Turbomachinery Aerodynamics

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Lecture No. # 01
Introduction to Turbo Machines
Syllabus References and Schedules

Hello and welcome to this lecture series on turbomachinery aerodynamics. Today's lecture is the first lecture of this forty-odd lecture series on turbomachinery aerodynamics, where we are going to cover various aspects of the aerodynamics associated with the different types of turbo machines like axial compressors, axial turbines, and centrifugal compressors, and radial turbines.

So, we will, of course, be discussing the details of the syllabus and the course contained in in this particular lecture series. My name is Pradeep and along with me Professor Baskar Roy; both of us are from the department of aerospace engineering I.I.T, Bombay. We shall be taking up this course, which we shall be covering in about 40 lectures or so.

So, in today's lecture, which is basically an introductory lecture, I shall take you through the syllabus, the course contents of this course as well as the text books or reference and additional reading material that we feel could be appropriate for this course. And subsequently, we will also quickly go through the lecture wise schedule of this particular course, where I shall explain what are the course contents that we shall be covering in each of the next term several lectures.

So, this course on turbomachinery aerodynamics is a course, which will basically be looking at the aerodynamics of the flows associated with turbo machines, the various types of turbo machines and the theory behind working of these different types of turbo machines. So, as I mentioned, there are two of us who will be handling this course, Professor Bhaskar Roy and me - Pradeep - both of us from the Aerospace Engineering Department I.I.T.,Bombay. And this course is basically a video course, were we shall be taking up all the lecture contents through video lectures, and also of course, the the transcript of the lecture material also would be available on the NP-TEL website.

So, in this particular course on turbomachinery aerodynamics, as I mentioned, we shall be covering different aspects associated with the aerodynamics of many of the components, which constitute let us say an aircraft engine. For example, there are different components, which continental aircraft engine. Two of the most important components are the compressors and the turbines. These are the basic turbo machines, which constitute a gas turbine engine. Similarly, of course, turbo machines can be found in various other applications and the main intent of this particular course is to introduce the various concepts, the working principle and the theory behind many of these turbo machinery components. And so, let us take a very quick look at, what are the different topics that we going to cover in this lecture series.

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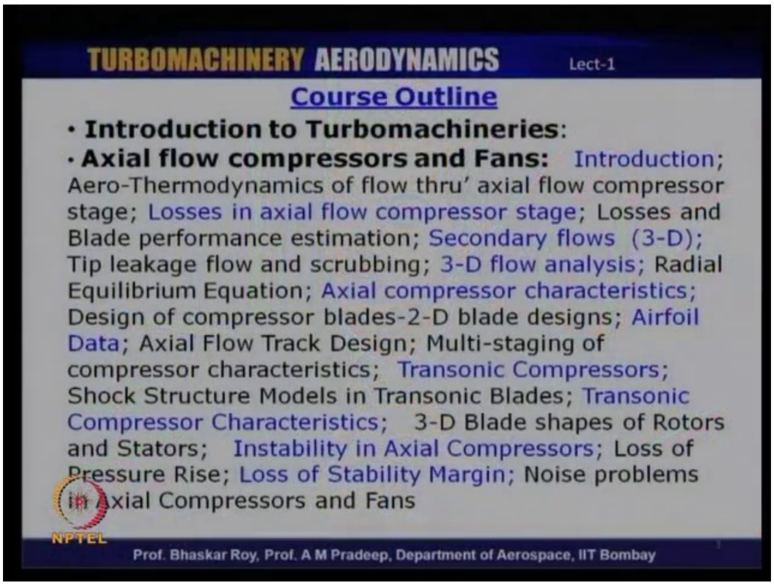

So, the course outline is what I will be discussing in the next few slides. We will, of course, begin the lecture series with an introduction to turbo machines, which we will start in this second half of those lectures, which Professor Roy will be covering. He will begin the introduction to various aspects of turbo machines in this lecture itself. So, subsequently we will start our course with discussion, a detail discussion on axial flow compressors and fans. We will be discussing, the Aero-Thermodynamics of flow through axial flow compressors.

We will also be discussing in detail, the losses associated with axial flow compressors stage. And once we have looked at the different losses and which constitute an axial flow compressor, we will also look at how we can estimate these losses and how these losses affect the performance of an axial flow compressor stage.

