Mechanical Behaviour of Materials - 1
Prof. Shashank Shekhar
Department of Materials Science and Engineering
Indian Institute of Technology, Kanpur

Module - 1
Lecture - 1
Introduction

Good morning, students. Welcome to this course on Mechanical Behaviour of Materials. So, this course will be taught by myself. I am Professor Shashank Shekhar from IIT Kanpur; and we will also have another instructor, Professor Sudhanshu Shekhar Singh. So, before we begin the contents, let us briefly go through what this course is all about. So, let me share the course details that are there available on the course website.

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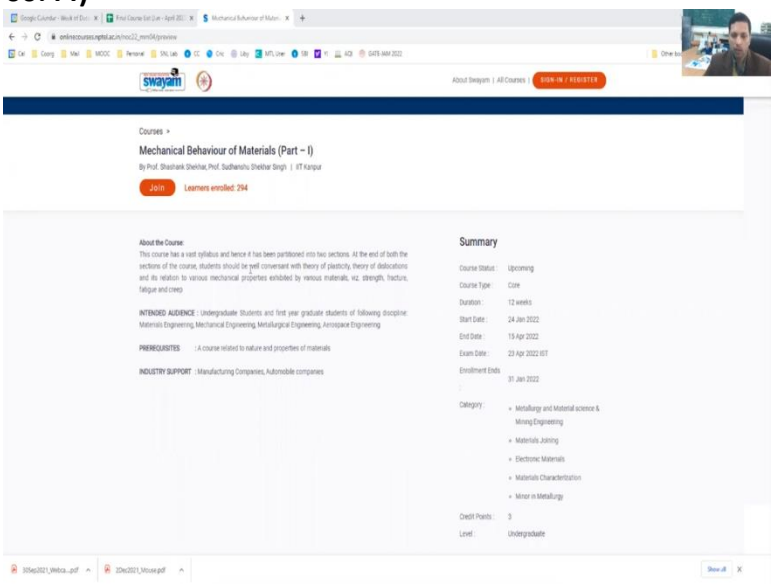

So, here are the course details that has been given on the SWAYAM or the NPTEL platform. Now, when we say mechanical behaviour of materials, you would realise that it is a very vast course. We are talking about mechanical characteristics or the mechanical response of materials. And materials are not just one type of material, there are several types of materials. There is metals and alloys; there are ceramics; there are polymers; and then nowadays we also have composites, which is actually a mixture of one of these primary materials.

So, the overall response or the characteristics that we understand and we relate with the structure of the materials is very different and it is related to their structure, like I just mentioned. And therefore, this course becomes really vast. And even in the mechanical characteristics, the first thing that comes to our mind is tensile behaviour, compressive behaviour, but mechanical properties are a lot more than that.

It is about the tensile and compressive behaviour; it is about the fatigue fracture behaviour; failure behaviour; then there is also creep phenomena; and then there are three-point bending, impact test and so on, so forth. So, there is a wide array of tests and characteristics that needs to be understood, and our aim is to be able to find out the commonality or the fundamental principles that govern this behaviour.

And this will obviously be different for different classes of materials. So, this makes the course very huge. And with this understanding, the overall course has been divided into two sections. So, the next one is the part 2, which is of 12 weeks, and then there will be a follow up which will be of 8 weeks. So, overall this is a 20-week course, mechanical behaviour of materials.

If you were at one of the IITs or in fact any of the engineering institutes, most likely this would be a full-fledged course, meaning a 40-hour course; but since it is a distant learning module or distant learning platform, so, all the contents can be very easily compressed into 20 weeks as you will see. Who are the intended audience? Meaning, are you the right person to take this course?

Any undergraduate student or first year graduate students from the discipline of materials engineering, mechanical engineering, metallurgical engineering and aerospace engineering would find this course to be very helpful and meaningful, because most of you are dealing with different types of materials and you would be putting the materials under different kind of loading condition; in fact, I should have also mentioned civil engineering.

And whenever you put a material under a different kind of a loading condition, then you want to understand how the material will deform, when the material will deform, what kind of shape it can be given, and you would be able to understand and appreciate only after going through the contents of this course. Now, when we are going through this course, you would need that we need certain amount of fundamental understanding of certain topics.

What are those topics? Something related to nature and properties of materials. So, like I said, when we say materials, it is a vast classification of materials itself, which means you have metals and alloys, ceramics, polymers and composites. Now, what are their characteristics? What are their structure? Those things we will not be able to cover in this particular course.

