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NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

Tutorial - 1
Materials Characterization
Quantitative metallography

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Hello everyone welcome to this online course on materials characterization organized by NPTEL. I hope you all have gone through these video lectures of optical microscopy and its applications and laboratory demonstration and so on. What I wanted to do in this class is to have some kind of tutorial sessions where I would like to introduce the applications of optical microscopy.

As you see in these video lectures I have just demonstrated variety of applications optical microscopy has got tremendous amount of applications in almost every field where we use materials, structures and micro structures, topology and so on. But then when my tutorial sessions will be more with relevant to materials science and metallurgical engineering and so on. But then some of these applications are more general which can be used to know in the field of medicals as well as biological materials and so on.

So in this class I just want to introduce a technique called quantitative microscopy. You see optical microscope is just used, not just, not only just to observe the topological features of materials or biological systems or any other context. But then it has got tremendous capability to obtain quantitative information. In fact the quantitative microscopy itself is a separate science in itself; I will not get into the elaborate procedures of quantitative microscopy or metallography which is out of the scope of this course.

But then if you want to appreciate the infective application of optical microscopy I think you need to understand the basic idea of the quantitative microscopy. I will just introduce here I am not getting into details, but I will just introduce a basic concepts which is there in a quantitative microscopy.

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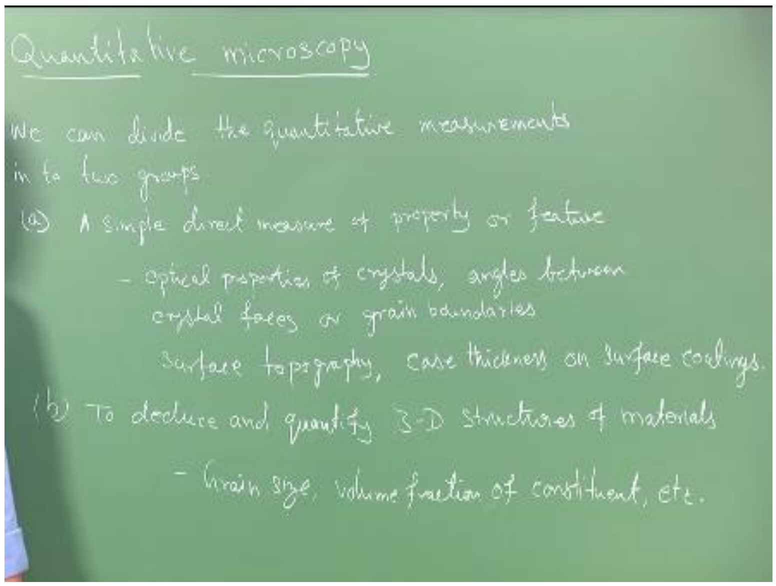

So what I will do is I will just demonstrate basic idea behind this. So what I have written here is when we talk about a quantitative microscopy we can divide them into two measures one is a simple direct measure of property or feature on a material which could be an optical properties of crystals or angles between the crystal phases or grain boundaries or surface topology or topography, or you can see the case thickness on a surface coatings or even if you look at the metallurgical phenomenon, a case hardening treatment and so on.

So this is a direct measure, the other one is to deduce and quantify three dimensional structures of materials, so this is the second measure in a quantitative microscopy so how are, these things are visualized let us see. Example so what are coming into 3 dimensional structures of materials such as grain size or particle size you have volume fraction of constituent in a 2 phase materials it could be a practical fraction or a independents phases of a multiphase or poly course line material there.

They can be deduced and can be quantified in a microstructures they are 3 dimensional structural parameters so there are these are the 2 broad category under which one can use quantitative microscopy, so what are the mathematical relationship to obtain a quantitative measurements briefly I am going to just tell one by one.

