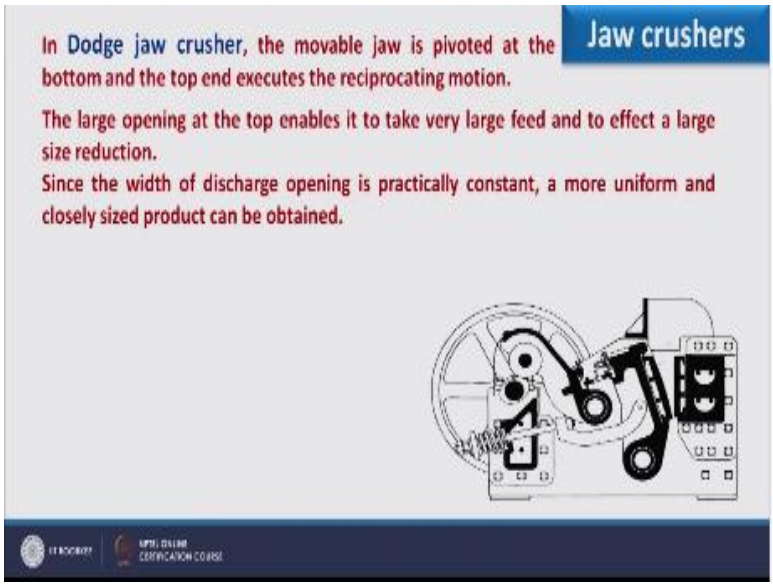

Is fixed and here we have this open section where the reciprocating action takes place to break the material. So large opening at the top enables it to take very large feed and to effect a large size reduction, since the width of discharge opening is practically constant a more uniform and closely sized product can be obtained so here we have the advantage that we can handle large feed.

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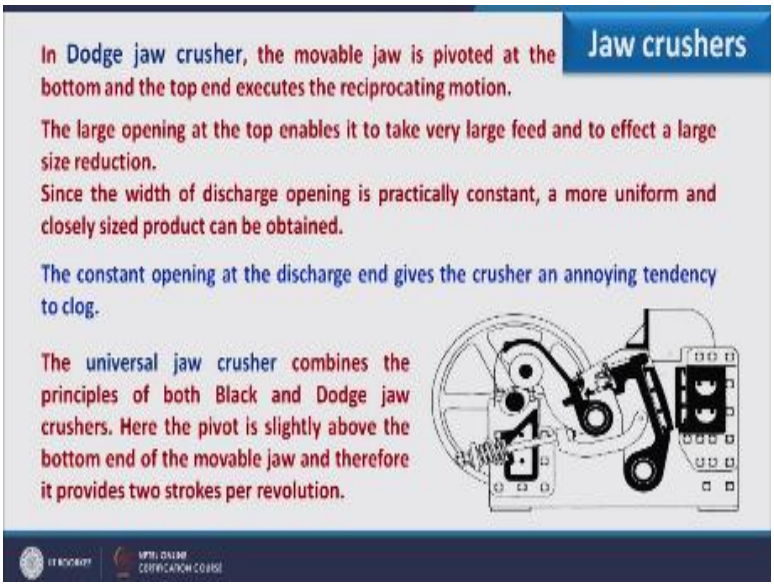

In comparison to jaw crushers, the constant opening at the discharge end gives the crusher an annoying tendency to clog. So here there is one problem with this crusher that here due to pivoting this section is fixed so it has sometimes the annoying tendency when material is clogged over here. So another category of jaw crusher is the universal jaw crusher which combines the principle of both Blake as well as dodge jaw crusher. Here the pivot is slightly above the bottom end of the movable jaw and therefore it provides two strokes per revolution, so here basically it works like this, this is the fixed jaw, it pivots slightly above so both way it puts the reciprocating and then it can break the material. So this is the working of universal jaw crusher.

