INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NPTEL
NPTEL ONLINE CERTIFICATION COURSE
Mechanical Operations

Lecture-01
Introduction

With
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Hello friends, I am Shabina Khanam and I am working as associate professor in the department of chemical engineering, IIT Roorkee.

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I am offering an online course on mechanical operations under NPTEL program. And today I will start the introduction of this course which comes under module 1 of week 1.

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So let us start the course with the definition of mechanical operation. What is mechanical operation? This figure speaks completely about mechanical operation. Now what this figure shows, it shows the particles of different sizes, therefore the mechanical operation is basically dealing with the particles, that is all about mechanical operation.

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However, the technical definition of it says that it is the branch of science and engineeriung dealing with the practice, description and study of the processing, handling, characterization, conversion and use of wide variety of particulate material both wet or drying in sizes ranging from micron to centimeters, based on the general theory concerned with the physical property of finely divided substances including powders, crystalline solids, granules, dispersion, slurries and pastes.

Now if I consider this definition it basically deals with the particulate material, its processing. What is the meaning of processing? When we convert the particulate metal from one size to another size or when we process the particulate material for –

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Any particular application it is called processing. Handling means how we handle this, it means how we transport the particle, how we store the particle, that comes under handling.

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Further I am having the characterization, now what is this characterization, it basically measure the size and shape of the particle, conversion, to convert the raw material into the product. So this conversion basically speaks when any reaction will be done on the particulate matter. So it completely speak about handling and processing of particulae matter, and therefore the mechanical operation is nothing but the dealing of particle for any useful application.

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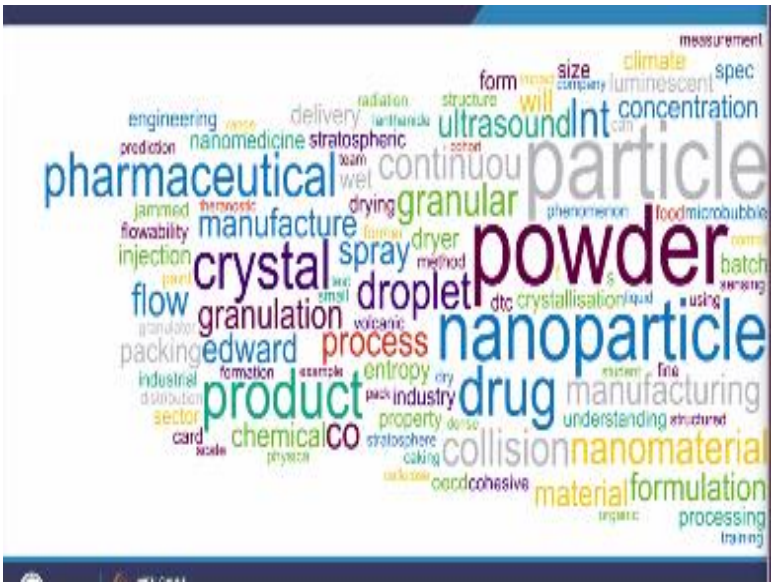

Now if you consider this particular slide, it shows different kind of application of this like pharmaceutical, crystal powder, nanoparticle. What is shows basically; it shows the complete application of mechanical operation.

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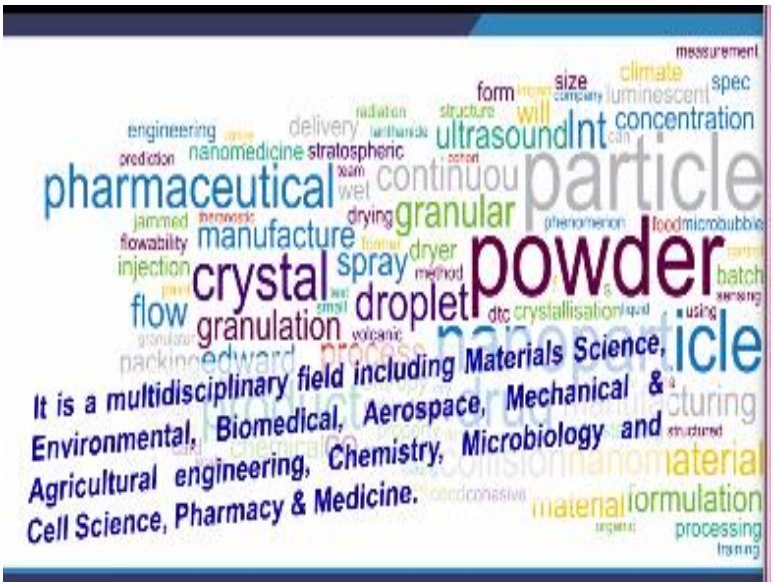

Therefore the mechanical operation is a multidisciplinary field including materials science, environmental, biomedical, aerospace, mechanical and agricultural engineering, chemistry, microbiology and cell science, pharmacy and medicine. So if you see this it covers significant area of engineering, therefore the utility of this particular course mechanical operation is significant as far as the industrial application is concerned.

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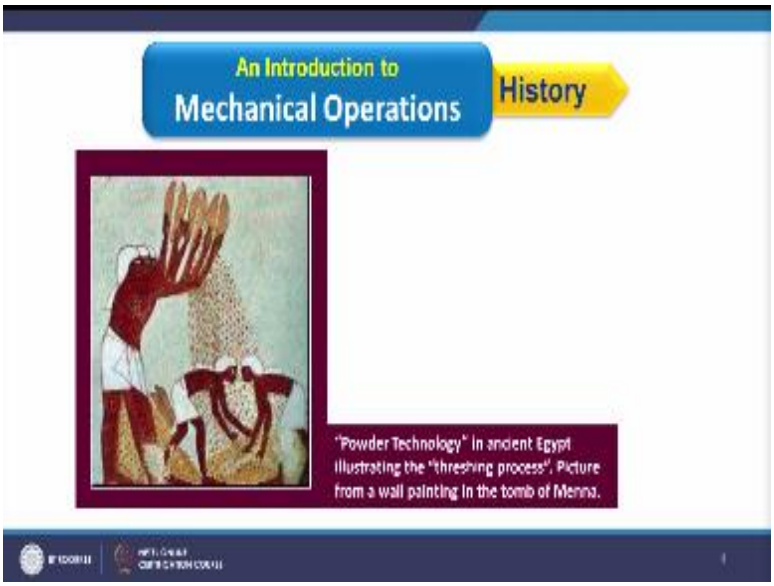

Now I will speak about the history of mechanical operation to make you understand that from how long we are using the concept of mechanical operation in our day to day life knowingly or unknowingly. So in this slide, this particular figure I have taken and it is the powder technology in ancient Egypt illustrating the threshing process. And this picture is taken from a tomb of Menna.

So it is very old figure which shows the threshing process. What is the threshing? To remove the edible solid from the grain we call that threshing process. Now if you consider this particular picture what this person is doing, it is basically screening the edible solid from the waste that is in terms of grain. Now while standing this, when it is doing the screening of this the lighter particle which are available that can be taken out by the air, and then the heavier particle which we call as an edible solid, it comes down.

And this person can collect this, so it is very old figure, so you can have the idea of the use of particle in our day-to-day life. Now here if you see there is one word powder technology and I am speaking about mechanical operation. So if we consider this powder technology.

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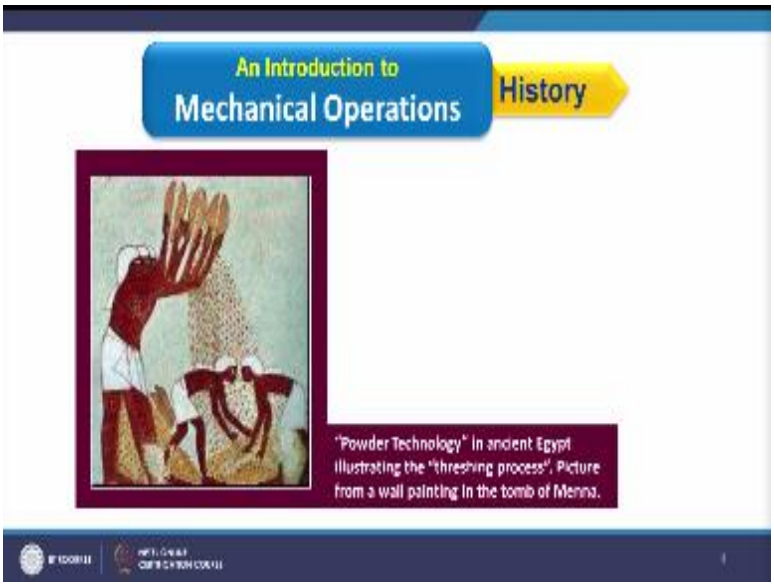

It is the synonym of mechanical operation. Along with this particle technology also comes under mechanical operation. So as far as history is concerned while seeing this figure we can say.

