**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**
**NPTEL**
**NPTEL ONLINE CERTIFICATION COURSE**

**Mechanical Operations**
**Lecture-15**
**Size reduction equipment-2**

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Welcome to the second part of lecture 4 which is on size reduction equipment. In the first part we have discussed the working of jaw crushers, gyratory crushers and crushing rolls which are falling in the category of crushers or we call it in the category of coarse crusher. Now here we will discuss intermediate crushers and the first equipment in this is the roller mill.

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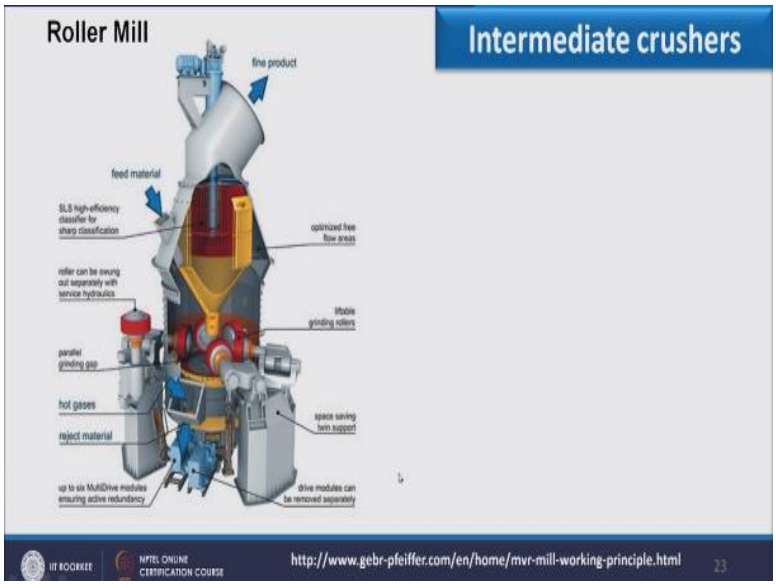


You can see its photo on this slide. Here if you see all these red sections these are nothing but the rollers.

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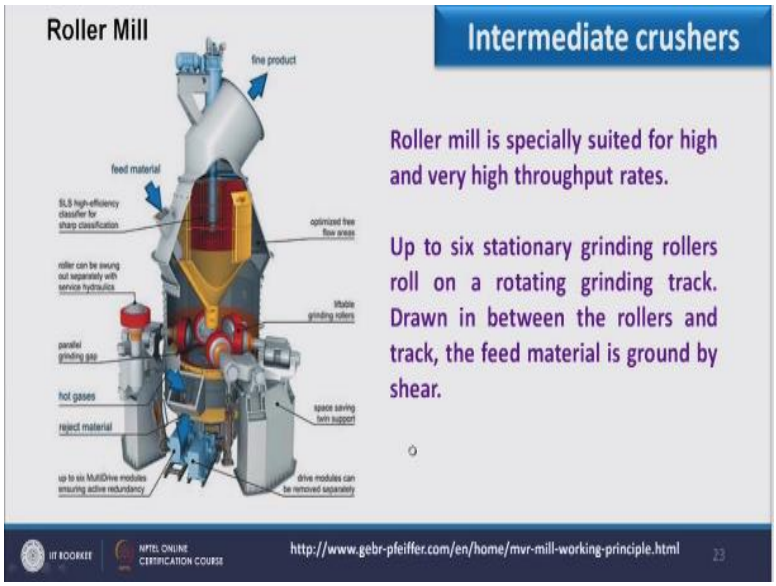


So roller mill is specially suited for high and very high throughput rates. And in this roller mill up to six stationary grinding rollers roll on the rotating grinding track drawn in between the roller and track, the feed is grounded by shear. Now what happen over here, if you see this image, from here we have the feed inlet, feed is falling in between this section.

Now what happens, if you see this bottom disk this is the rotating disk and all these rollers are stationary. So when the material is coming to this disk rotates and due to shearing of material between rollers as well as rotating disk the material is reduced in size, and the fine material which are as a result of shear between roller as well as rotating disk is collected from the top.

Now how it is collected from the top, if you see from this side the hot air and gases enter into the mill and these gases take the fine particle with them and it can exit from the top. So this is the basic working of a roller mill. Here we have another equipment which is falling under intermediate crusher and it is hammer mills.

So hammer mills are among the oldest, then also these are most widely used crushers.

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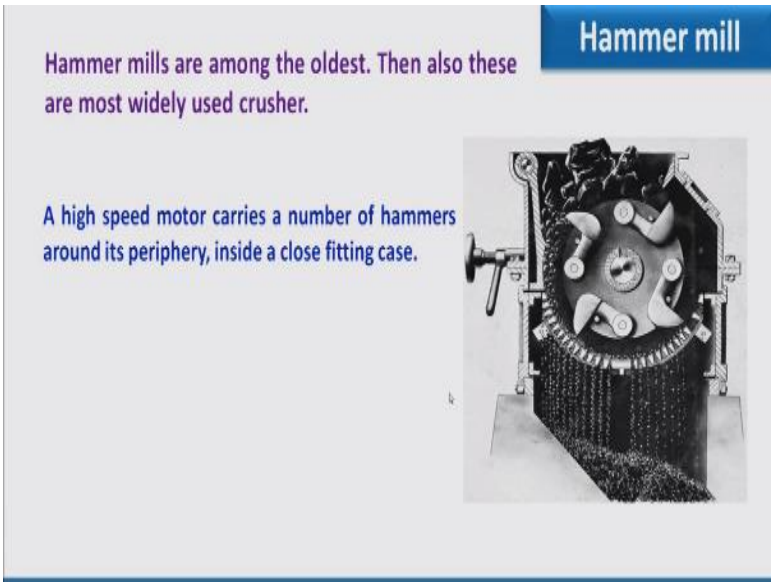


A high speed motor carries a number of hammers around its periphery inside a close fitting case. So you see this figure, in this figure the material is coming from the top and the complete assembly is inside the case where hammers are attached on the rotating disk. When material is coming from the top and disk is rotated due to rotation these hammers are in hanging position which put the impact on the material which is falling between the, this plate as well as hammer.

So due to this impact material gets crushed and the material, crushed material is coming out from this side and so you see, and crushing material is coming out from this side, so you see coarse feed is coming from the top due to impact action it crushes and exit the machine from bottom.

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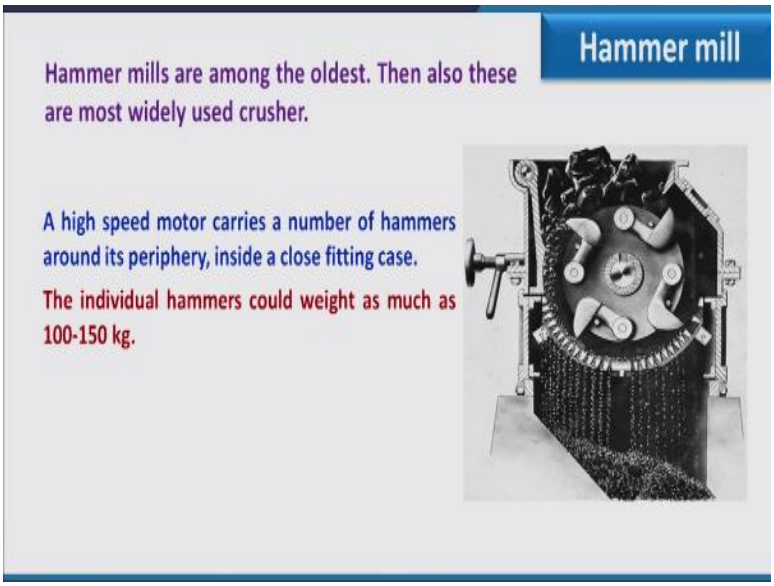


So the individual hammers could weight as much as 100-150 kg. So you can imagine the impact, they put on the feed.