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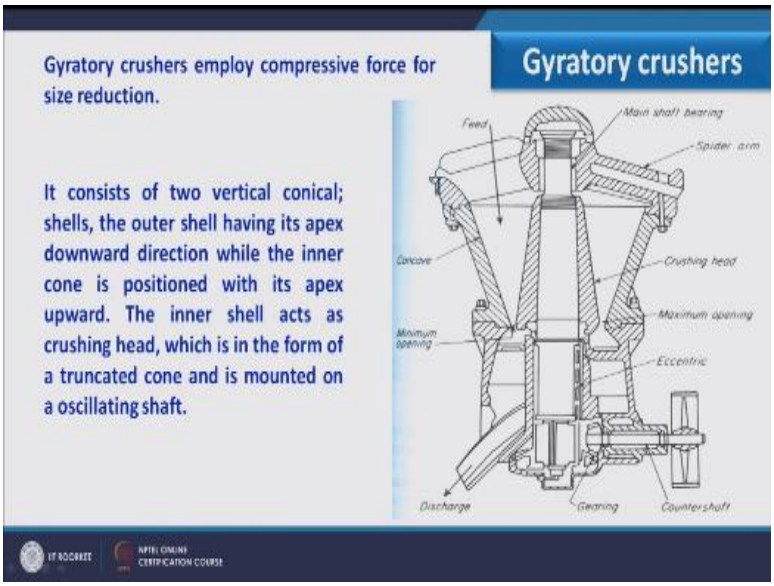

Another crusher we are having is the gyratory crusher, gyratory crushers employ compressive force for size reduction. Now what is gyratory crusher, the schematic of this is shown over here.

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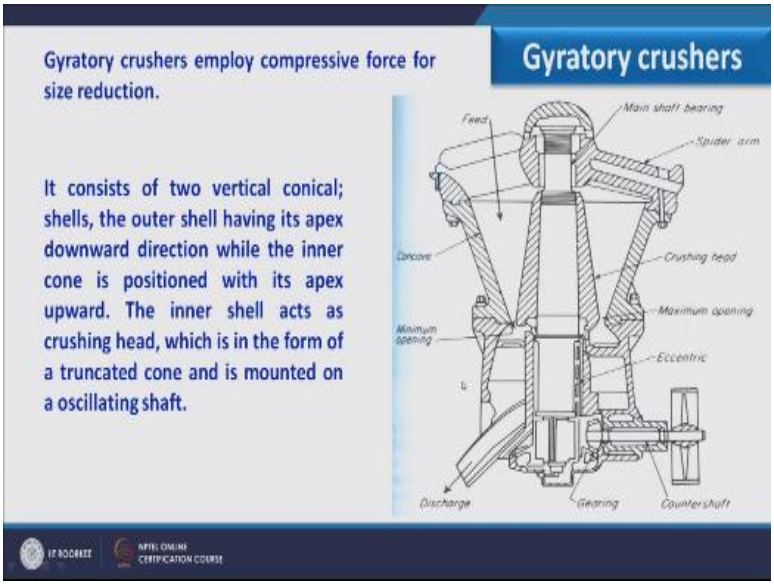

Here you see we have two conical section, first section is this and second section is in between this, so gyratory crusher consists of two vertical conical shells the outer shell like this, this section is called the outer shell it is having apex downward direction like here we have this section so apex is downward, on the other hand the inner cone that is this cone if we see this cone is positioned with it is apex upward. The inner shell x as the crushing head which is in the form of truncated cone and is mounted on the oscillating shaft.

So if we see the cone in between section is basically oscillating shaft over this, this cone is placed so due to oscillation of shaft also this inner cone also have the oscillatory motion and due to this oscillatory motion it compresses the material which is falling in between and then crush it. So if you see here we have the outer cone and here we have inner cone, in between this we have the feed, so feed is continuously falling between outer cone and inner cone and due to oscillatory motion, due to gyratory motion it continuously compresses the feed and breaks it, so that is why it is called gyratory crusher.