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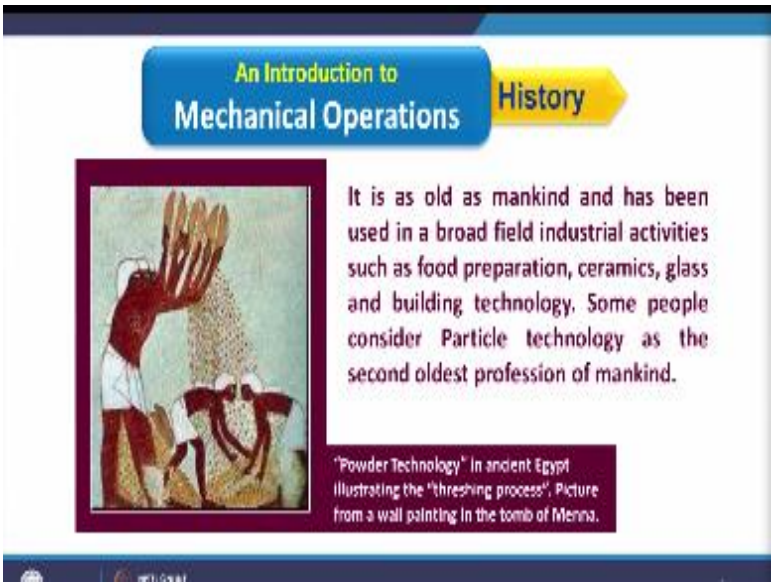

It is as old as mankind and has been used in a broad field industrial activities such as food preparation, ceramics, glass and building technology. Some people consider particle technology as the second oldest profession of mankind. So if you see here two terms are there, powder technology as well as particle technology, these both are the synonymous of mechanical operation.

So once I am telling about particle technology and powder technology I am telling about mechanical operation only. Technology I am telling about mechanical operation only.

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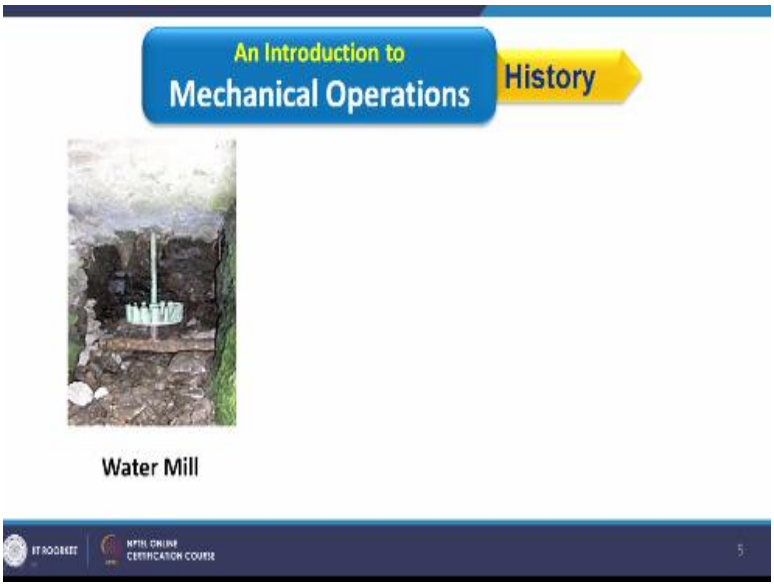

Another example from the history I have taken is if you consider this, this is basically the water mill, now what is this water mill? If you can see this figure it has a shaft, vertical shaft and over here we have the rotating disk. This rotating disk is over this stationary disk, stationary plate or these both are made from the stone so when we have some particle or some material over here and when this rotating disk rotates it basically grind the material which is available in-between this.

Now how the grinding will take place, once it will rotate and how this rotation takes place? When this water line come over here and how the water line come in this? To understand this if you see this figure it is nothing but a cave and this usually found in hilly area, now in hills what happens in this cave a water stream line drop from the top and when it strike over this fill it makes this complete disk rotate, and then when it rotates it material which is available in between this it gets grinded by the iteration as well as rubbing action.

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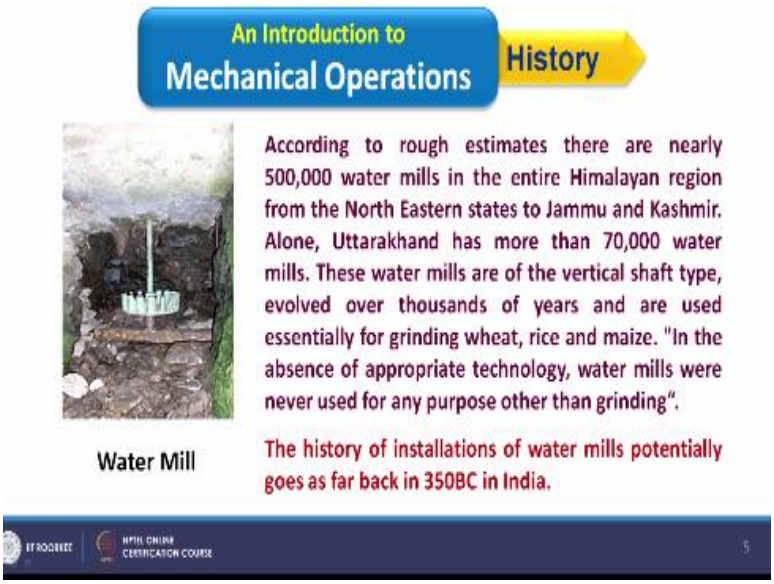

So this water mill when I am considering and how I am relating this with the history that according to rough estimates there are nearly 500,000 water mill in entire Himalayan region from the north eastern states to Jammu and Kashmir. Alone, Uttarakhand has more than 70,000 water mills, these water mills are of vertical shaft type like I have shown over here evolved over 1000's of year and are used essentially for grinding wheat, rice and mazie.

In the absence of appropriate technology water mills were never used for any purpose other than the grinding, so if you see this statement it says the history of installation of water mill potentially goes as far back in 350 BC in India. So when I consider the water mill I am speaking about the history of mechanical operation. Another example of the history of mechanical operation is the henna.

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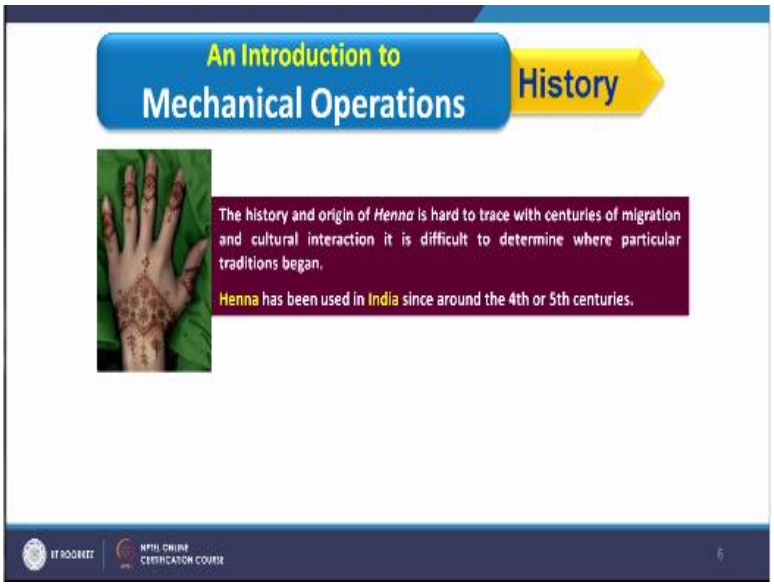

If see in this hand it is nothing but henna is available over here, now if I trace the history of this particular henna it is quite unknown because it comes into tradition from very beginning, and how this is prepared? This is prepared from the henna leaf, so we basically grind the henna leaf and then mix water in this to make a paste and then we use this. So as far as from leaf to powder is concerned this is the process comes under mechanical operation.

Therefore the history and origin of henna is hard to trace with centuries of migration and cultural interaction it is difficult to determine where particular traditions begin. If I consider henna it has been used in India since around 4^{th} and 5^{th} century, so you can understand from how long we are associated with the mechanical operation. Another very common example is the spices which we are using in our food.

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So as back as 3000 BC in India turmeric powder, spices powder and ayurveda medicine made up of powders using particle technology were used, so while considering the ayurvedic medicine or the species or the henna or the grinding we are associated with the mechanical operation. Another very good example of mechanical operation which we are using since the beginning, that is ancient equipment for preparation.

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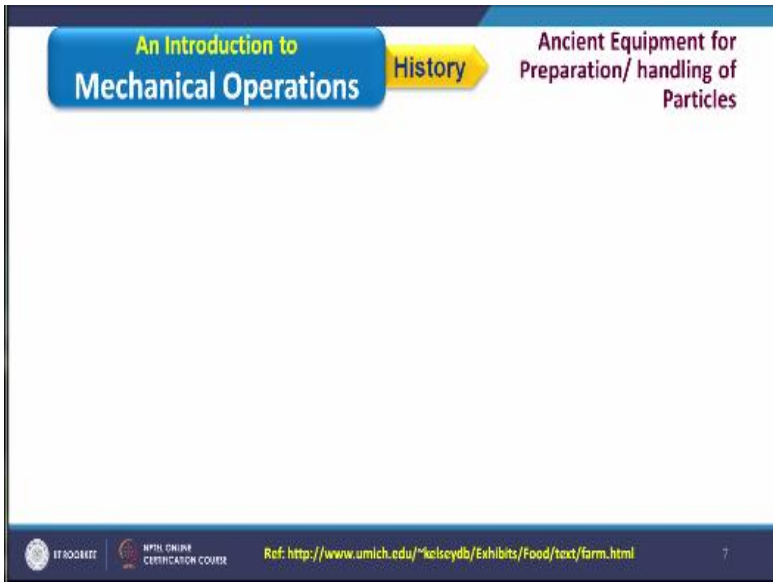

And handling of particles. Here I'm showing some of the photographs to make you understand from how long we are using. If I consider this.