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Reduction is mainly by impacts as the hammer drives the material against the breaker plate. So this is basically the breaker plate, shear sometimes may also play a role when the operation is done under choking condition.

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So if you see this photograph here we have different rotating disk and in between this different hammers are placed. So this complete roll is inserted into the case and when feed is coming from the top it rotates and when it rotates the hammer put the impact on the feed and then it gets crushed. Due to excessive wear hammer mills are not recommended for fine grinding of very hard material.

And here you see, here I have put some of the photograph of individual hammer, from this it is attached with the disk and this is the hanging section of the hammer which put impacts on the feed. If you want to study about this more you can go through this link.

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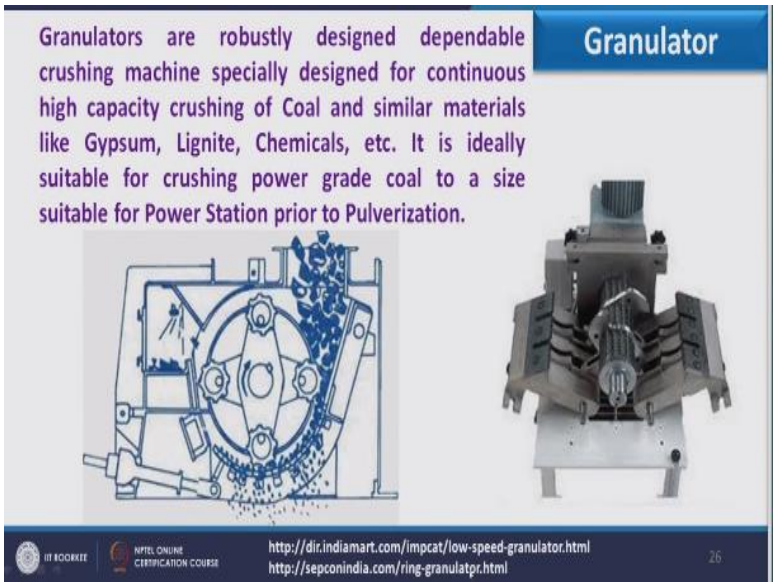


Another equipment we are having is the granulators, granulators are robustly designed dependable crushing machine specially designed for continuous high capacity crushing of coal and similar materials such as gypsum, lignite, chemicals, etcetera. It is ideally suited for crushing power grade coal to a size suitable for power station prior to pulverization.

So here you see it happens due to impact as well as shear the, and in granulator what happens the crushing section attach with the disk and this disk is continuously rotated. In better way you can refer this figure where we have a cylinder and on this cylinder we have knife kind of structure so when material is falling in between and when it rotates it put the impact as well as shear so that the material which is falling in between can be crushed and taken out from here as a fine product, so this is the working of granulator, for more you can go through this link.

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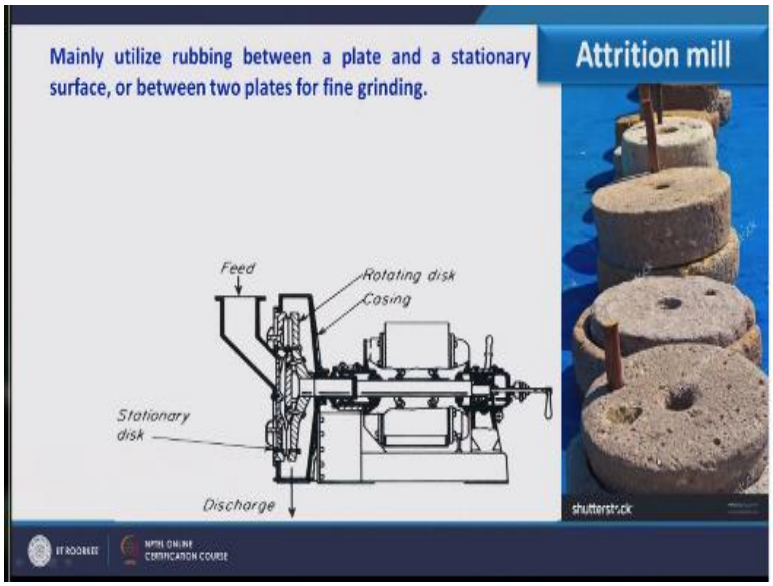


Attrition mill, in the attrition mill mainly utilize rubbing action between a plate and a stationary surface or between two plates for fine grindings, so if we consider the granulator hammer mill or roller mill these are falling in a category of intermediate grinder. Now here we are starting the fine grinders or fine crushers so first equipment in the category is the attrition mill, now what is attrition is the rubbing of material between two surfaces.

So if you see this image it is basically having the two section, first is stationary another is moving so due to rubbing of material in between or scraping the material in between the feed is converted into the smaller particle product, and this kind of assembly we usually have seen in our houses in previous days. These days such kind of mills are not utilized in houses and as far as industrial attrition mill is concerned it looks like this schematic of this shown over here. Now here what happens feed is coming from the top and this feed is falling in between two plates in which first plate from this side is the stationary plate and another plate is rotated continuously so due to this rotation and one plate is stationary due to its rotation continuous attrition takes place or rubbing takes place and whatever material is falling in between it will be crushed by rubbing action.

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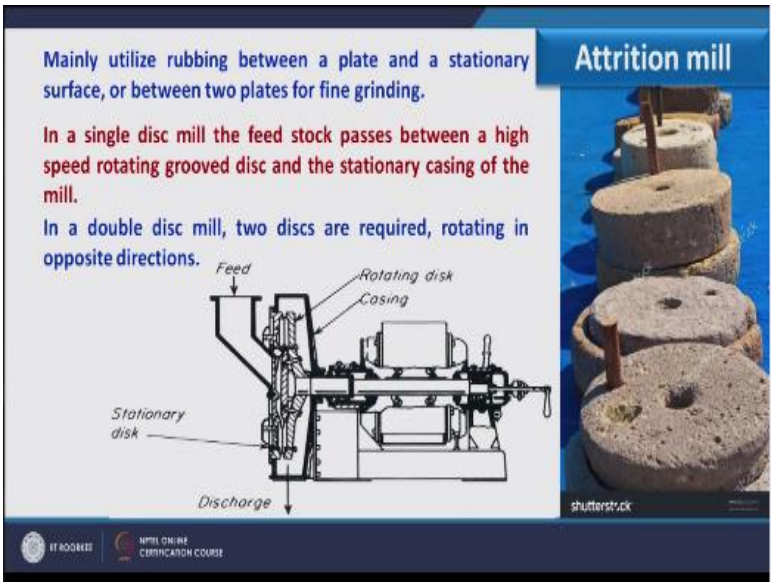


So in a single disc mill the feed stock passes between a high speed rotating grooved disc and the stationary casing of the mill. In a double disc two disc are required, rotating in opposite direction so some time one is a stationary another is moving and whatever movable disc is there on that sometimes we have the grooves also, in double mill both plates are moving opposite to each other like this.

So here you can understand the working of attrition mill.