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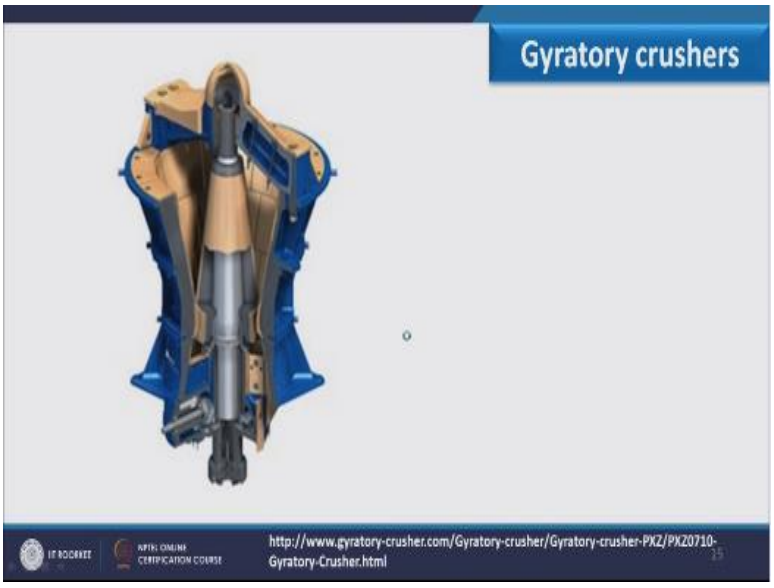

Here the, you can see the photographic view of this here we have the outer cone, this is the inner cone and this is the oscillating shaft. In which this cone is fixed, so if you see this.

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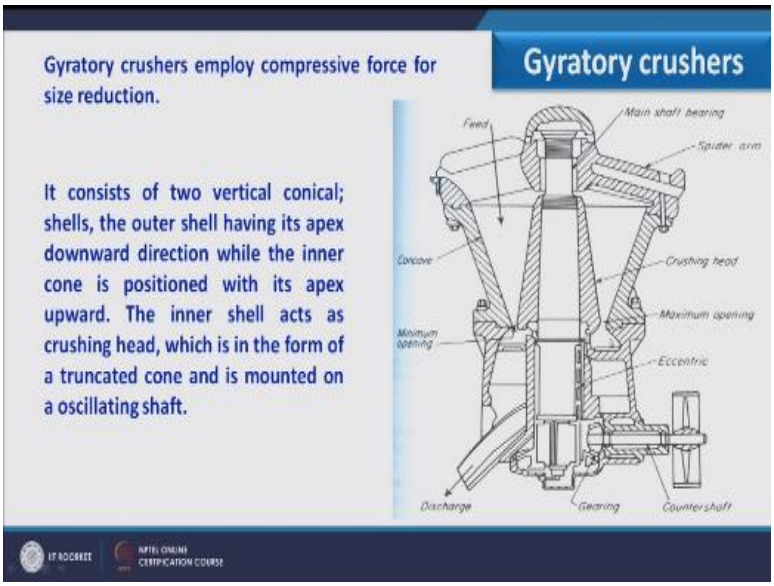

Schematic again here due to this oscillation at some point here we have minimum discharge and here we have the maximum discharge, so instead of getting uniform size we have the size distribution when we do the screen analysis of the product, because here we have maximum opening as well as minimum opening. So when oscillation takes place.

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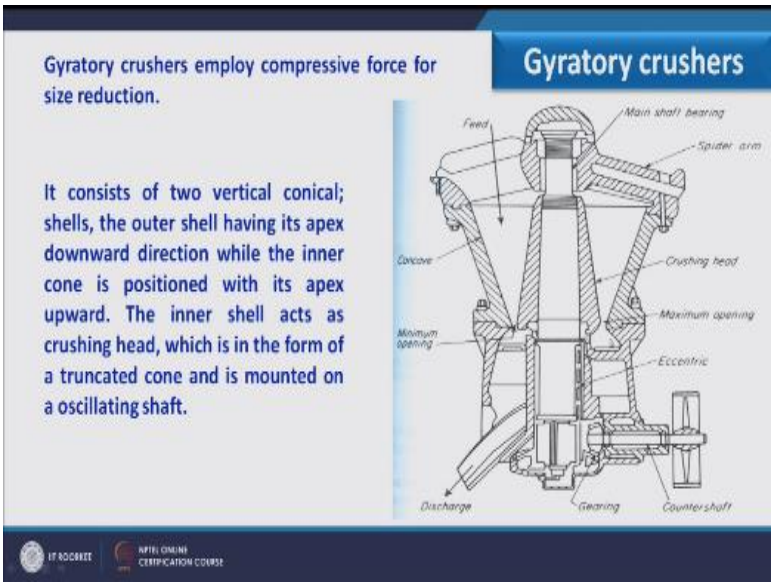