We will be able to cover only their mechanical behaviour, mechanical characteristics. But what is their structure? We may briefly recollect or bring back those important concepts, but those details cannot be covered in this course. And hence, it is good if you have gone through a course like nature and properties of materials. Which industries would find this course to be meaningful?

Then, for that, you must realise that this course would be useful for various types of manufacturing companies, and that is a very large class of industries; even automobile companies come in that; even aerospace industries come into that. Everywhere you are basically manufacturing some material. So, you are applying stresses, which causes deformation and hence the material gets the shape.

And how much stresses to apply? What will be the overall final shape? What will be the defects? And why the defects arise? There will be interaction between strain, strain between temperature, which will give the or determine the final properties of the materials. And hence, any manufacturing industry would need or anyone working in these industries would need an understanding of this course.

So, we have classified this course type as core. And the duration is given as 12 weeks as it is shown over here. Start date is twenty-fourth January and it ends on fifteenth April, and the exam will be held on twenty-third April. So, the category, it will be useful, like I mentioned for Metallurgy and Material Science and Mining Engineering, Materials Joining, Electronic Materials.

Even people working in Electronic Materials would see that there are stresses and strain and because of that the semiconductor or any of the components may break; and therefore, they need a good understanding of the mechanical behaviour of the materials. So, even Electronic Materials people would find this course to be meaningful. Materials Characterization and in even doing Minor in Metallurgy would also find it useful.

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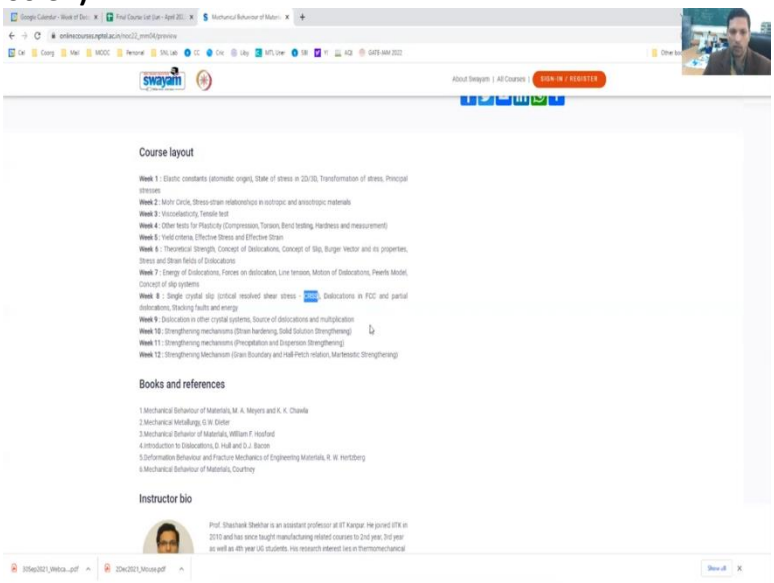

So, what are the overall course contents? This is briefly what we have laid out in the contents and according to the weeks. So, we would be dealing with elastic properties of the materials, like elastic constants, what are the atomistic origin. And then we will understand the state of stress in 2D and 3D; transformation of stress; principal stresses. And in this context, we will also introduce the idea of Mohr circle, which is very useful in understanding stresses; then stress-strain relation in isotropic and anisotropic materials.

Then we will also talk about viscoelasticity, which is a time dependent elastic properties. And then finally, we move on to the first plastic behaviour, which is the tensile characteristics. And as you would see that tensile characteristics is; when you obtain a tensile characteristics of a material, you would be able to obtain a lot of very important information for the material

response and that is why tensile test is such a widespread and ubiquitous mechanical characterization technique.

You will see a UTM almost everywhere where there is under some kind of material testing going on. So, but this is not the only plastic deformation behaviour, the other tests or other behaviour where you need to understand are; other test for plasticity are compression, torsion, bend testing, hardness and measurement; but you would see that overall tensile properties give you some of the most important and fundamental information about the materials.

Then we will move on to the yield criteria. When do we say that material we yield? What is the effective stress? What is the effective strain? Because, you can apply deformation in more than one direction. In simple tensile characteristics, we know that this is the yield stress. But what about when you are doing the deformation such that the stresses are multidirectional? There are not only normal and compressive stresses but also shear stresses.