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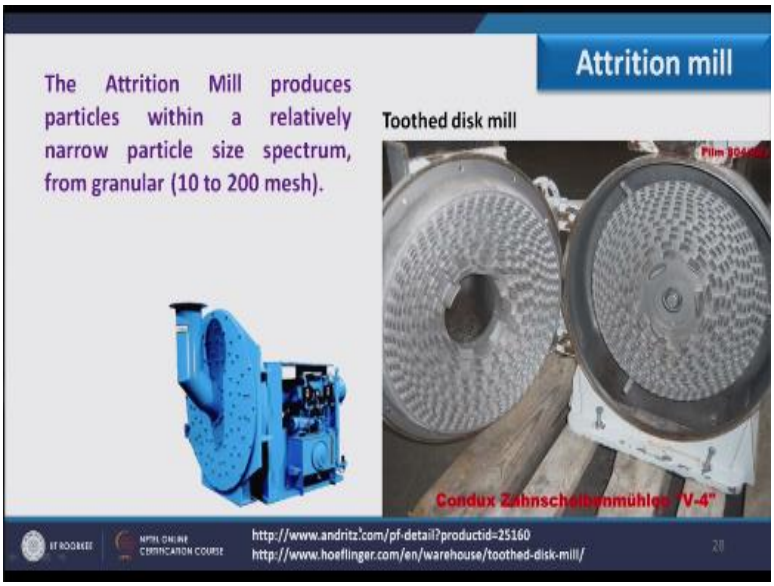


The attrition mill produces particles within a relatively narrow particle size spectrum from granular such as 10 to 200 mesh. If you this image this is the this blue image is basically the photographic view of attrition mill where this is the stationary plate and inside this secondary second plate which is available that is the movable plate so feed comes from here and when it falls between two plates due to rubbing action the size of the feed is reduced, and here you see we have the groove or teeth on the plates and this we call the toothed disk mill and if you want to study more about this you can go through this link, basically here we have two links.

So you can go through these links if you want to study more about these mills. Another mill we have which is falling in a category of fine grinder is the tumbling mills. Tumbling mills are two types; first is ball mills and rod mills are rotating or tumbling or vibrating chamber is filled with steel balls or rods, these are extensively used in chemical industries.

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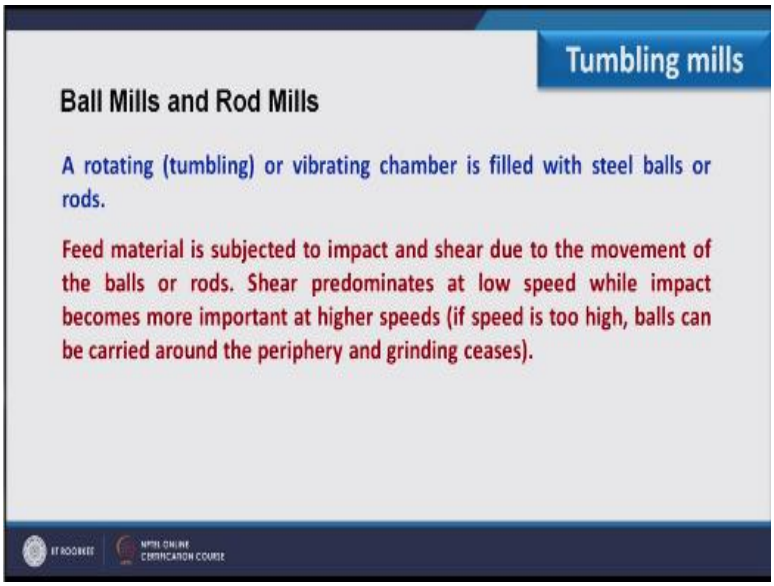


So feed material is subjected to impact and shear due to the movement of balls or rods. Shear predominates at low speed while impact becomes more important at high speed. If a speed is too high balls can be carried around the periphery of the machine and grinding will not happen further, so finer product is produced by smaller balls, higher ball density or longer residence time, it means when we have the lower feed rate.

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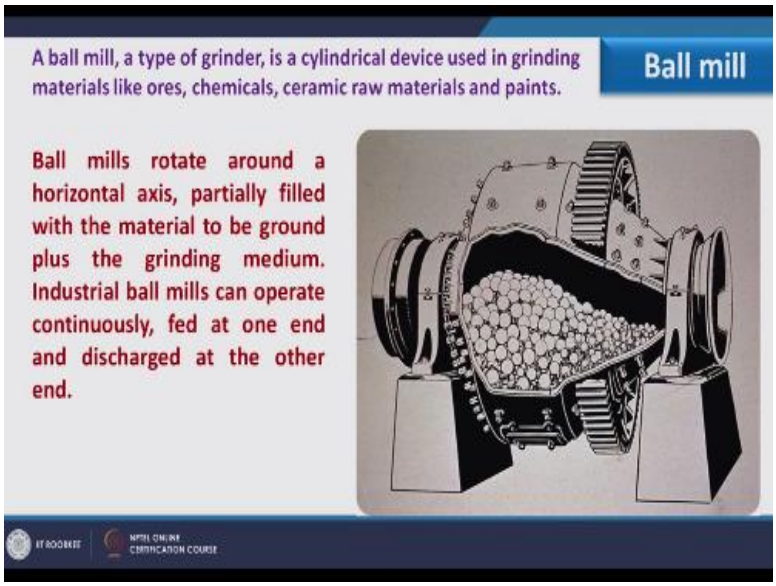


So therefore we have the ball mill as well as rod mill as a tumbling mill. Let us discuss first the ball. A ball mill a type of grinder is a cylindrical device used in grinding materials like ores, chemicals, ceramic raw materials and paints, so here you see this is the schematic of a ball mill, inside this almost half of the mill is filled with the ball which works as a grinding media, size of these balls are varying from larger to smaller. Larger size are used to crush the large feed however smaller size balls are used to convert the finer feed to further finer product. So here feed enters from this side and then due to rotation balls are continuously falling when it goes to the.

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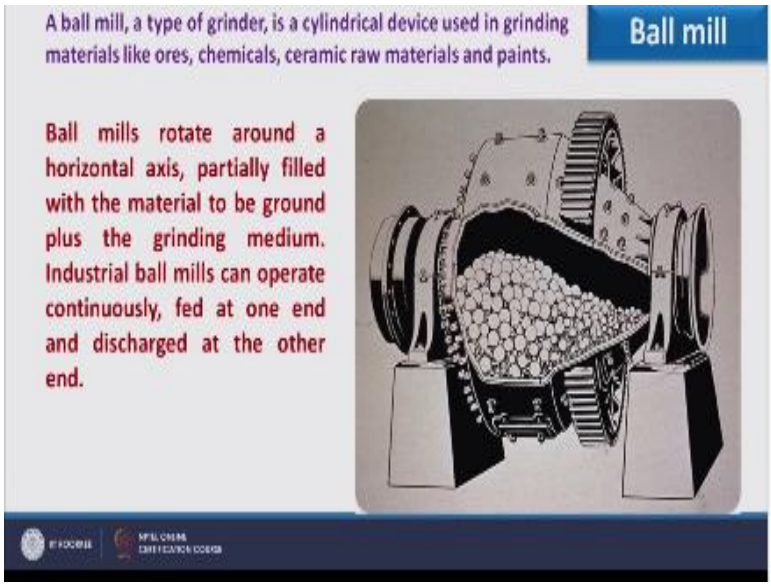


Top it continuously falling so here we have impact as well as shear both action both pattern will be followed, so once feed will enter into here larger balls are helpful at that time to crush the material and once it is reduced in size then the role of fine balls will come. So ball mills rotate around a horizontal axis partially filled.