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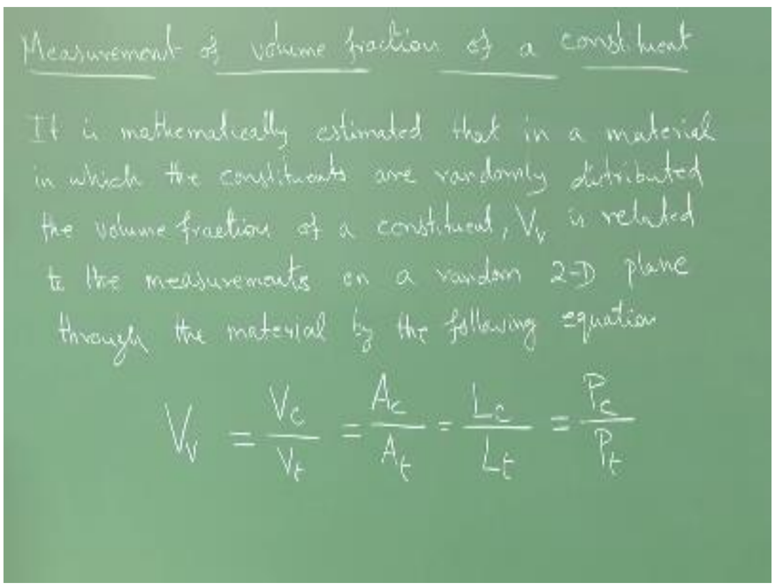

First we will take it up measurement of volume fashion so what I have written here is it is mathematically estimated that in a material in which the constituents are randomly distributed the volume fraction of the constituent that is Vv is related to the measurements on a random 2D plane through the material by the following relate equation that is Vv = Vc/ Vt which is equal to Acc/ At Lc/ Lt = Pc/ Pt so what are all these things we will just describe 1 by one see the Vv is the volume fraction.

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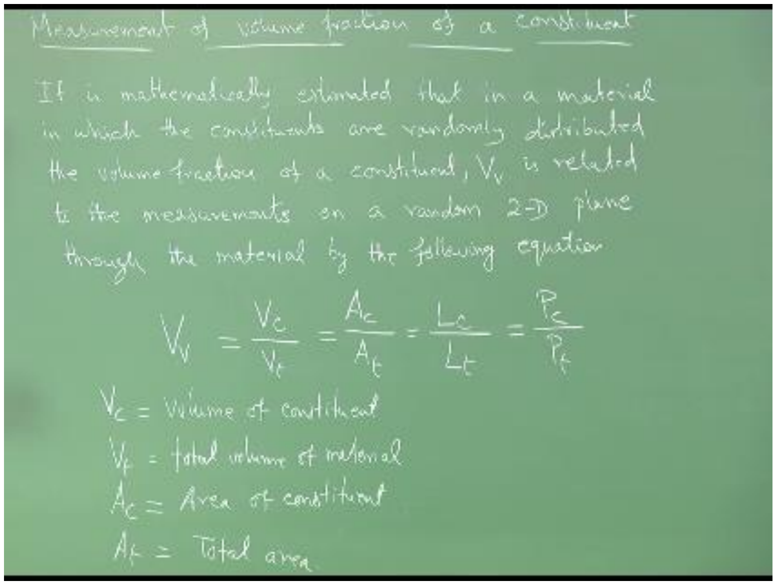

So Vc volume of constituent V_t is total volume of material so V_c/t is a volume fraction so you have the volume of the constituent divided by the total volume of the material, similarly you have area of constituent total area so similarly you have A_c/A_t that means you have area of constituent divided by A_t will give you the fraction and then you have two more that is.

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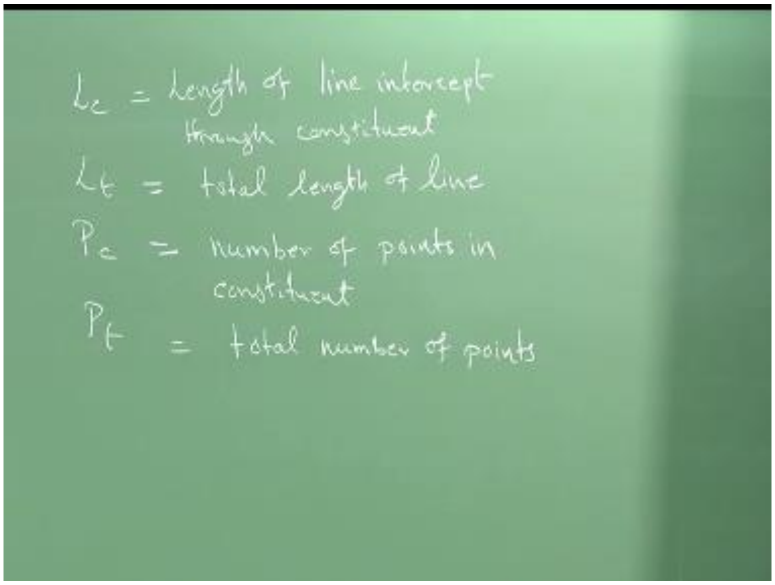

So what you are now seen here is, so the volume fraction of constituent in a two phase material or a multiphase material or a second phase particle fraction and a matrix can be related to areal fraction or areal analysis or a linear analysis or point concurrent so this is the fraction of line fraction or intercept fraction this is a point fraction so point fraction, line fraction, area fraction is equal to volume fraction.