Then how do we know when would that material move on from elastic regime to plastic regime, which is called an effective stress? And that will be the yield stress in that multidimensional stress condition. So, the material shows some plastic behaviour. Now, what is the origin of that plastic behaviour? For that, we need to; and particularly when we are talking about metals and alloys, we need to understand the concept of dislocations.

And when we talk about dislocation, you would see that these happen on a particular plane which are called slip planes and the dislocations are associated with burger vector and there are certain characteristics of these dislocations. And these dislocations in itself are elastic in nature and they have stress and strain fields. So, the very fundamental element during this plastic deformation, which is dislocation is in itself guided by elastic properties.

Then we will also talk about energy of dislocations, forces on dislocations, line tension, motion of dislocations, Peierls model and concept of slip system. Then we will move on to describe the deformation in single crystal. So, in single crystal also you will have slips, you will have critical resolved shear stress and it will give you a very good understanding about when does the plastic deformation begin.

And once we have a good understanding of that single crystal, we will move on to the dislocations in about; not directly about the poly-crystal but about particular types of, you can say crystalline system. So, we will talk about dislocations in FCC; we will look at partial dislocation, stacking fault and energy. Then we will also look at dislocations in other crystal systems like BCC and HCP.

And then we will move on to understand when and how the dislocations get multiplied; what is their source? And once you understand, have a good understanding of dislocation, we will be able to appreciate why we apply some kind of strengthening mechanism. You would know that we apply some kind of rolling for straining of steel. We apply ageing, age hardness for aluminium alloys and that gives it a strength. So, what are the origin of this?

Why do this give it a strength? So, we will look at straining mechanism, strain hardening, solid solution straining. We will also look at precipitation and dispersion straining. And then we will also look at grain boundary and Hall-Petch relation when we are talking about grain refinement for straining; and we will also talk about martensitic straining. So, this is all what we plan to cover in this course.

And along with this, as we go along, we will also talk about the mechanical response in not only the metals and alloys, but also in say polymers or composites and so on. Now, what are the good books or the references from which we will be covering this. So, some of these important books which you would find present in almost all the institutes are listed here. So, books like Mechanical Behaviour of Materials by Meyers and Chawla; Mechanical Metallurgy by Dieter; Mechanical Behaviour of Materials by William Hosford.

This is one book that I particularly prefer. This is the book I would mostly refer to when we are going through this course. And when we are talking about dislocations, then this is the particular course that I like to follow; this is the Introduction to Dislocations by Hull and Bacon. Then there are also other books like Deformation Behaviour of Fracture Mechanics of Engineering Materials by Hertzberg; Mechanical Behaviour of Materials by Courtney.

And all these books are very informative and very classic. So, you can look at all these books and select which one is, works best for you, and accordingly you can follow that book. Whatever ideas and concepts we talk about, you would see that they are present and covered in all of these books.

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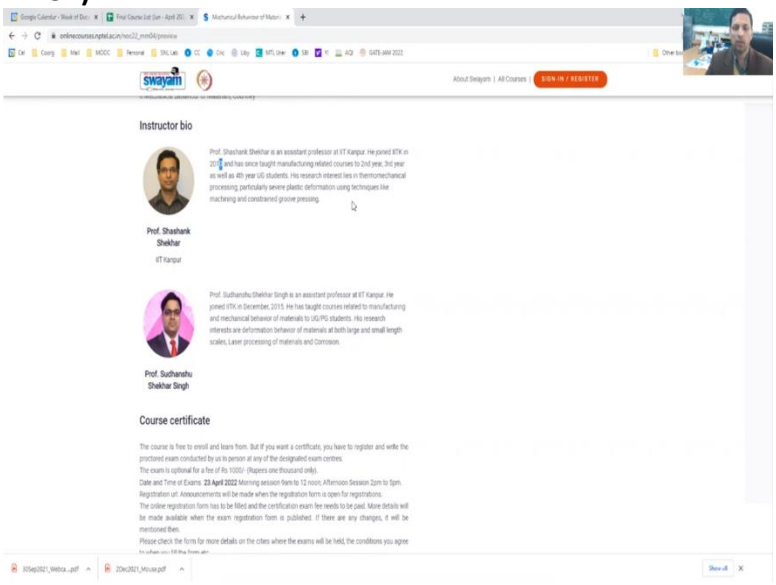

A little bit about the instructors, which would be myself. This is myself, Professor Shashank Shekhar from IIT Kanpur; and another one is Professor Sudhanshu Shekhar Singh who is also from IIT Kanpur. So, I have been in IIT; it should be 2011; since 2011. And right now I am an associate professor and I have taught this course in IIT Kanpur for several times. And even Professor

Sudhanshu Shekhar Singh has taught this course on Mechanical Behaviour of Material several times.