Here as we have the minimum opening and in this side we have maximum opening when oscillation take place here we could have the minimum and here we can have the maximum opening, so due to this oscillatory motion the feed gets compressed and it breaks into smaller size.

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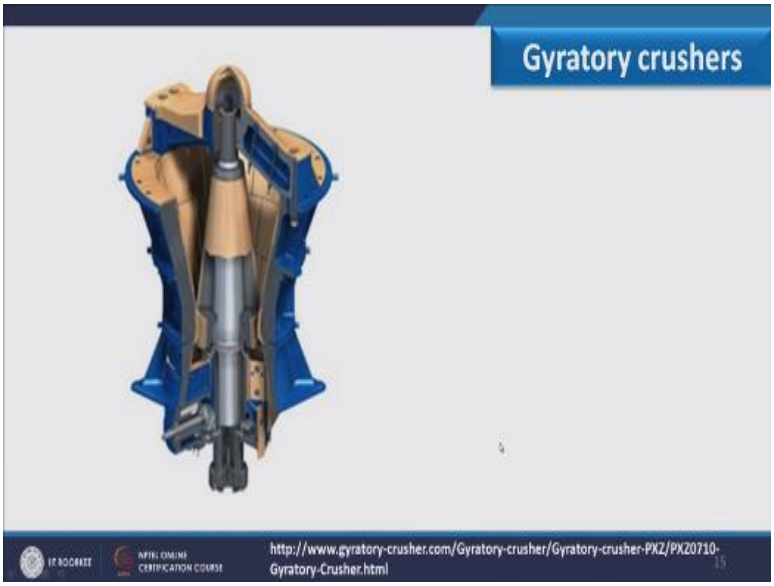

So this is the functioning of gyratory crusher, for more you can go through this link.

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And here we have the installation and commissioning of primary gyratory crusher so sometime its size is too large you can imagine the size over here, so continuously material comes over here and due to gyratory motion or oscillatory motion of this vertical shaft the material gets crushed and from here it can pass. So this is basically the installation of gyratory crusher is going on. For more you can visit this link, and here in this.

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See this is the already installed gyratory crusher where material is coming to this and sometime when the crushing is done with the help of water we call it hydraulic gyratory crusher, and how it is done? At the top we have the water supply line through which water is continuously fall in this. The advantage of this hydraulic gyratory crusher is that, it has minimum finds to be coming out from the crusher, because they are usually installed in.

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A mine side or rock side where these are used to crush the material so there we have maximum chances for fines to come out and for that purpose we go for the hydraulic gyratory crushers.

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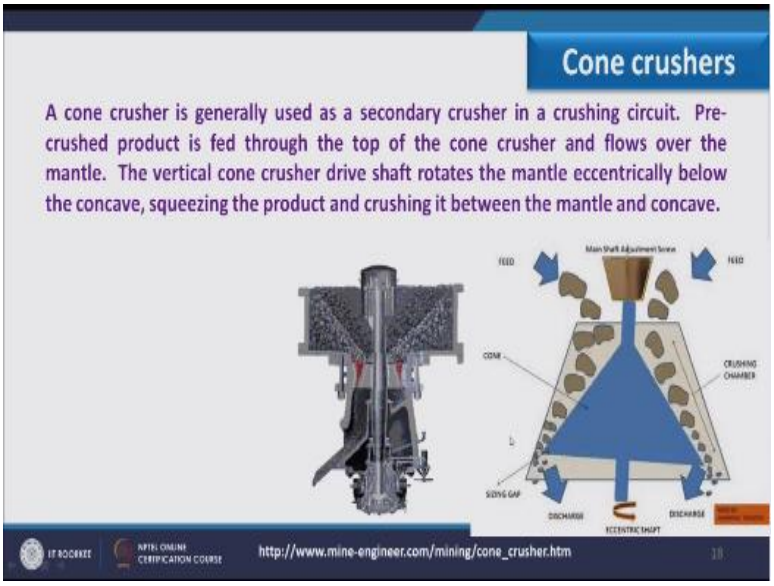