So it is very powerful expression to get some numbers out of from the topological micro structures or material features, so we will now briefly introduce or briefly mention how to carry out these things in a actually terms , so what I do now is I will write two lines about what is area analysis, what is linear analysis and what is point counting and how you can carry out this exercise in a using optical micrographs or even a scanning tool micrograph. So on but then let me first define what are these technique means.

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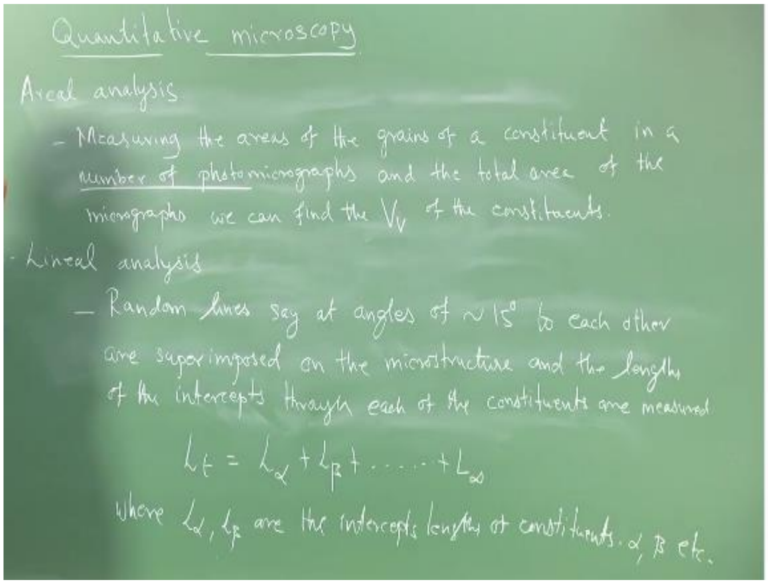

So what I have written here area analysis means, measuring the areas of the grains of the constituent or the particles whatever we are interested in a the two phase or a multiphase material in an number of photo micrograph so these at as I mention here this is you cannot do this is in on a single photo micrograph it is a number of photo micrographs the more number of micrographs we make a measurements the more the to receive in the or in other words the more number of micrographs involve it will be a more representative of your material rather than it will have a biast result.

So for this is applicable to all the technique which I am going to mention so the number of micrographs you measure or make measurements you have to maximize the count or the measure in order to get a appropriate representation of the material or more accurate values second thing is linear analysis, so what we do in linear analysis the random lines say at angles approximately 15^0 to each other or supreme post on the micros structure and the length of the intercepts through the each of the constituents or measured so you have the Lt is $\sum$ of L_α L_β etc.

Up to $L\propto$ where L_α L_β or the intercepts length of the consequence α β etc. So no matter how many constituent you have these expressions are valid in this fashion so this is a brief a definition of linear analysis let us move on to the next one.

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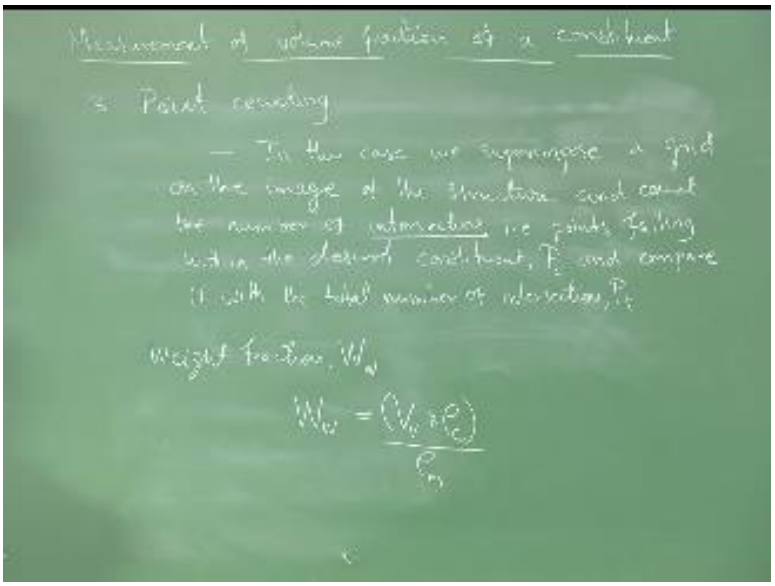