Other than that, I have also taught courses on manufacturing. So, my domain is physical mechanical metallurgy and Professor Sudhanshu Shekhar Singh also works on similar domain, physical mechanical metallurgy.

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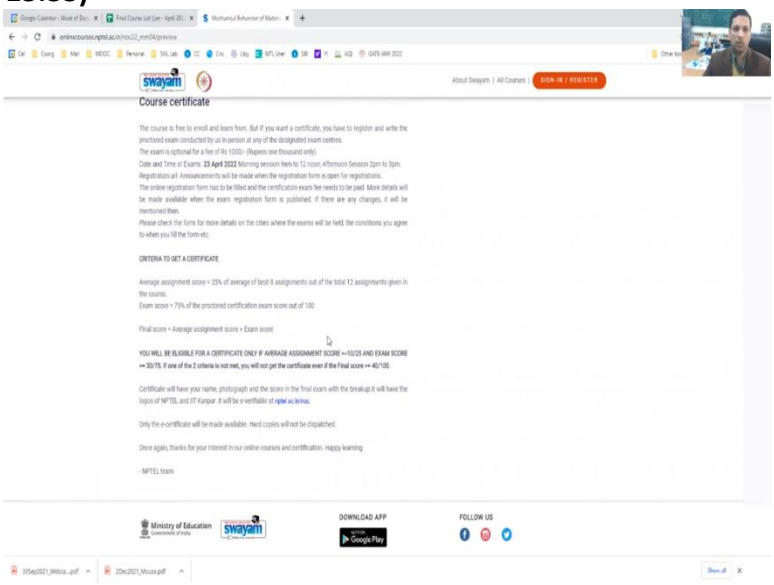

So, now coming to the course certificate. So, as long as you want to just learn, enrollment is completely free. Thanks to this platform, SWAYAM by Government of India. This course is free to enroll and learn from. However, if you want a certificate, then you have to pay a nominal fee which is currently only 1000 rupees. And the exam, you will have to complete an exam which will be held on twenty-third April 2022; in fact, it will be held in 2 sessions.

And in order to get a pass certificate; and in fact there are several levels, elite, gold, platinum and so on. So, in order to get any of these, the minimum requirement to get a pass certificate is that you have to pass 2 parts or 2 components, the assignments which will be given out weekly, then the exam which will be held on twenty-third April. And the weightage of the assignment is 25% and the exam weightage is 75%; and you will be evaluated out of the 8 best assignments out of the total.

So, since there are 12 weeks, so there will be 12 assignments and your 8 best assignments will be counted towards these 12; 25% weightage. For the 75%, which exam that will be conducted at the day of the exam, twenty-third April 2022. And your final score will be average score plus exam score. Now, for you to be eligible for a certificate, you have to score 40% in both the components; meaning 40% out of this 25 and 40% out of this 75, which means you must have greater than equal to 10 out of 25 in the assignment and 30 out of 75 in the exam.

If you do not meet one of this and it is very unlikely. See, if you follow the course regularly, you will be easily able to get 40% in both, the assignments as well as in the exam. However, if you are

not able to clear even one of these, then you will not be able to get a certificate. So, please keep in mind that you must get 40% in the assignment as well as in the exam; and 40% in the assignment means 10 out of 25; and 40% in the exam means 30 out of 75.

And the certificate will have your name, photograph and a score in the final exam with a breakup and only e-certificates will be given to you. So, this is the overall summary of the course that we will be going through and I sincerely hope that you get to learn in this course and there will be lot of learning in the course in terms of, like I said, the mechanical behaviour of materials; and we will be talking about metals, alloys, ceramics, polymers and composites as we go through.

And this again to remind you; this is the first part of the course which is 12 weeks and then there will be a follow up course which will be part 2, which will be an 8-week course, where we will mostly talk about fracture, fatigue and creep. So, with this we will end this introductory lecture. And when we get back, we will talk about elastic properties of materials.