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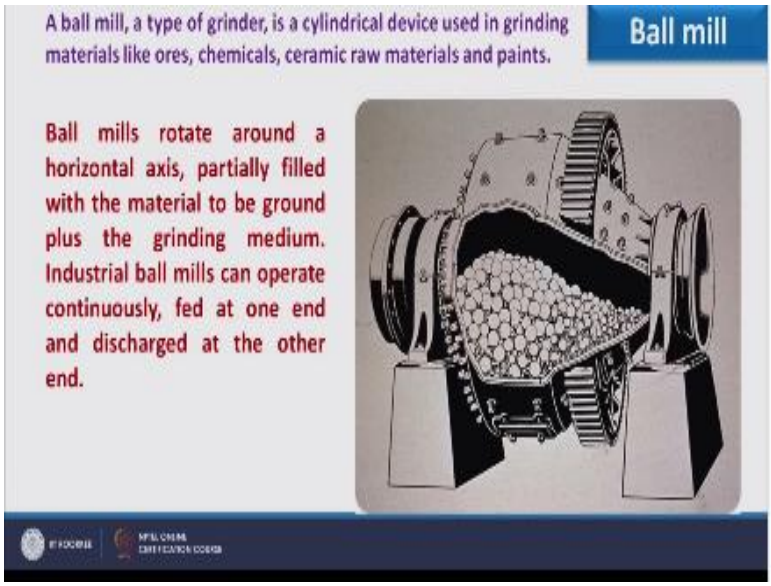


With the material to be ground plus the grinding media, so when we consider ball mill in this ball mill the media as well as the feed both will rotate simultaneously. So ball mills rotate around a horizontal axis partially filled with the material to be ground plus the grinding media. What is the meaning of this, that in ball mill material which we have to crush or the media by which we have to crush both of this will rotate will plate simultaneously inside the equipment, inside the mill so industrial ball mills can operate continuously fed at one.

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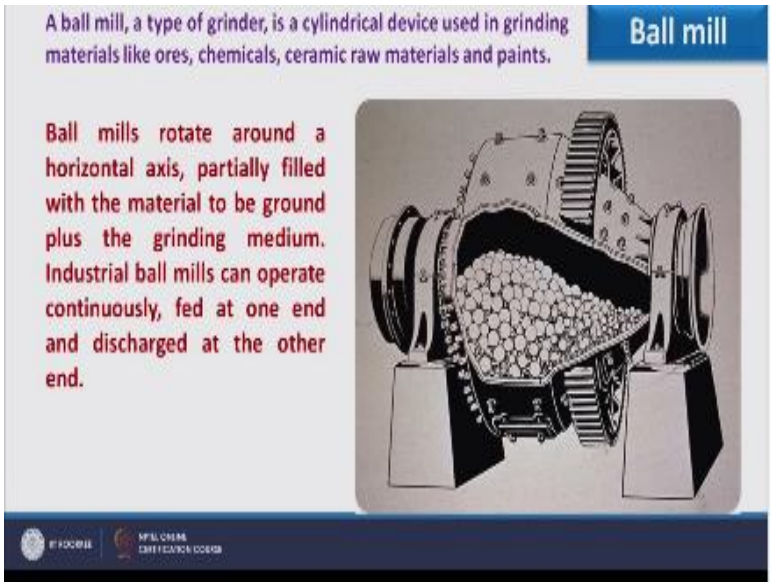


End and discharged at another end, so you see this is the animation of ball mill.

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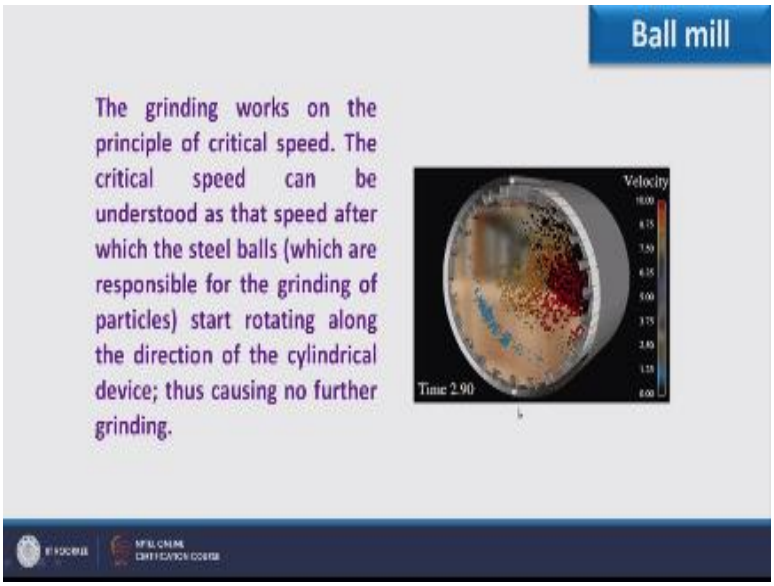


Here inside the ball mill we have groups in which balls are fixed and when they move to the top continuously they keep on falling and then it puts the impact on the grinding feed, so the grinding works on the principle of critical speed. The critical speed can be understood as that speed after which the steel ball which are responsible for grinding of particles start rotating along the direction of the cylindrical device thus causing no further grinding.

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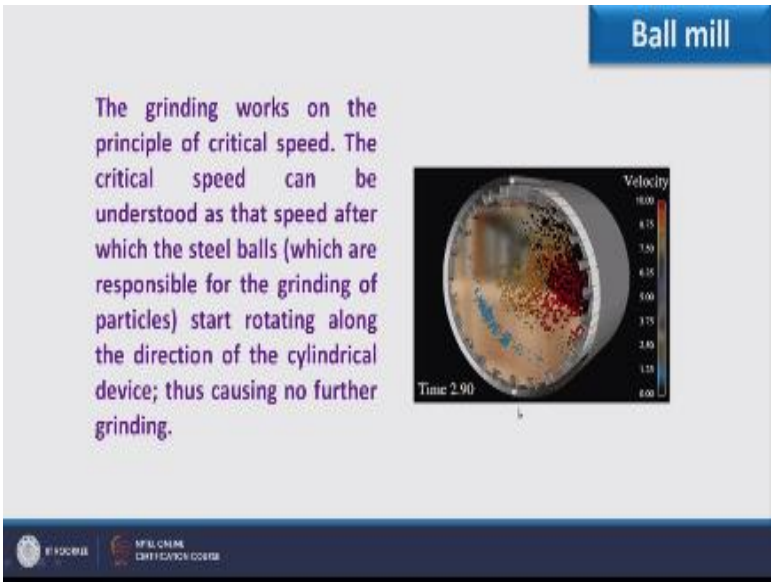


So when we have to get the product of desired size we have to operate the ball mill below its critical speed.

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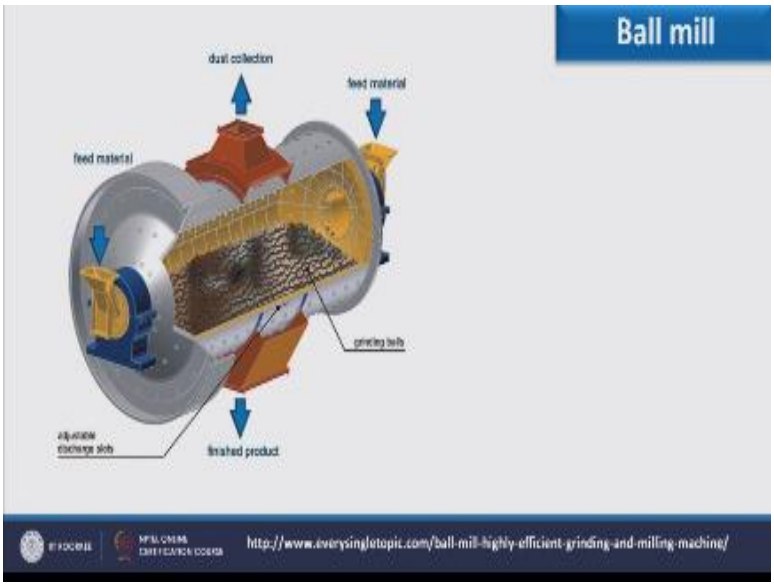


And in this figure I have got section of ball mill is shown and if you see in this figure from two side we have the feed inlet material and from here we have the finished product and from the top dust which is generated due to grinding action it takes out, so for effective or high efficient grinding we use such type of assembly, for more you can go through the link which is placed at the bottom of the slide. Now let us discuss the grinding media of ball mill, first is ceramic grinding media we use it is light in weight and very hard.