And now we have the cone crusher, what is a cone crusher? A cone crusher is generally used as a secondary crusher in a crushing circuit. Pre-crushed product is fed through the top of the cone crusher and flows down the mantle. The vertical cone crusher drive shaft rotates the mantle eccentrically below the concave squeezing the product and crushing it between the mantle and concave. So what is mantle, if you see this any machine here we have the cone, so due to this it is

called the cone crushing and this is the concave section and material which is falling in between this due to that movement of cone between concave section the compression of feed takes place and continuously we can get the crushed material. Here it is shown more clearly feed is coming from here.

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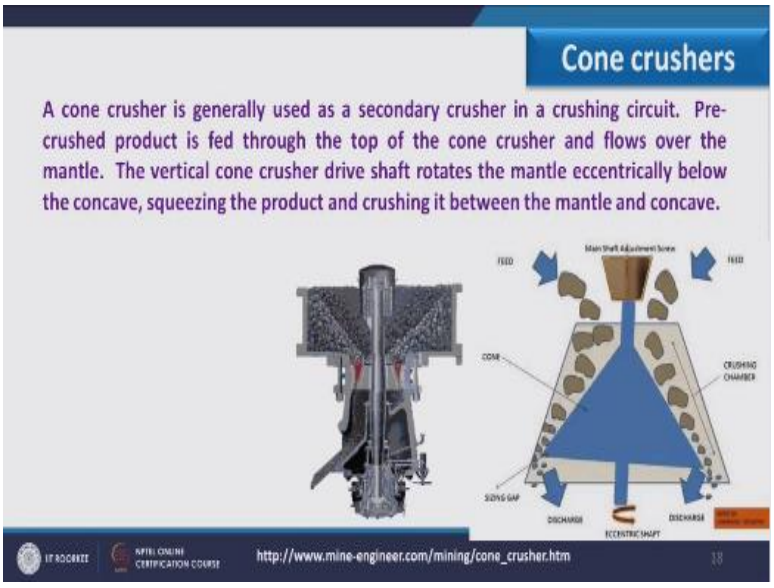

And due to the compression between concave section as well as this mantle part or conical part the compression takes place and material is crushed and exit the crusher from downward side, this is the functioning of cone crushers.

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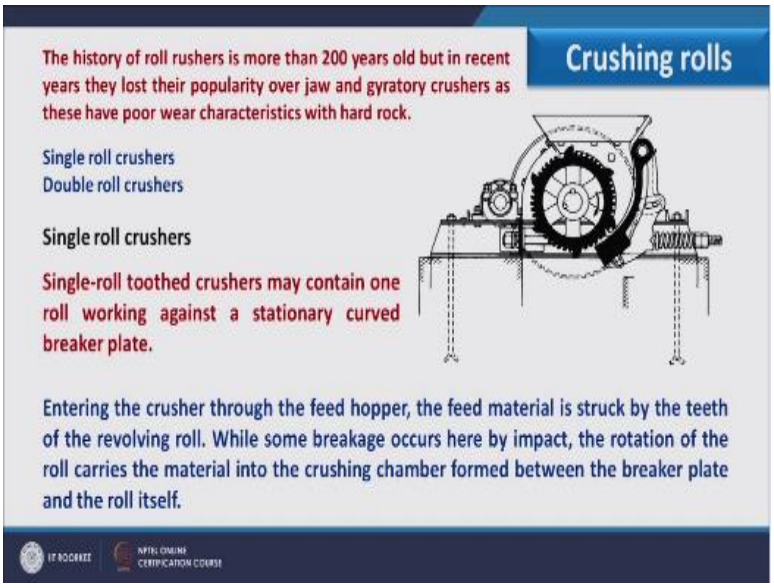