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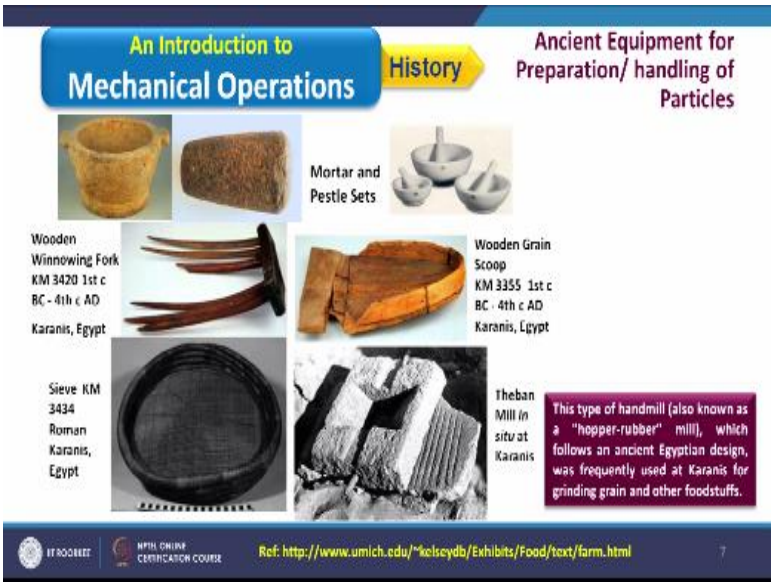

This is nothing but the grinding bowl in which the metrical can be grinded by this stone and here we have another example of this, so these are mortar and pestle sets. Further I am considering another equipment which we call wooden winnowing fork. Now if you consider this particular equipment this is basically used for screening in threshing process as I have told previously, so this all these equipment we are using since very beginning, like if I consider the example of this fork it comes in 1^{st} c BC to 4^{th} c AD and it is extensively used in Egypt .

Another example is this scoop, this scoop we are using in our houses today also; it is basically used to remove impurity from or to remove grain from the edible solid. Further I am having another example of this sieve which we call the screen to remove the uniform size particle from the non uniform mixture, and here if we consider this example it is nothing but the grinding mill in which this particular stone is fixed and this particular stone is movable. As we use in water mill there was one stone which is at stationeries position and another is in rotating state, here it is a stationary stone and this particular stone is used for rubbing not for rotation, but it slides over the stationary stone.

So this we call as Theban mill, so this type of hand mill like I am talking about this Theban mill, this type of hand mill also known has a hopper rubber mill.

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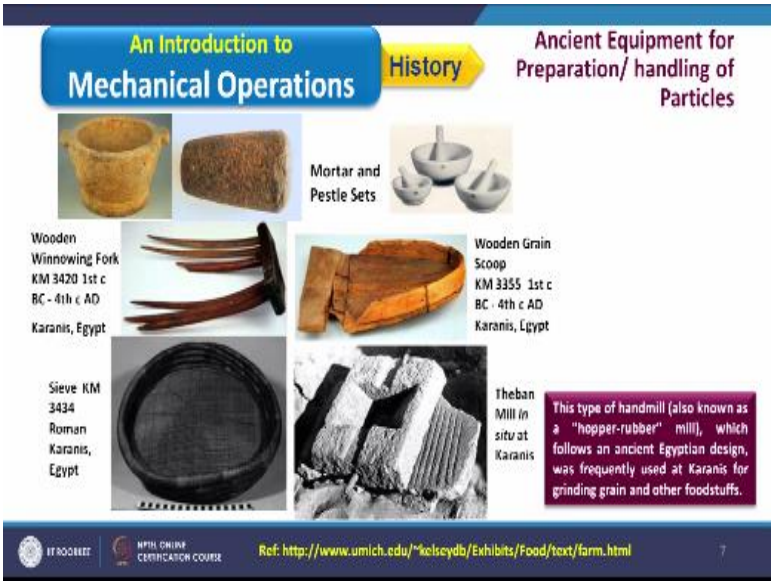

Which follows an ancient Egyptian design was frequently used at Karanis

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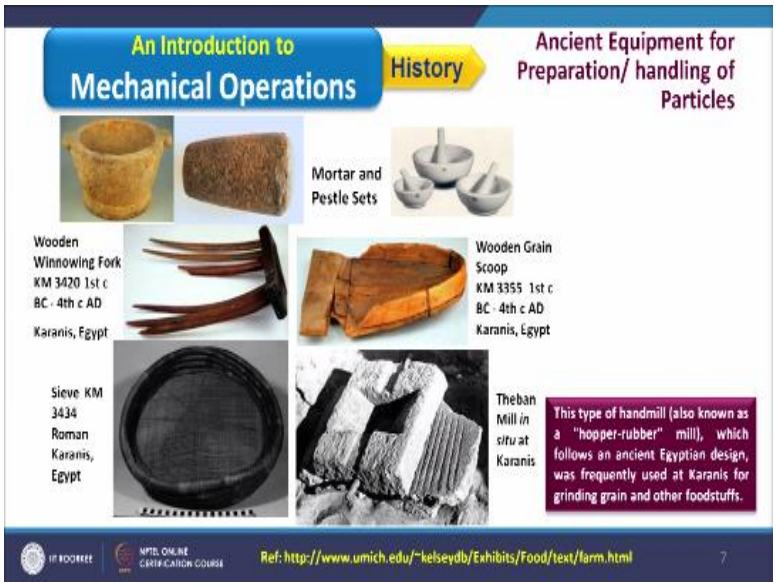

For grinding grain and other foodstuff. Now if I consider all these examples these photographs taken during the excavations at Karanis demonstrate that farmers in early twentieth century of Egypt used methods of grain processing. This testify that people at Karanis had a good understanding of the mechanics of both grain harvesting and wood working. So considering all these figure we can associate ourself with the mechanical operation we were using since the history or since very beginning.

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So now another example from the history is this stone grinder. This we have found in our houses these days also, it is this we are using since very beginning and right now also we are using this. It has the particular stone of rectangular shape or sometime oval shape and here we have another stone which rubs over here to grind the spices. So similar type of stone grinder we have found in Sudan and if I considered these grinders these are basically the old traditional method of grinding the grains in India and Africa which was widely used until twentieth century was crushing them by stone.

So if we consider the history of mechanical operation we are using this though whether we are aware about this or not. So right now as far as mechanical operation is concerned we are technically sound but previously when we were not have that much technical knowledge then also we were using this for our benefit.

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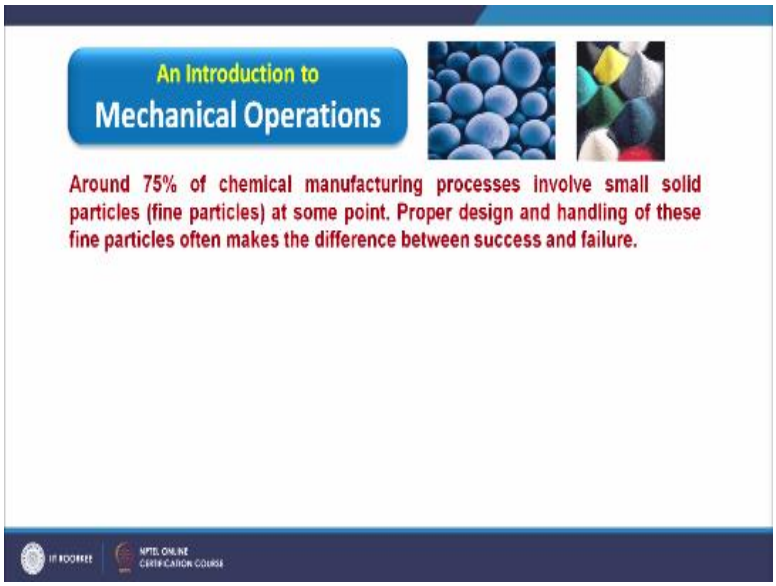

So mechanical operation if we consider or whatever I have shown previously, from this around 75% of chemical manufacturing processes.

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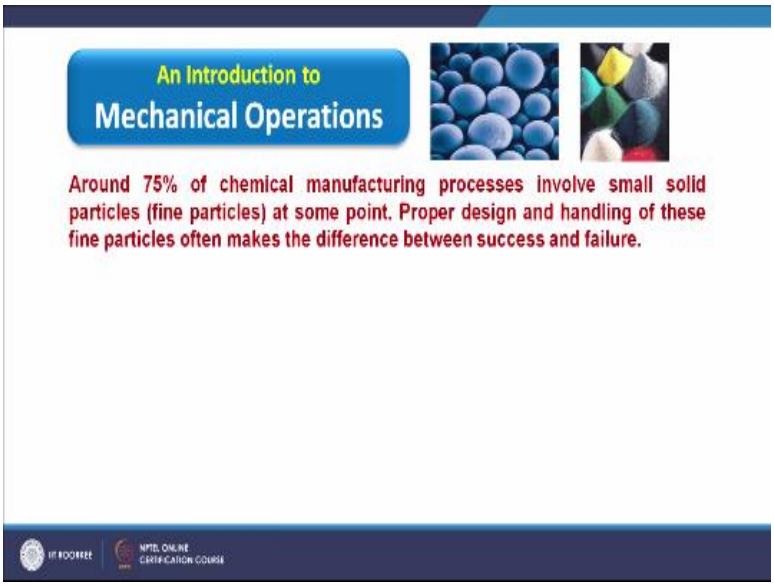

Involve small solid particles that is fine particles at some point. Proper design and handling of these fine particle often makes the difference between success and failure. Now if you consider this here I have used the words success and failure and this depends on the handling of fine particles. What is the meaning of this? That for a success and failure of a particular product the size of particle is very important. How it is important and why it is important that I will speak later on.