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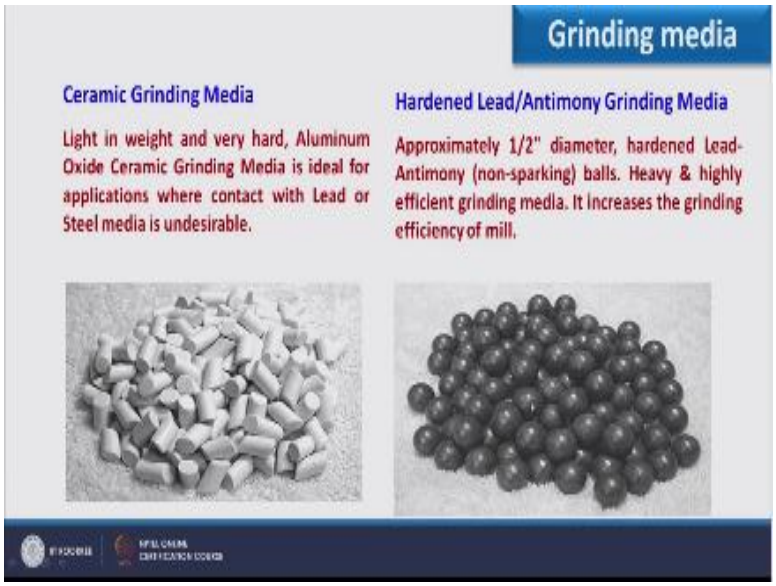


Aluminum oxides ceramic grinding media is ideal for the application where contact between lead or steel media is undesirable so these are the ceramic grinding media which is in the cylindrical shape. Another media is hardened lead or Antimony grinding media approximately half inch diameter hardened lead Antimony which is non-sparking balls, these are heavy and high efficient grinding media, it increases the grinding efficiency of the mill, so these are looks like this which is shown in this image and these are of ball structure.

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And here we have the standard chrome plate steel grinding media, it is approximately half inch diameter, heavy chrome plated steel ball bearing are used as a media, these are used in place of lead balls where any contact with lead is undesirable or if very hard materials are grinded, so you can these balls in this image, here we have another image of the chrome plated steel balls. Now in this slide we will discuss the factors which are influencing the size of the product in ball mill, first is of course the feed rate, second property of.

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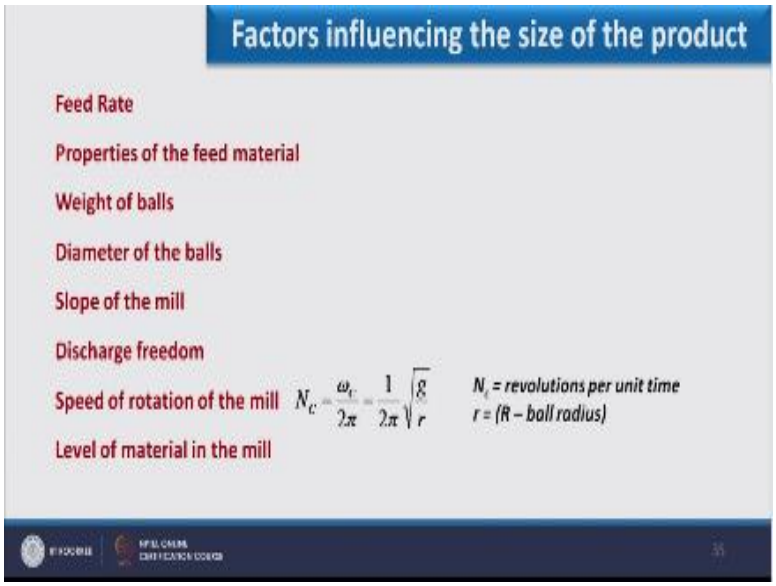


Feed material, weight of balls, diameter of balls, slope of mill, discharge, freedom, speed of rotation of the mill and here you see we were discussing about the critical speed, this is the expression of critical speed where $N_c$ = ½ л √over g/r so this is the critical speed of the mill. When we have to operate the mill properly we have to keep the speed of rotation lesser than $N_c$ where $N_c$ is the revolution per unit time and small r = R – ball radius, R is the mill radius and further we have level of material in the mill this factor which is influencing, which influence the performance of ball mill and here have the rod mills, rod mills are useful for sticking material.

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Which would glue balls together, when we are using the sticky material then we they can join the two balls together. So in that case instead of using balls we can use the rod. You can see here the cut view of the.

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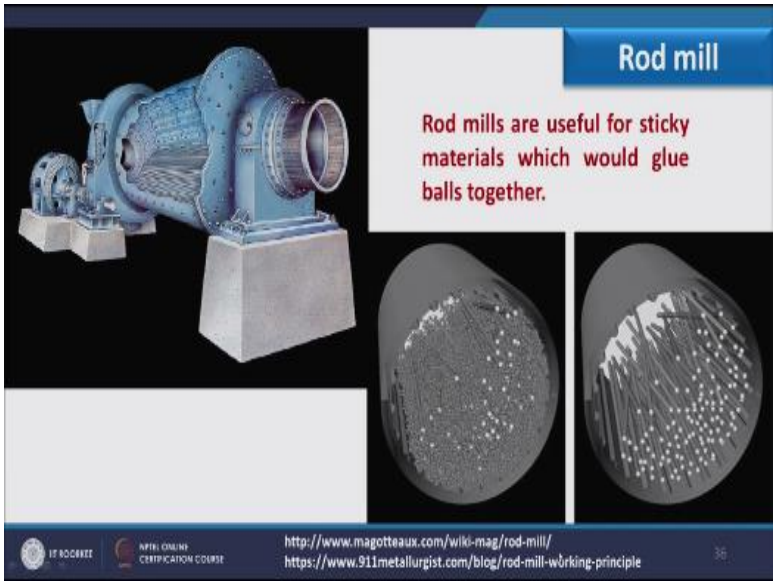


Rod mill where these bars are placed, these rods are placed which are used as a grinding media. Here in this images also you can see, for more you can go through these links. And further we have the ultra fine grinders, these are the fourth category for size reduction equipment. Many commercial powders must contain particles averaging.

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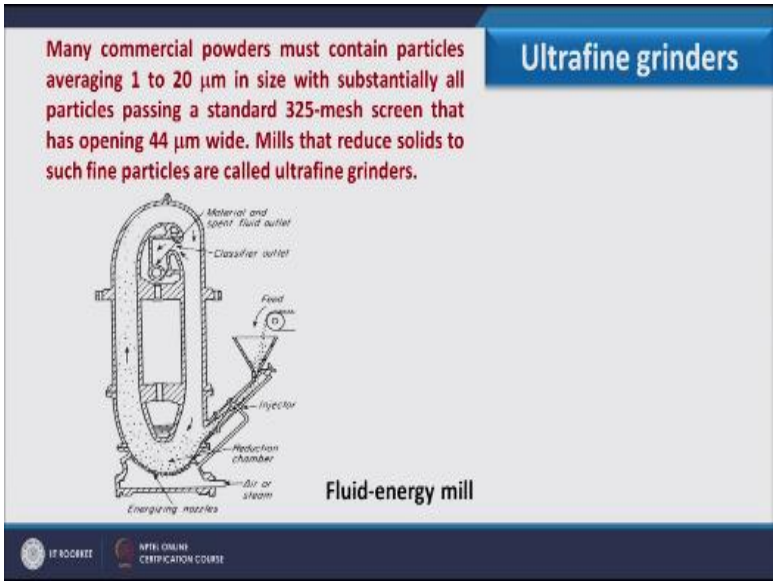


1 to 20 micrometer in size with substantially all particles passing a standard 325 mesh screen that has opening of 44 micrometer. So mills that reduce solids to such fine particles are called ultra fine grinders. So one of the example of ultra fine grinders is fluid energy mill, now in this mill what happens through this hopper feed is continuously coming into the mill and if you see here we have some open spaces from which air or steam is entering from this with high speed, so once I am having this high speed air as well as steam they take the material which is coming from the feed.