Now we are having the crushing rolls, the history of roll crushers is more than 200 years old, but in recent year they lost their popularity over jaw and gyratory crusher as these have poor wear

characteristic with hard rock. So here we have two kind of crushers, first is single roll crusher and second is double roll crusher. Single roll crusher, single roll toothed crushers may contain one roll working against a stationary curved breaker plate, so if you see this schematic here we have this toothed crusher or toothed roll and here we have the stationary plate so in between this when material comes the crushing takes place and we can get the final material. So entering the crusher through the feed hopper the feed material is stuck by the teeth of

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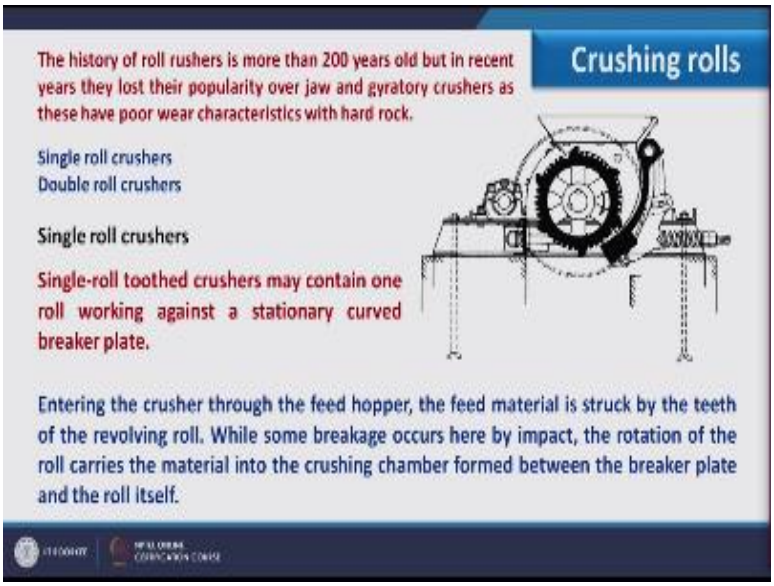

Revolving roll while some breakage occurs here by impact the rotation of roll carries the material into the crushing chamber form between breaker palate and the roll itself so in this way it work. Now here we will discuss double roll crusher you can see the animation over here, here we have the double roll crusher which are moved towards each other and material falling in between this can be crushed and exit from the bottom. So this we also call it free crushing, if you remember the free crushing concept, here you can see very well what is the free crushing which happens due to action of gravity.

So two or more heavy steel cylinders revolve towards each other in double cone crusher, force applied to the product is mainly compressive and over load compression spring protects the roller surface from damage, the distance between surfaces of the roller is termed as nip.

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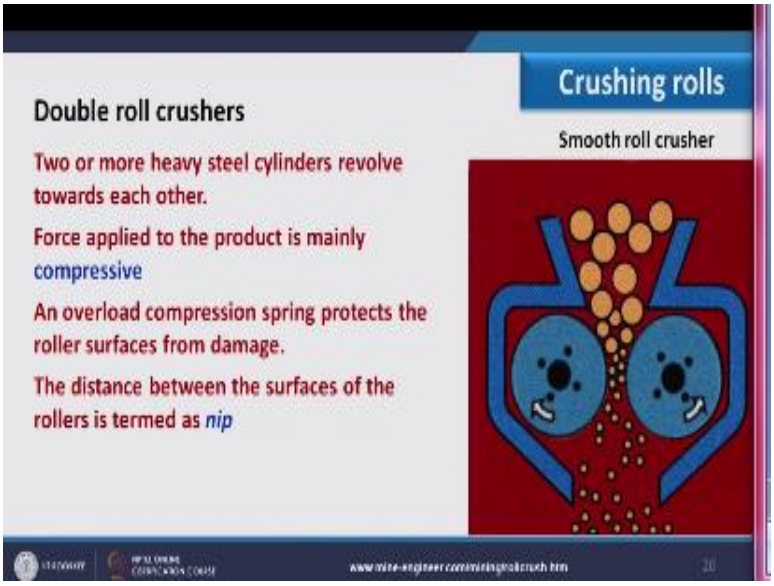

So size reduction ratio are usually below five for this double crone crushers, capacity is affected by speed, nip, diameter and length of the rollers, roll speeds range from 50 to 350 r/min and maximum size of the product is approximately equal to diameter of roll. So here we have double cone but smooth surface and due to this spring action the, if we are getting very hard material so it can pass through these rolls without putting any damage to without making any damage to the rolls.