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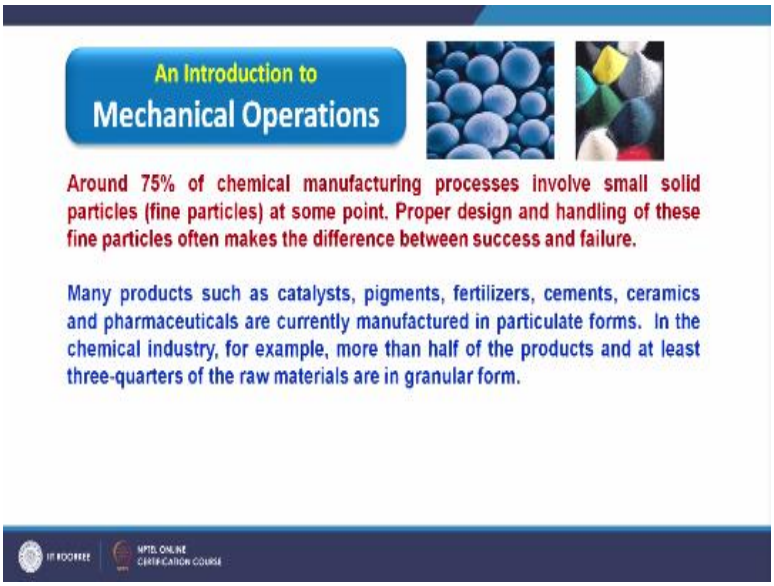

Further if I consider the solid material many products such as catalysts, pigments, fertilizers, cements, ceramics and pharmaceuticals are currently manufactured in particulate forms. In the chemical industry for example more than half of the products and at least three quarters of the raw material are in granular forms. So we are having sufficient, we are having significant material which we can used, which we can handle through mechanical operation.

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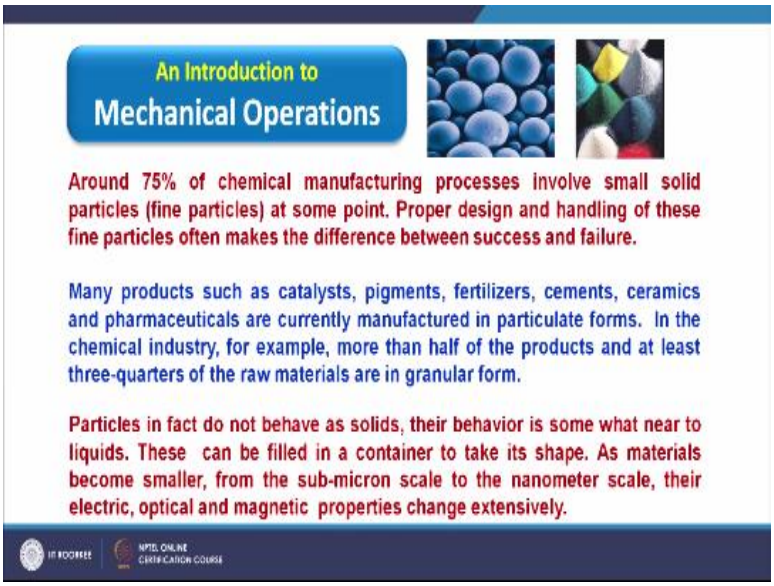

Now we have another statement like particles in fact do not behave as solid, their behavior is somewhat near to liquid. Now I'm saying this, if I considered the solid lump and if I place that solid lump over here it will not change its shape, however if I consider the number of particle and those number of particle if I put in one glass and if I change the position of glass, for example, if I tilt the glass.

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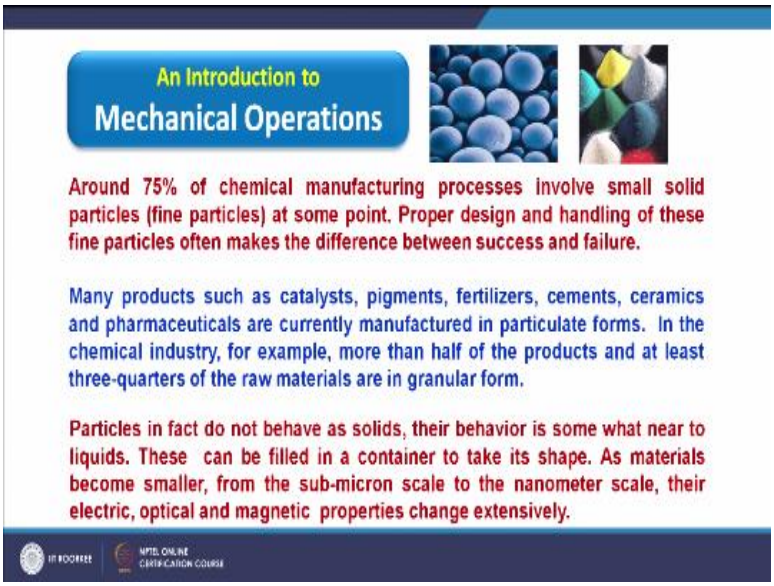

The particle which are available they will change their position. So its behavior is near to liquid, not as a solid.

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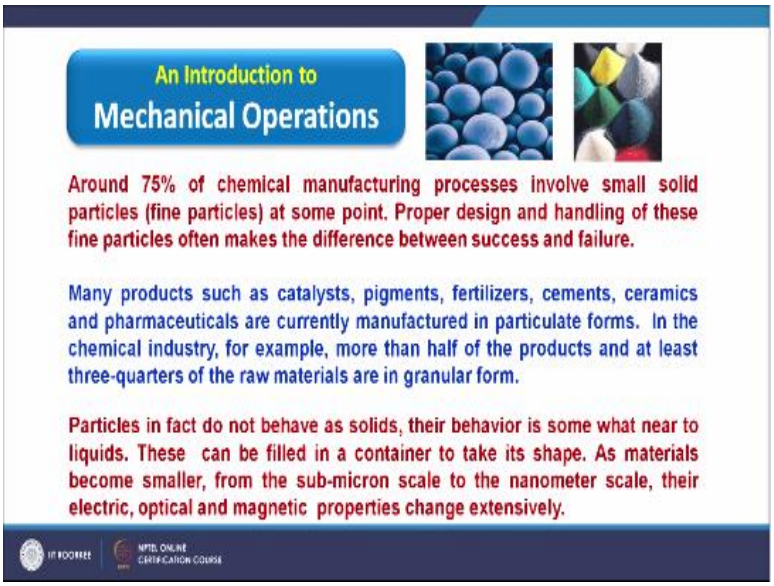

Therefore, as materials become smaller from submicron scale to nano scale.

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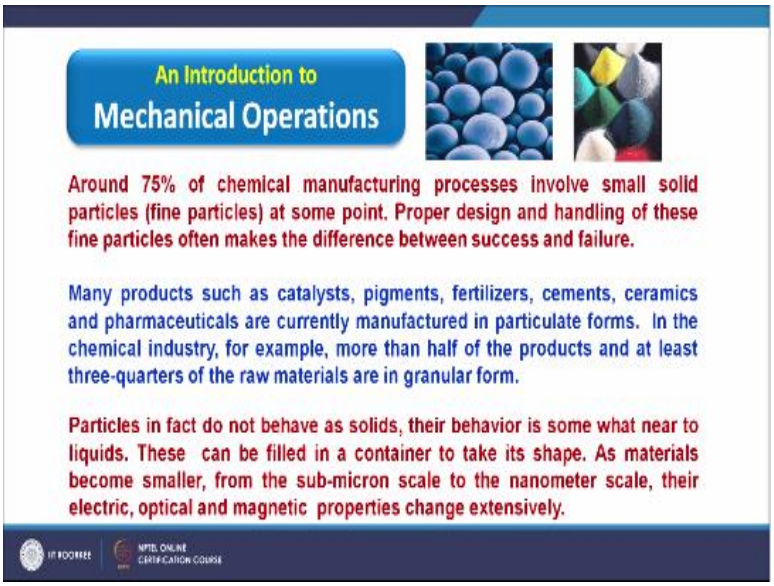

Their electric, optical, and magnetic properties change extensively. Now this is the reason why I have told that success and failure of a product depend, is dependent on the fine particle.

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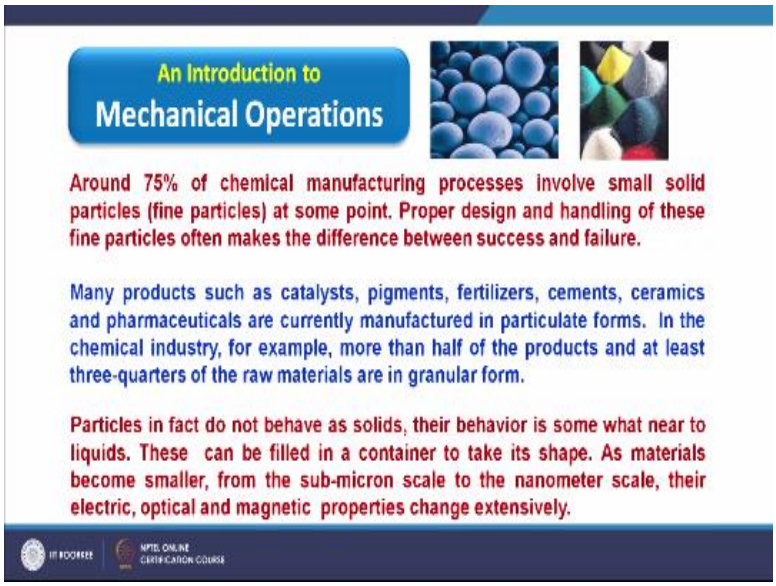

Because then we consider, when we change the particle size it, the property of particle changes, their behavior changes, so accordingly the success and failure of the product occur.