So when air or steam enter from this side with high speed they take the feed material with them and what happens then, due to the high speed of air material strikes either with the ball of the mill or with each other. So due to that impact it is further gets converted into the fine product.

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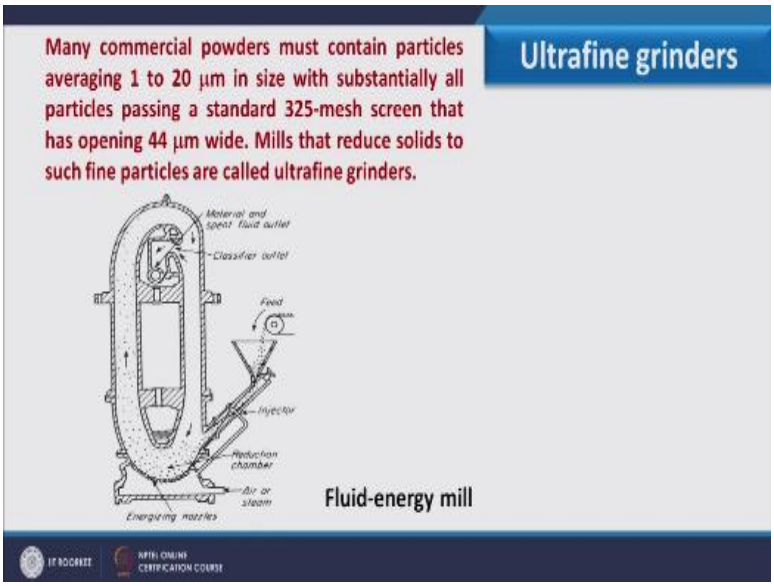


So the air as well as steam which is entering from the bottom it helps in reducing the size of material as well as that carry the material out from the mill from this side. If material is not converted into much smaller size they remain coarse so they cannot come out from this, again they will fall in the mill from this side and take part in further reduction. So here if you see the action or pattern are usually impact as well as shear, but mainly impact. The fluid used is either superheated steam or compressed air.

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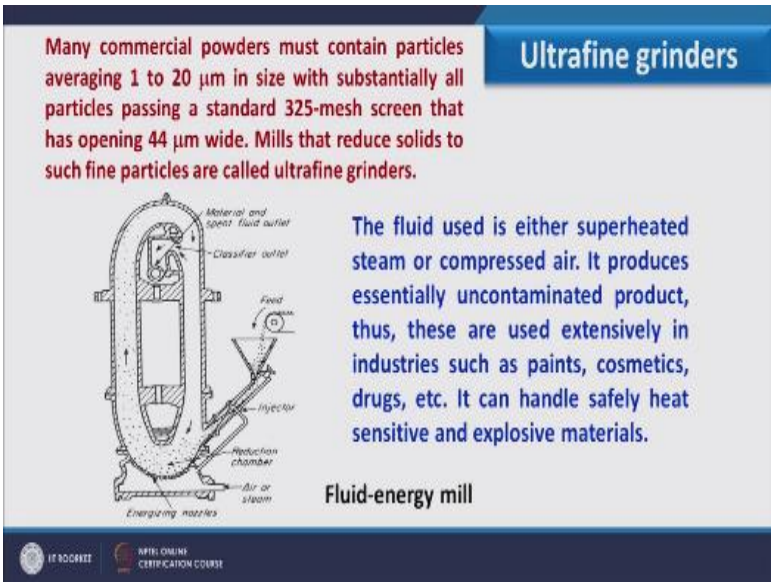


It produces essentially uncontaminated product, thus these are used extensively in industries such as paint, cosmetics, drugs etcetera. It can handle safely heat sensitive and explosive materials.

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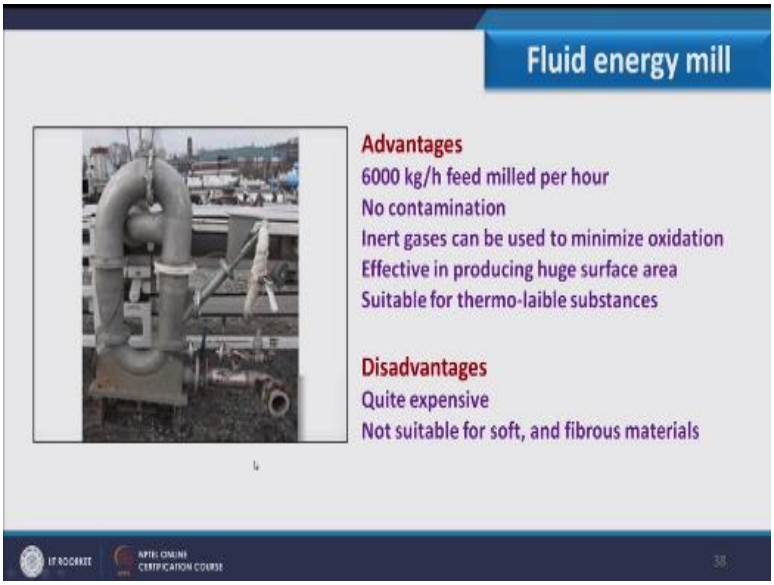


So here we have the advantages and disadvantages of fluid energy mill. The advantages are it can handle 6000 kg/h feed. It has no contamination, inert gases can be used to minimize oxidation, effective in producing huge surface area and suitable for thermo liable substances. Disadvantages include, it is quite expensive, it is not suitable for soft and fibrous material. So here we have the image of our photographic view of fluid energy mill, this is the feed hopper and the complete structure is available like this and from here we have the fine particle to be exited and from here we inlet the air.

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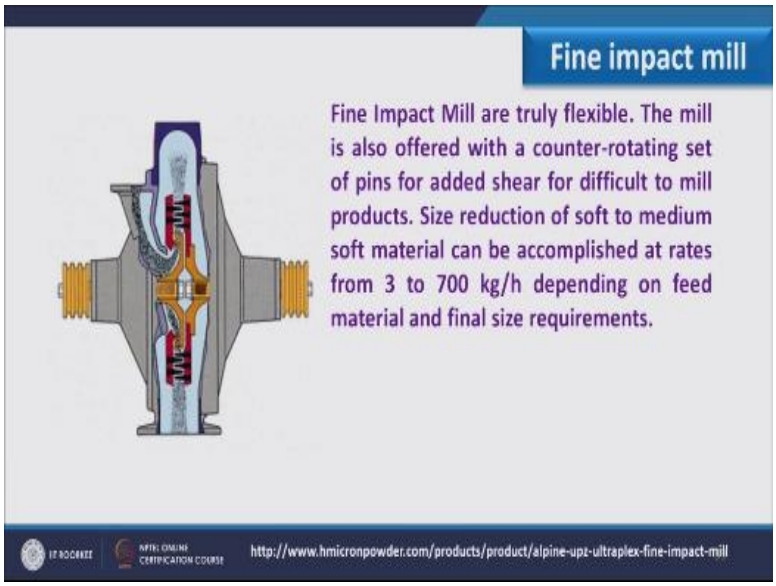


And next mill we have is the fine impact mill which is again in the category of ultra fine grinders. Now fine impact mills are truly flexible, the mill is also offered with counter rotating set of pins for added shear for difficult to mill product. Size reduction of soft to medium soft material can be accomplished at the rates of 3 to 700kg/h depending upon feed material and final size requirement, so this is the image of.