So toothed roll are more versatile than smooth-roll crushers with the limitation that they cannot handle very hard solid, they operate by compression impact and shear not by compression only as do smooth roll and therefore reduce much larger particles.

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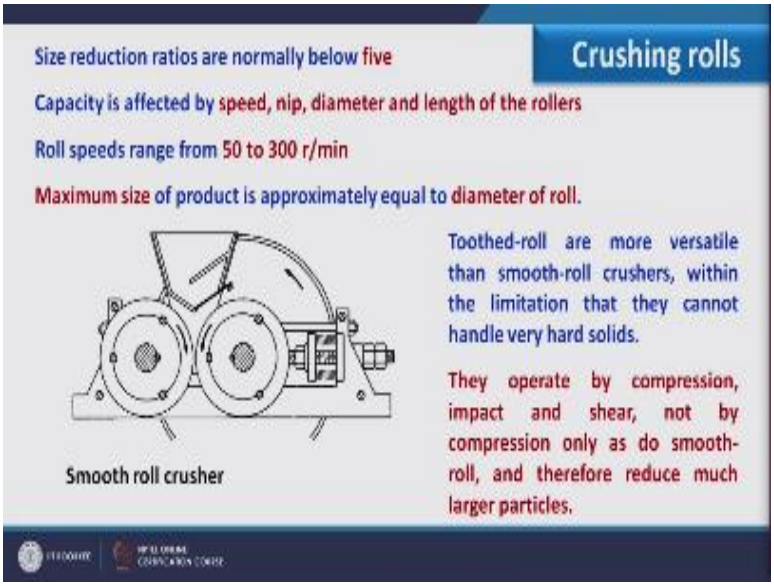

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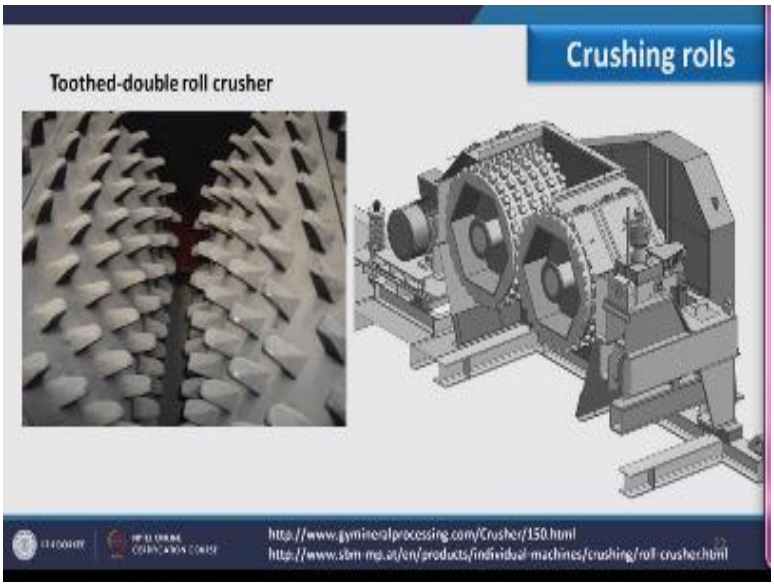

So here we have the photographic view of toothed- double roll crusher where we have these two rolls on which teeth are there which can be used which assist in crushing when the material fall in between, but disadvantage is that it cannot handle very large or very hard feed. This is another photograph of crushing roll, if you want to study about these more then you can go through these link and that is all for now, we will continue the discussion on size reduction equipment in next section, thank you.

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