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Some industrial issues are there which are related with the particle size, so here I am taking one example of common salt in which if I consider this particular figure it is having basically the free flow salt. Now how we make the salt free flow? To speak, before speaking on this let me consider one example, that when I was in my childhood and when we take the salt in a, in a bowl or in some container and when we put on the table it captures the moisture and becomes sticky. But right now whatever salt we are using when we put it outside also it does not absorb moisture and becomes free flow.

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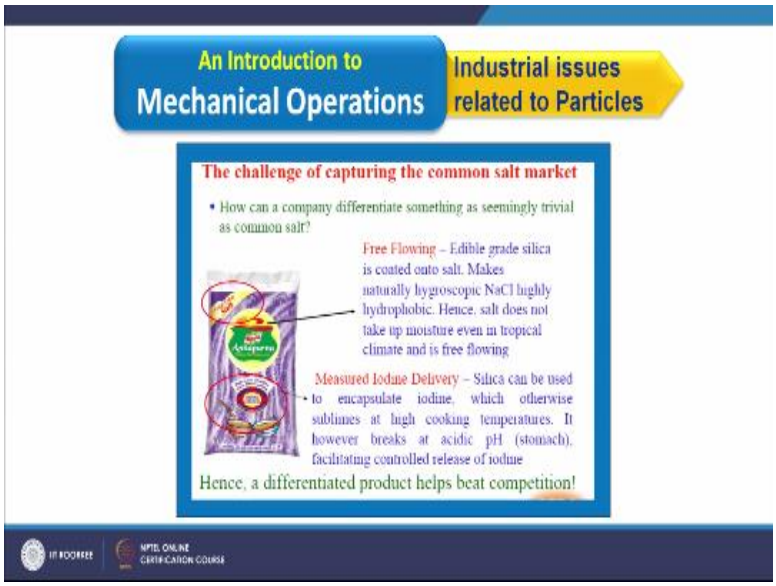

Now why it happens, it is due to edible grade silica is coated on the salt. It makes naturally hygroscopic NaCl highly hydrophobic. Hence, salt does not take moisture even in tropical climate and is free flowing. So due to silica coating salt can become free flow, another advantage is this.

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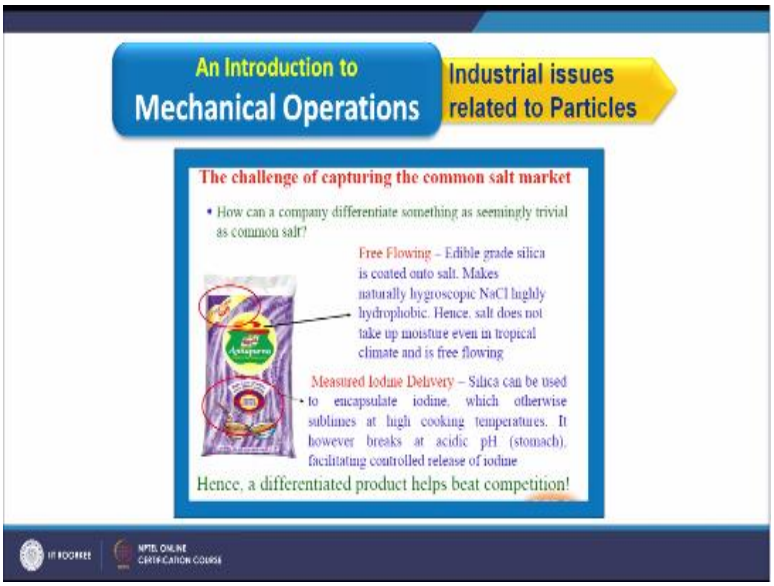

When we have the coating of silica on the salt what it does it basically encapsulate the iodine present in the salt. Otherwise what happens, it sublimes at high temperature cooking.

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It however breaks at acidic pH of the stomach, when we have that encapsulate iodine it basically breaks when we have the food inside our stomach. So, which facilitates control release of iodine, that is the benefit of silica coating, so that comes under mechanical operation. So after having slight change, slight modification in the product.

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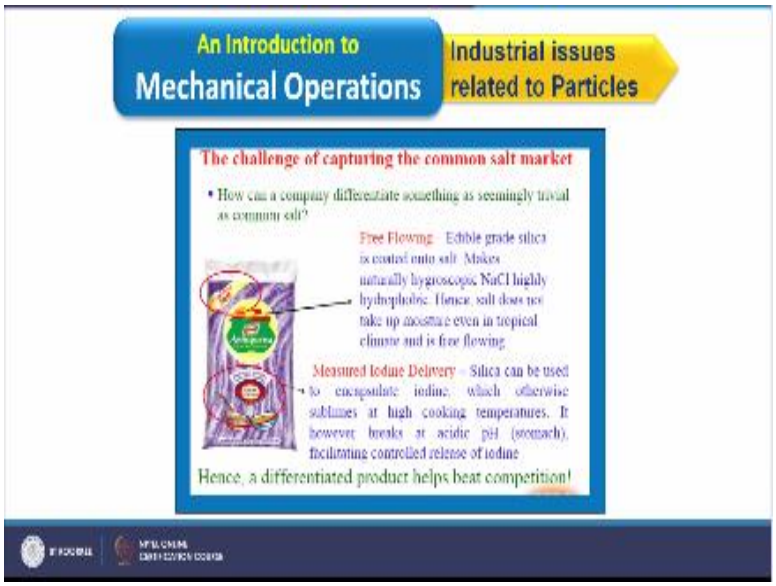

The product become favorable for the customers. In this slide I am showing the range of particle diameter in different products.

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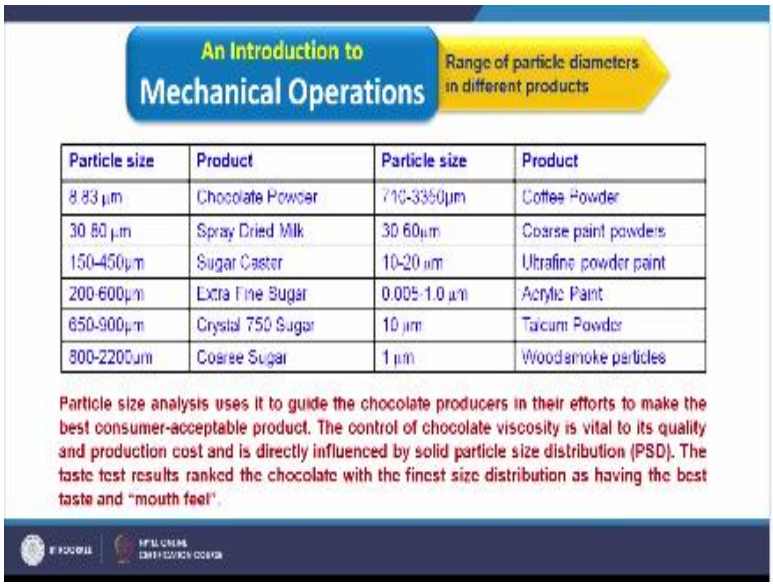

Now if I consider the chocolate powder it has a desirable size like 8.83 micrometer. What is the use of this particular size? If I consider particle size analysis uses it to guide the chocolate producers in their effort to make the best consumer acceptable product. Now what happens, when I consider the particle size of a chocolate it gives a special kind of feeling that we call the mouth feel which comes with this size particle. Now how it happens, because when we have different sizes of particle and when we go the particle size in very small or finest size I can say.

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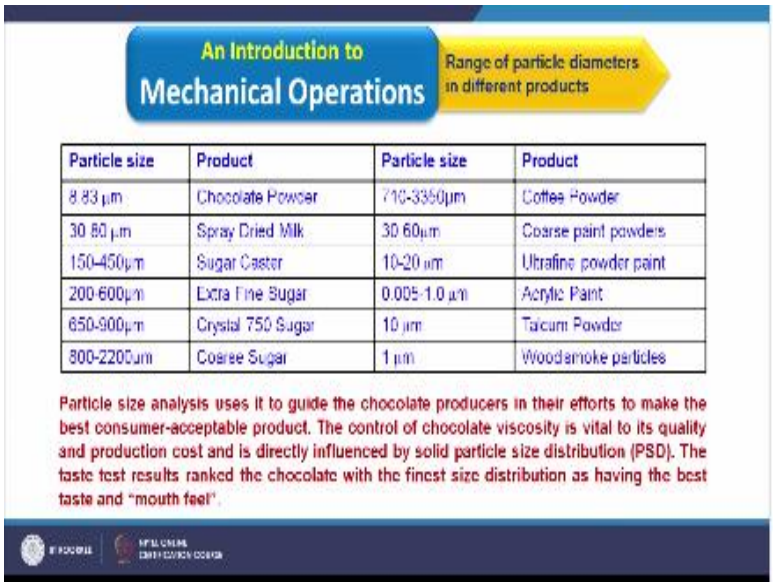

Like it is 8.83 micrometer so that is very small, if I have that small size particle in chocolate it basically controls the chocolate viscosity.