So here in point counting the super imposing at grid on the image of the structure and count the number of intersections that is points falling within the design constituent that is Pc and compare it with the total number of intersection Pt so that so that is what we required these two qualities we require to find out the fashion.

so this how it is done point counting so with this relation we can also find something called weight fraction when you have this relation we can also find weight fraction that is W which are useful that is so we have the Ww that is a weight fractions this is $Vvx\rho_c/\rho_m$ where ρ is the densities of the constituent and the matrix so we can also find the weight fractions if you have the data with you.

So what I have just gave a definition of what is the method of measuring the volume fraction of a constituent in a two phase or a multi phase material I just repeat we can do it in three methods one is aerial analysis secondly lineal analysis and third it is a point counting, okay. So this is the first technique on the quantitative microscopy, the next one is we will just look at some of the procedures or definitions of finding out the grain size.

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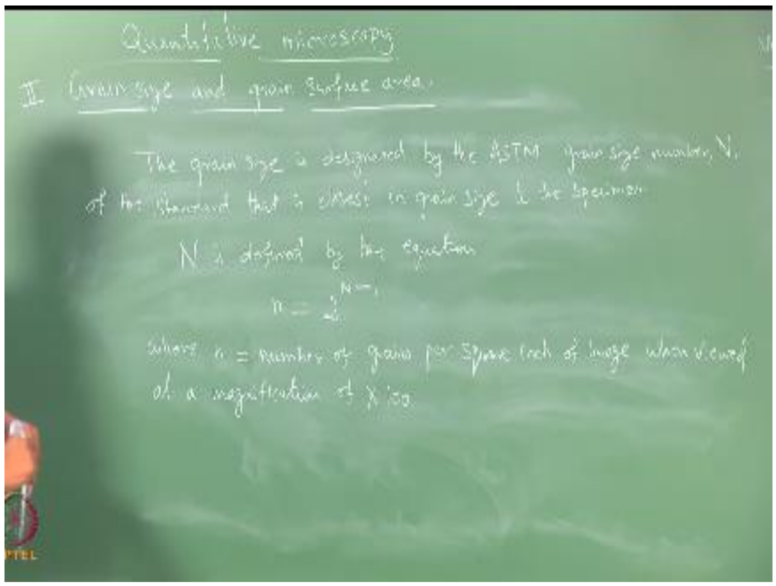

See the next one is grain size and grain surface area, what I am just going to say this is a very simplest way of looking at the grain size but there are more regress way of measuring the grain size if mathematically we can do it which also I am going to show you, but this is the most popular in the industrial practice where the grain size is designated by ASTM American Standard of Testing Materials grain size number N of the standard that is closest in grain size to this specimen.

So you have the standard charts available readily for reference to compare your specimen and the grain size available on the chart and where the N is defined by the equation a small $n=2^{N-1}$, okay where n is number of grains per square inch of an image when viewed at a magnification of 100 times, so this is very important because you once change the magnification then these things will not be valid so we can correct that expression also when we look at some of the other examples.

But this is how the basic definition is given to start with so a small n and there is a N only N is called ASTM grain size number, n is number of grains per square inch of an image when you look it at the 100 times the magnification.

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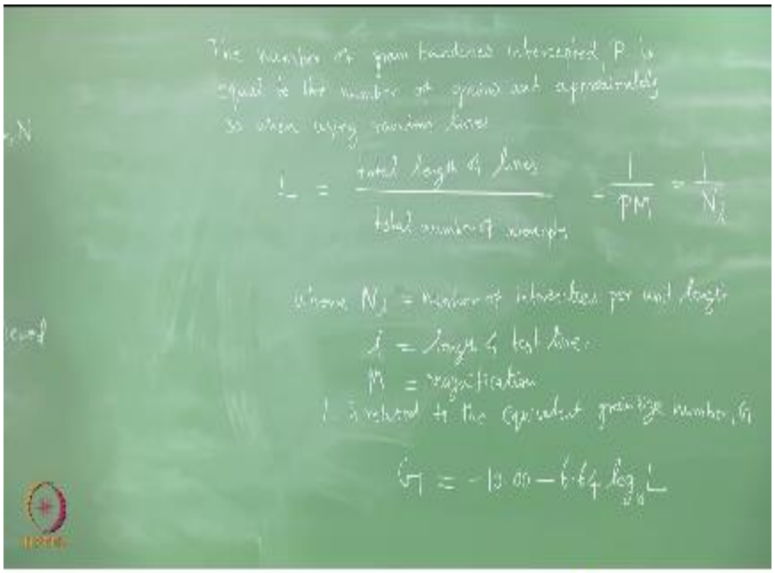