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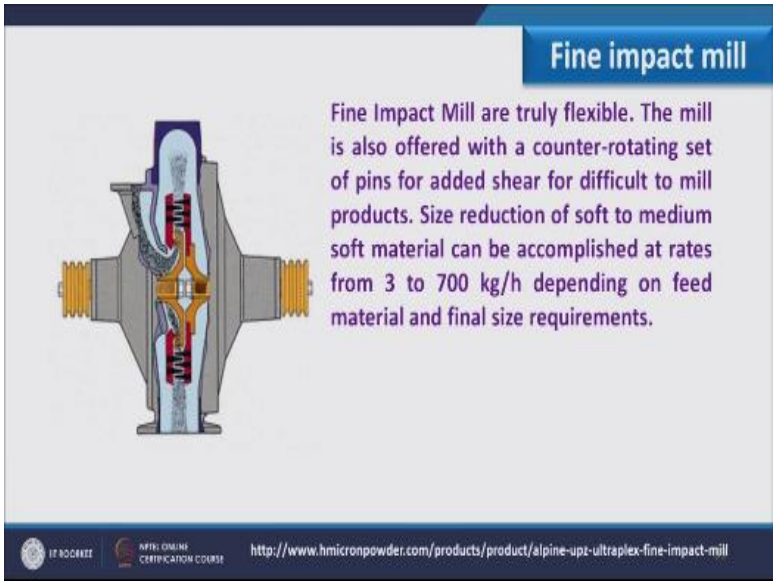


Fine impact mill and about this you can read at this link in detail.

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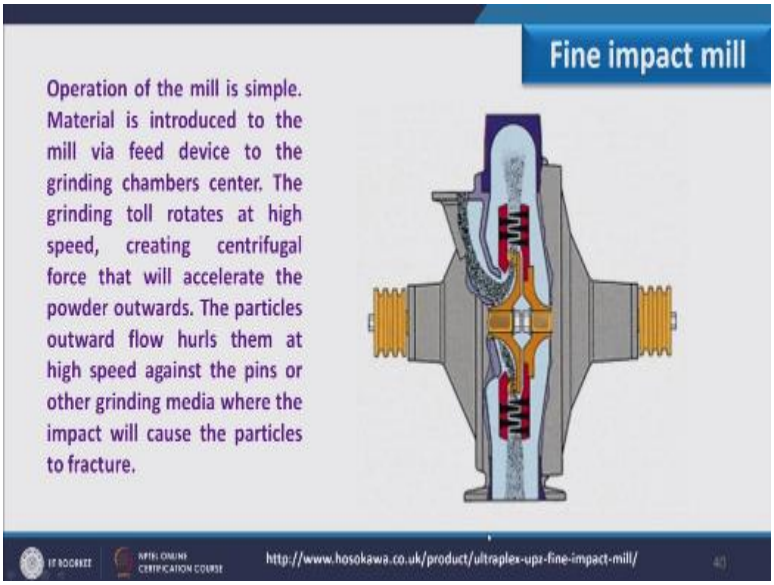


Now in this slide we will discuss the working of mill, the operation of mill is very simple, material is introduced to the mill via feed device to grinding chambers center. Now here if you see this image from this side we have feed to be entered and feed will enter into this grinding chamber. Now what happens, the grinding tool rotates at high speed creating centrifugal force that will accelerate the powder outwards.

The particles outward flow hurls them at high speed against the pins or other grinding media where the impact will cause particles to fracture. So in this way the feed is converted into further final product and from bottom or from this top it exit from the mill, so when we consider this particular.

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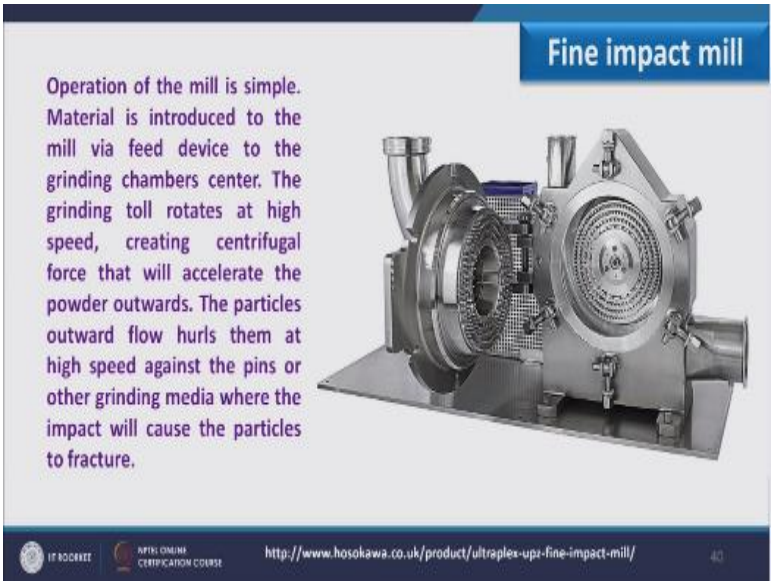


Fine product it is generated due to centrifugal action and when it comes out from this due to gravity it falls over here and then it can be collected from the bottom. This is the photographic view and if you see these small assembly this is nothing but the pins which are putting impact to

the fine feed and convert it in to the fine further finer product, for more you can visit this link, and finally we have the cutting machines.

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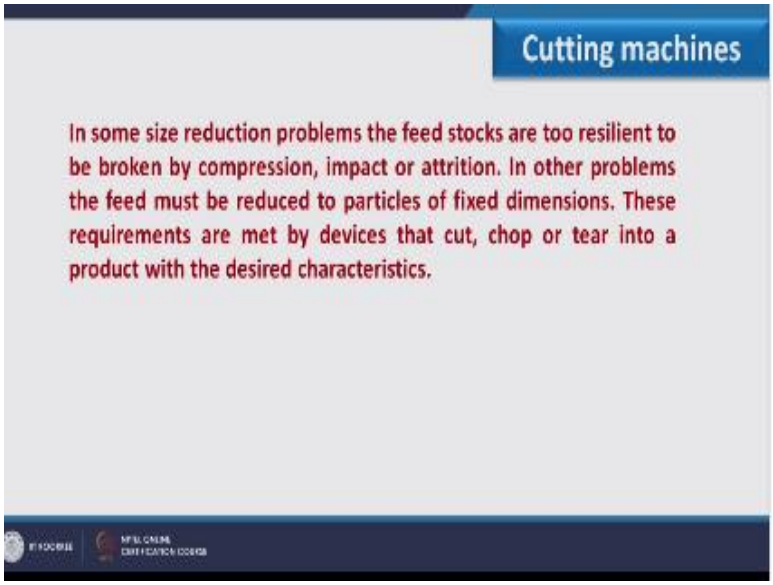


In some size reduction problems the feed stock are too resilient to be broken by compression, impact or attrition, in other problem the feed must be reduced to the particles of fixed dimension,

these requirements are met by devices that cut, chop or tear into a product with desired characteristics. So in this category we have rotating knife cutters, these devices are well adapted to size reduction problems in the manufacturing of rubbers and plastics and these are also extensively used in food industries.