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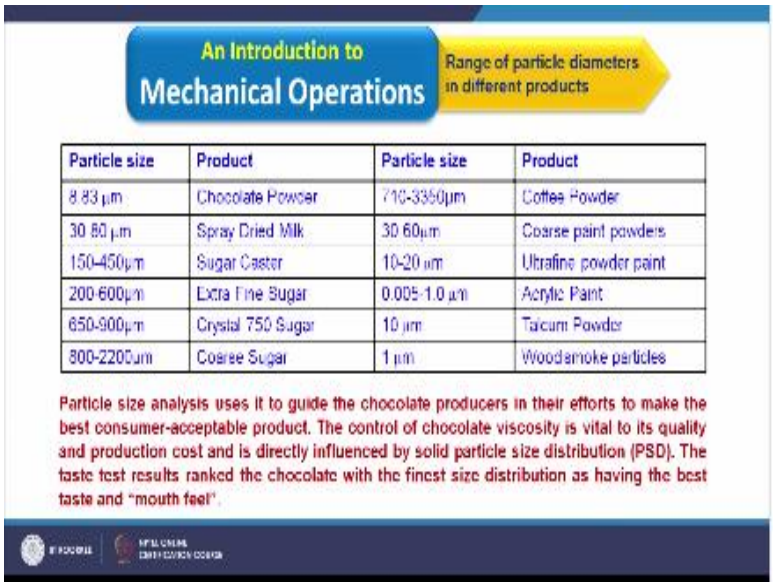

So when we have chocolate and when it mix with the saliva it controls viscosity in such a way so that it is spread in our mouth and it gives the mouth feel, it happens with a particular size only. So therefore if we consider the chocolate.

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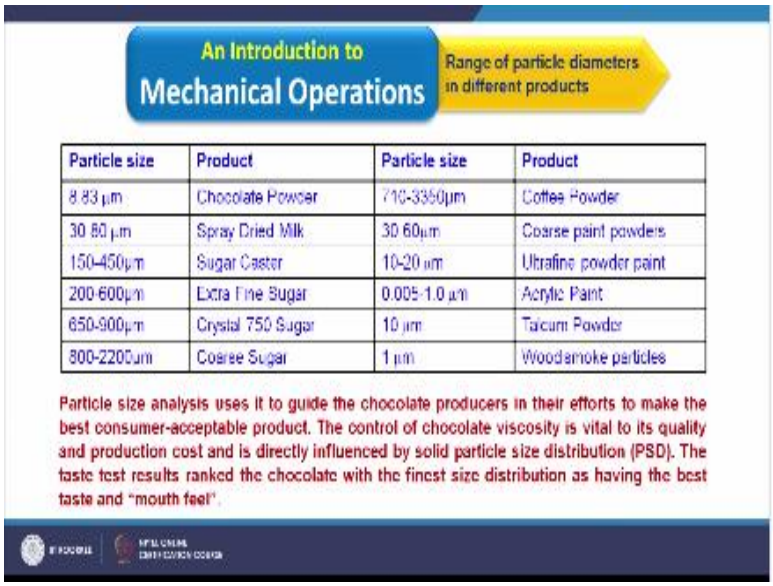

And if we want to have the mouth feel we have to choose this particular size and right now the chocolate loving customers they really love such kind of feeling. So here this is another example how the particle size basically give a product or basically make a product successful or failure.

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In continuation to this I am having some optimum particle sizes, there is an optimum particle size or at least a smallest and largest acceptable size for most items involving particle.

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The very one example just we have discussed, the taste of chocolate is affected by the size of their respective ingredients. So if I consider the mouth feel of the chocolate it comes with very fine size of particle and these days we can find the chocolate which have different particle size in it, for example it has very small particle and some chocolate chips also there in-between this.

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So this give the very crispy feel and the very fine particle gives the mouth feel, so that is quite different experience when we have different particle size chocolates.

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Another example extremely fine amorphous silica is added to tomato ketchup to control its flow, further pharmaceutical tablets dissolve in our system at rates determined in part by particle size and exposed surface area. So you can understand the optimum particle size also play important role in medicine.

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And setting time of concrete, dental filling and broken-bone casts proceeds in accordance with particle size and surface area exposure. So if I consider optimum particle size we can have the product of customer, we can have customer loving products interms of edible products.

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And in terms of medicine, here I am having another example of a particle size and the researchers have used this particle size analysis to treat arthritis.

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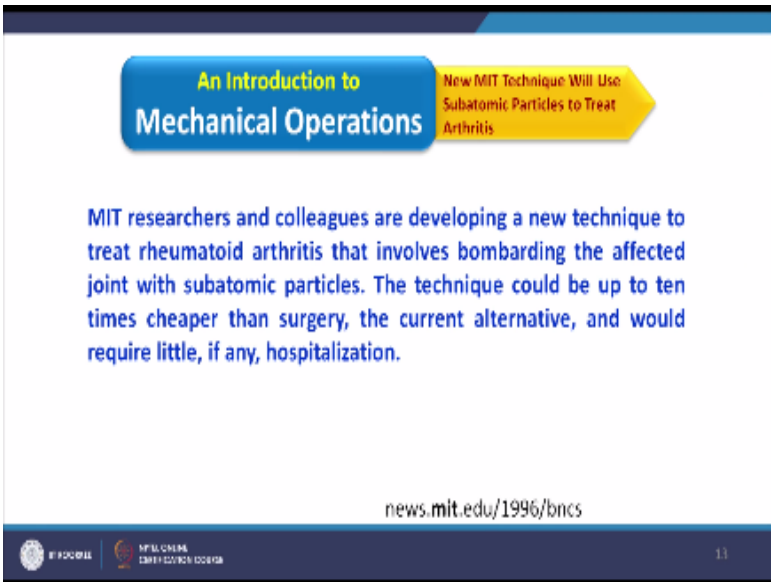

This research has been done in MIT, MIT researchers and colleagues are developing a new technique to treat rheumatoid arthritis that involves bombarding the affected joint with the subatomic particles. So you can understand that particle has very important role in such severe diseases. So the technique could be upto 10 times cheaper than surgery which is the substitute at present day like rheumatoid arthritis doctor used to suggest that you should go for the surgery. Now instead of surgery using that particle technology.

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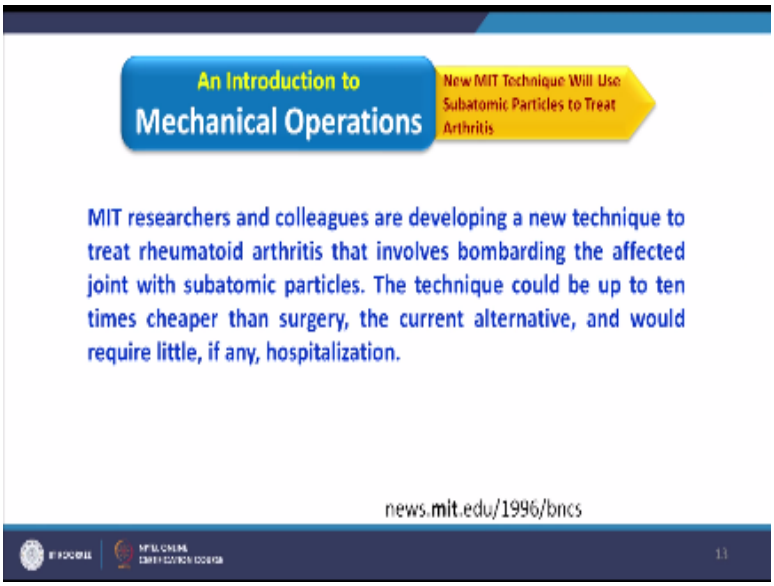

We can also have the recovery from rheumatoid arthritis and this technique require very little hospitalization if any, above this you can study in detail at this link.

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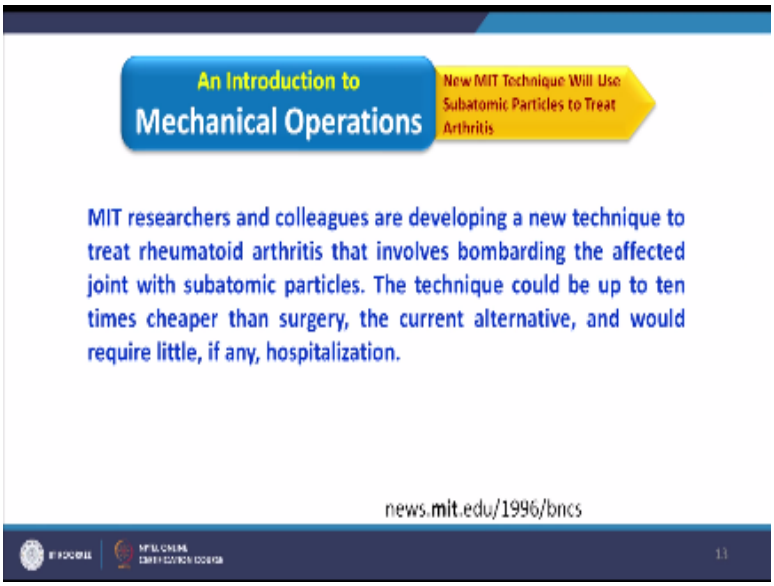

Further I am having the property that are affected by the particle size which I have discussed in the beginning that when we have different particle size the property of the material changes significantly. Now what are the property that are changes?