So I will also written is I said this is a very basic way of looking at the grain size. You have little better accurate methods were if you use the number of grain boundary intersected P. that is if you count the number of intercepts which is P it is equal to the number of grains, and approximately when you use this random like line. Of course all this technique you have to consider using the random lines. And that L = total length of lines and total number of intercepts which is equal to 1/ PM were P is the number of grain boundaries intercepted. And M is magnification which is nothing but inverse of number of intercepts per unit length.

So this is a relation again, you can see that were NL is the number of intersections per unit length. L is the length of the test line, M is the magnification. Suppose if you measure by L capital L like this which is related to the equivalent grain size number G. So we were talking about earlier ASTM number capital N. now is we call it equivalent grain size number in another estimate of grain size number capital G. Which is related to L by this expression, that is capital G

$= -10 - 6.64 \log_{10} L$. so this is another limitations by which you can measure the grains size with little more accurate by the equivalent grain size number G as compared to M.

So I will also show some more rehearse methods of grain size or a practical size I think I will also show some of this techniques hoe it is used in a practice. In some of the examples I am going to work out in one or two problems in each category. Then you will appreciate what we are talking about. So what I suggest is now before us going to the next level of more regresses calculations for grain size I would like to show some of the applications of this itself, or first let me show you what I mean this grain size ESTM grain size number. For example if you look at this.

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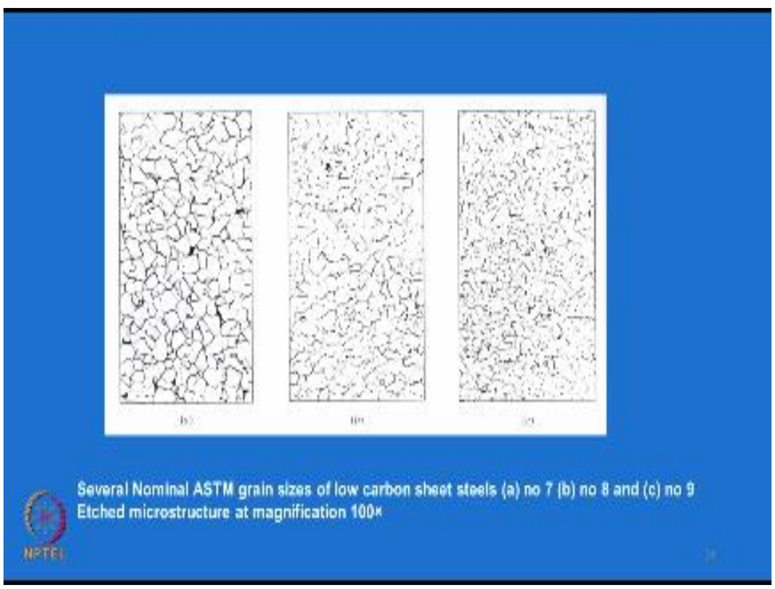

Slide you have the three different micro graphs A, B, C and if you want this is a politely sign material. Of the exact material name is low carbon steel and you have the several nominal ESTM grain size as shown here. For example the image grain size number is ESTM grain size number 7, and B number is 8 and C number is 9. So there are all etched microstructure at the magnification of 100 times. So what I want to do just appreciative is as the grain size number increases okay. the physical size of the grain size you know it has become smaller.

So this we have to appreciate so as the higher the ESTM grain size number means you have the smaller grains okay. So that is one thing you have to do keep in mind. And I will just show you in the next class with few examples. How we can calculate the ESTM grain size number from the optical micro graph. Or some of this measured are done even using a standing micro graph. And these are all really available in industrial shove loads were you can readily look at the grain size for a quick reference. You cannot be accurate calculations but for a quick reference you have this a in the industrial practice e will see it in the next class thank you.

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