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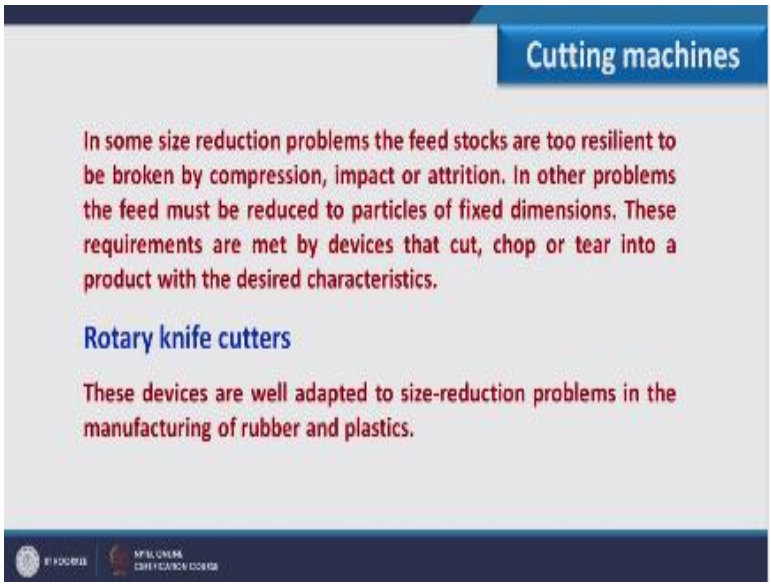

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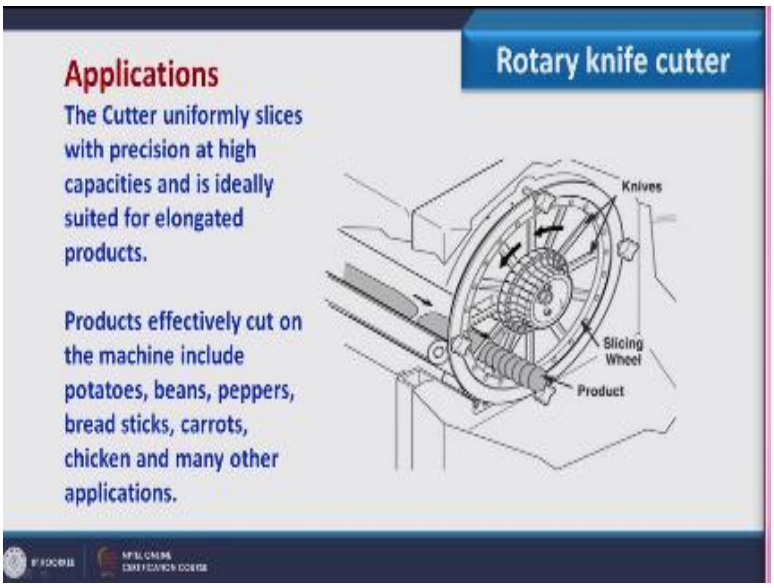

So rotating knife cutter, you see the image, here we have a rotating disk and after certain interval we have blades which we call the knives, when feed is coming in between it will be sliced in regular size so here basically this kind of cutter is required when we want product of definite size. Its application, the cutter uniformly slices with precision at high capacities and is ideally suited for elongated products.

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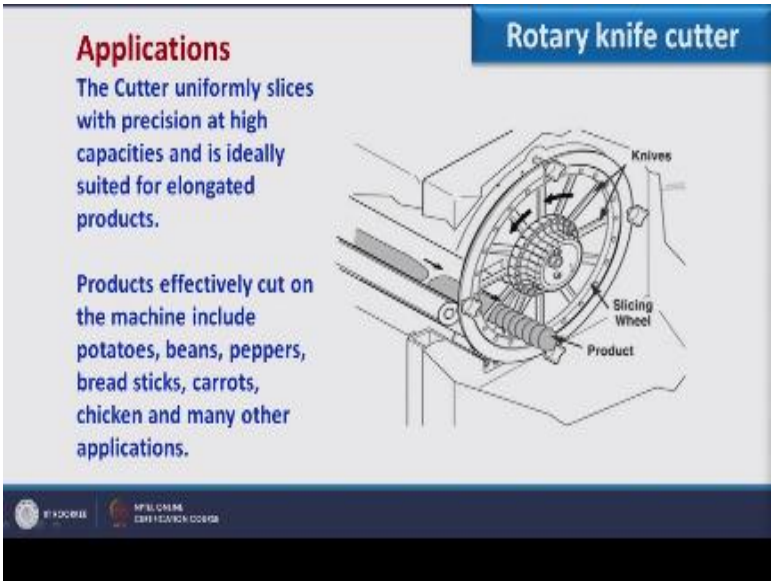

Products effectively cut on the machine include potatoes, beans, peppers, bread stick, carrots, chicken and many other application. Therefore these types of knife are extensively used in food industry, as far as its photographic view is concerned.

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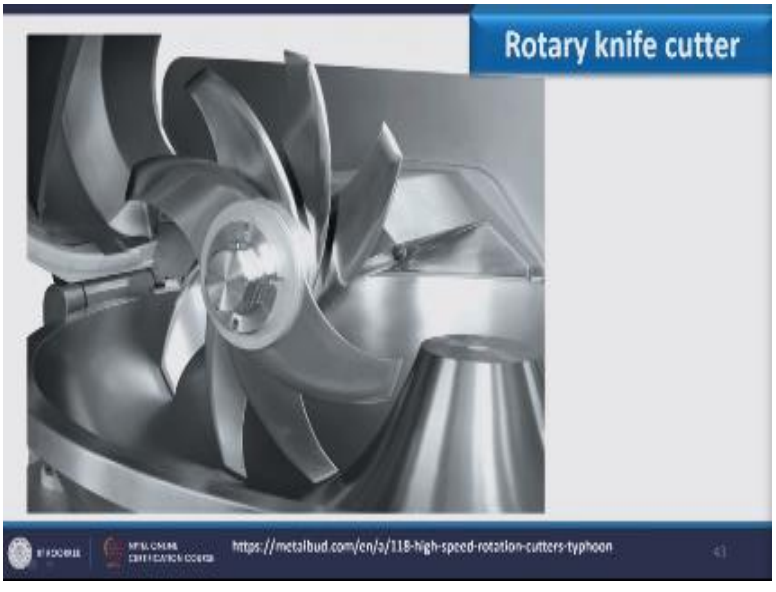

It is look like this, you can read more about this on this link. So these are the different equipment we have used for size reduction purpose and here we have the summary of this lecture. Different categories of size

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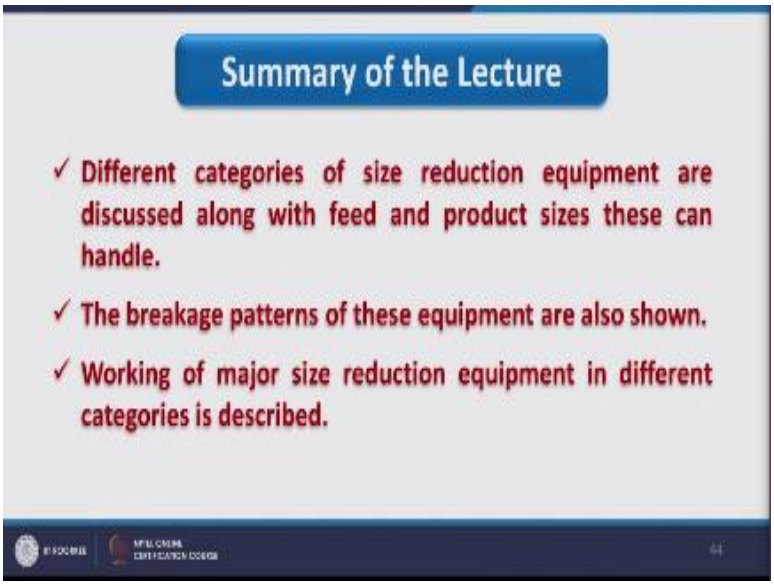


Reduction equipment are discussed along with feed and product sizes these can handle. The breakage patterns of these equipment are also shown. Working of major size reduction equipment in different categories is described in this lecture and that is all for now, thank you.

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