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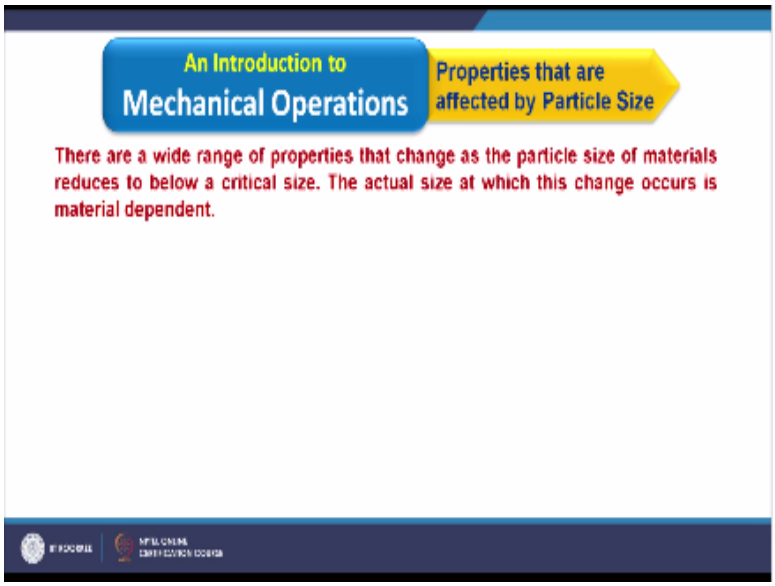

There are wide range of properties that change as the particle size of material reduces to below a critical size and that critical size is basically dependant on material to material, therefore I cannot say for a particular material what should be the critical size for this, it can be different for different material.

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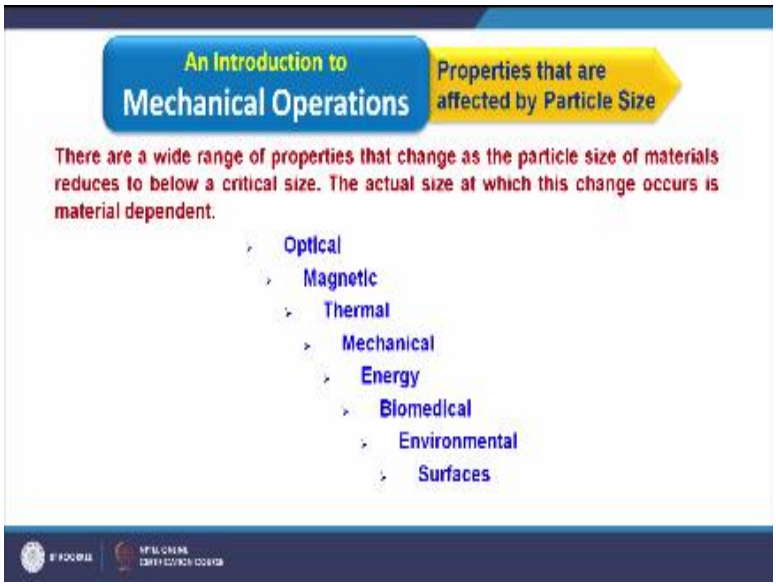

And the property which can be affected by the particle size are optical, magnetic, thermal, mechanical, energy, biomedical, environmental and surfaces, surfaces means surface area. So when we have different particle size we have different property it has different effect on the final product.

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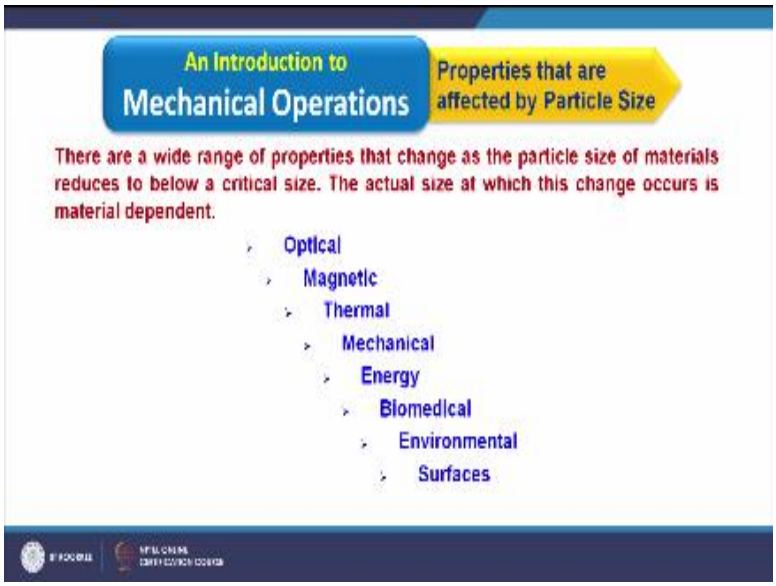

And it makes the product successful or fail, so here I am having partial list of industry that uses particle processes and these are.

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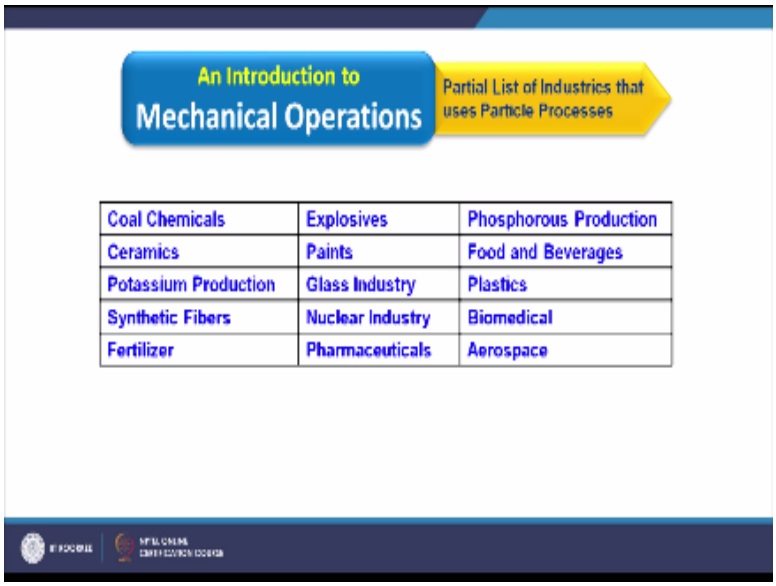

Coal chemical, ceramics, potassium production, synthetic fibers, fertilizer, explosives, paints, glass industry, nuclear industry, pharmaceutical and there are many more. This is a partial list however as far as industrial application of mechanical operation is concerned that is very huge. And here I am having list of the operation and the equipment which use particle.

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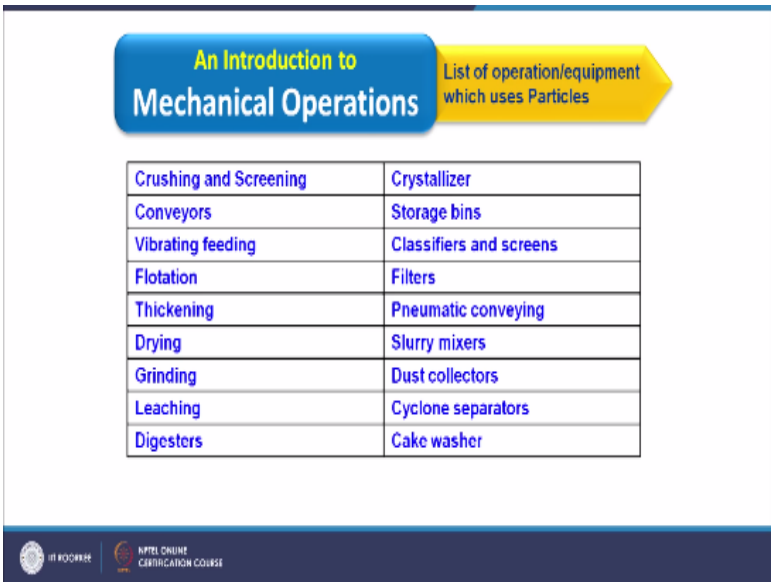

So there are different operation we have like crushing and screening, conveyors, vibrating feeders, flotation, thickening, drying, grinding, leaching etcetera, and equipment like crystallizer, storage bins, classifiers and screen, filters, pneumatic conveying and there are many more. So these are some operations as well as equipment which involve mechanical operation. Now till now what we have discussed basically, what is the definition of mechanical operation, how it is useful for us and what is its industrial application.

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So as far as it s utility is concerned it has been used since ancient or it has been used from very beginning to the present life also knowingly or unknowingly, so you can say the mechanical operation is a part of our day to day life. So at present I can say that you have enough background that why you are studying this course, so the target audience for this particular course is anyone of any professional level.

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Preferably holding a college degree or with substantial industrial experience, working in the production, handling, processing, modification, storage, transportation or characterization of particular solid, that is powder or bulk solid, so any one can join which has such kind of experience and professional degree.

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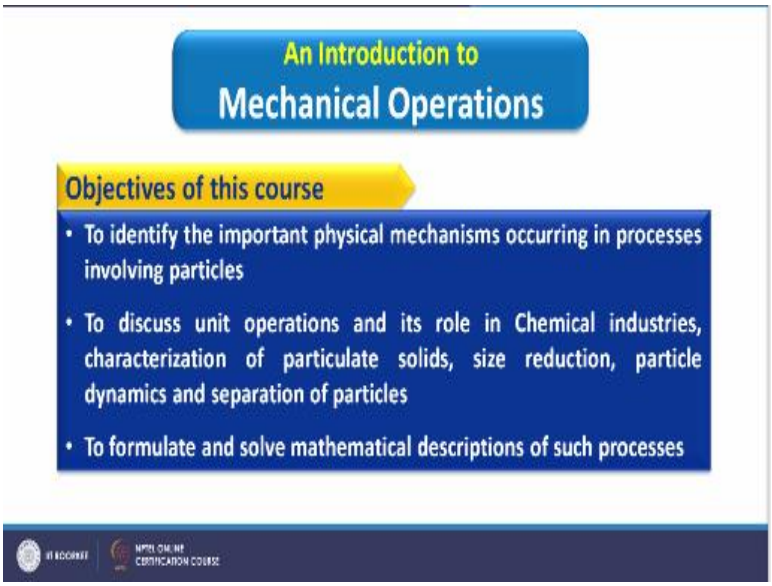

Objective of this course is to identify the important physical mechanisms occurring in processes involving particle, so if we are dealing with the particle what is the mechanism behind this for a particular process that we can identify. Further I am having the objective as to discuss unit operations.

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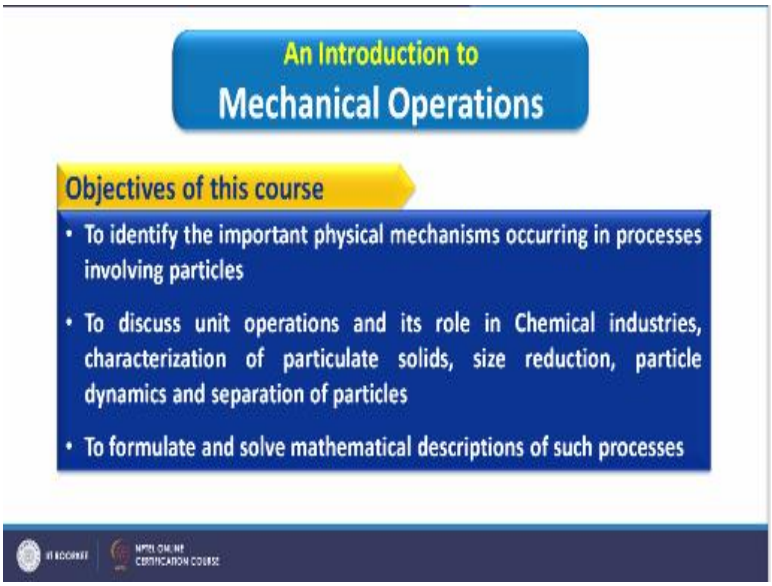

And its role in chemical industry, characterization of particular solid, size reduction, particle dynamics and separation of particles, so in this particular course we have, we will study about the unit operation involved in this.

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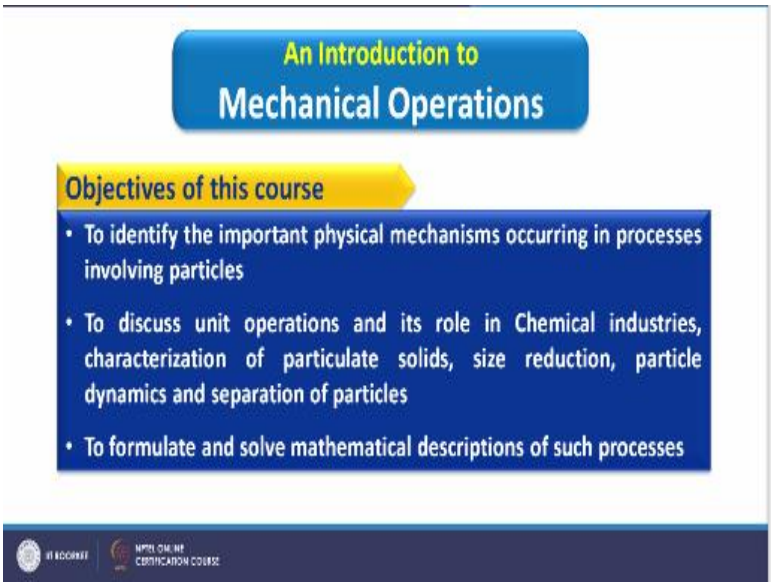

Further I am having third objective that is to formulate and solve mathematical description of such processes, so while studying this course you can meet these objectives, the course plan is.

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Here this is four week course which is divided in total eleven modules. In week one I am having module one which is introduction which I am discussing right now. Module two consists of characterization of a single particle. Module three, characterization of collection of particle, that is the whole content of week one. In week two I am having four modules, first is fine grain size distribution, second module effectiveness of screen, third industrial screening equipment, fourth size reduction. Third week involves two module, that is laws of comminution, size reduction equipment.

And four week again involve two module, that is particle dynamics, classification and jigging, so this is the complete course plan. Further important points of this course is shown in this slide that is it is basically the core course as far as B.tech is concerned, B.Tech in chemical engineering is concerned this is the core course, pre-requisite.

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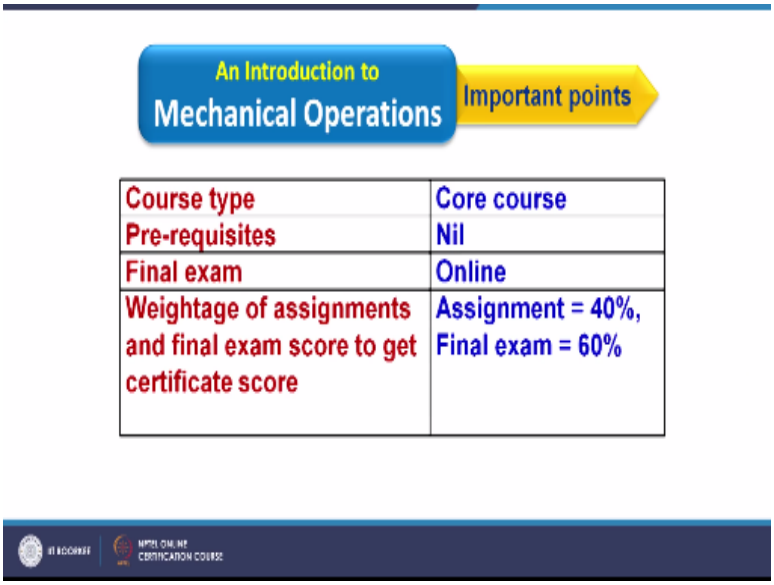

There is no pre-requisite required for this course, final exam will be online, weightage of assignment and final exam score to get certificate course the assignment has 40% weightage and final exam is having 60% weightage, so accordingly if we have the distribution of marks for to get the certificate.

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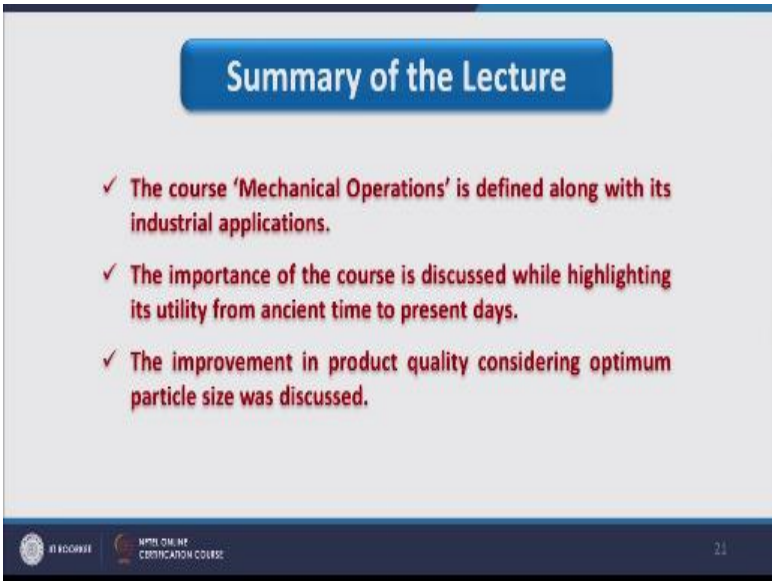

The summary of this lecture goes as the course mechanical operations is defined along with it s industrial application, another point is the importance of the course is discussed while highlighting its utility from ancient time to present days. Further I have discussed the improvement in product quality considering optimum particle size, so these three are basically the summary lines of the present lecture.

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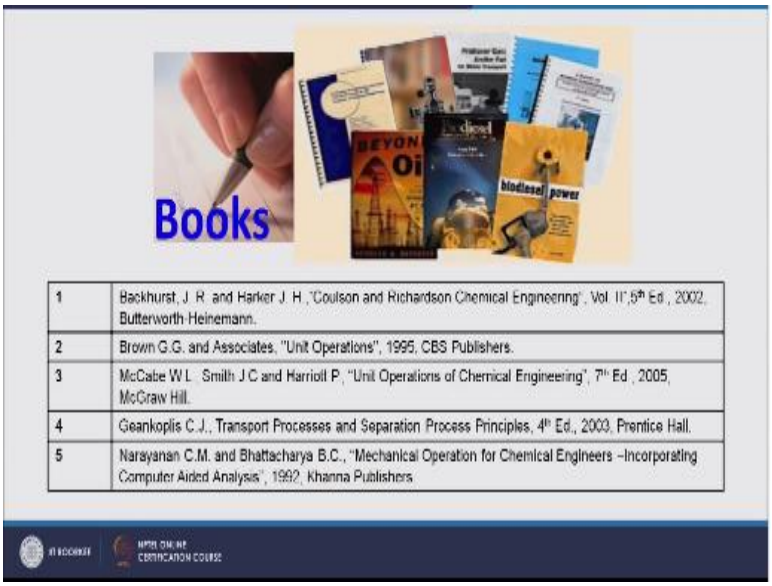

And these are some of the books which you can refer for this particular course, however in between I have used some other sources on which I will speak at that time only, so that is all for now, thank you.

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