And then the different aspects of the three-dimensional flow, which constitute an axial flow compressor stage like secondary flows, the tip leakage flow and the flow scrubbing, which are basically some of the laws generating mechanisms, which are constituents of an, which are inherent part of an axial flow compressor machine. We will also be carrying out certain amount of 3-D flow analysis, the radial equilibrium and the associated equation, which constitute the 3-D flow analysis of an axial flow compressor stage. We will be spending quite some time in understanding the compressor characteristic, we will be looking at the axial flow compressor, the single stage as well as the multi stage characteristics of an axial flow compressor.

This is very important, because the way in which the compressor performance is expressed is basically through the compressor characteristics and it is a very important ingredient, which is required by an aircraft engine designer to understand the compressor characteristic carefully.

We shall be also looking at the certain fundamental aspects of compressor blade design. We will begin with 2-D blade designs and Airfoil Data will subsequently take up, the axial flow track design and also the characteristics as I just mentioned. Now, most of the modern day compressors, in fact many of the modern day compressors are not necessarily low speed, there are essentially at transonic compressor.

So, we it is also important that we understand the working principle, behind transonic the high speed compressor or the transonic compressor stages. So, we will spend some time in understanding aerodynamics of the transonic compressor stages. We will also look at the shock structure associated with a transonic compressor blade and also the characteristics of a transonic compressor.

We will then move on to the 3-D blade design of rotors and stators, because the aspect of related to the airfoil data and and all those things are basically limited to two-dimensional blades, but most of the modern blades are three-dimensional in nature. So, we will also look at the 3-D blade design of both rotors as well as stators. We will then spend a substantial amount of time in discussing about the instabilities of axial compressors, where different instability mechanisms of axial flow compressors and it is necessary that we understand these instabilities in detail, so, us to enable us to design an axial compressor, which is more efficient.

So, we will look at the instabilities and the laws of stability margin, and the associated problems with laws of stability margin, in axial compressors. We will also spend time in understanding, the noise problems associated with axial flow compressors and fans. Because modern day engines are required to have or to limit noise to certain levels, which are very stringent, then getting stricter every year or so, and it is necessary and most of this the major junk of this noise is originating from the axial fan and the compressor.

So, it is necessary that we understand, the noise generating mechanism of these axial flow compressors. Now, once we have understood and covered the axial flow compressors in detail; we shall then now look at another component, which is also an axial flow component, but it is a turbine.

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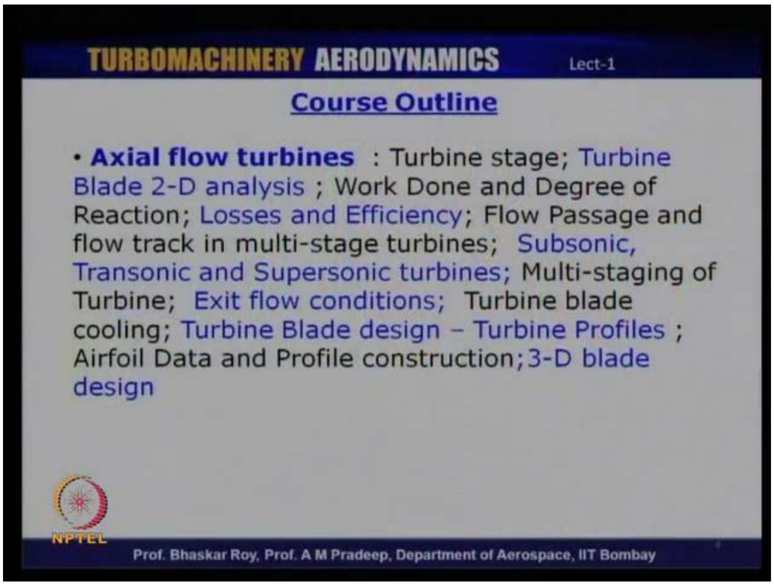

So, we will also look at the design and the performance characteristics of Axial flow turbines. So, that would be the second module of this particular course of Axial flow turbines. We shall understand, what constitutes a turbine stage and the turbine 2-D analysis will look at Work Done and Degree of Reaction in detail, and then we will understand, the laws mechanism losses and the efficiencies of an axial flow turbine. We look at the flow passage and the flow track in multistage turbines, same way as we have done for axial compressors. Will then look at, the three different types of or classes of turbines: the subsonic, the transonic and the supersonic turbines.

And in terms of characteristics, how we can understand and analyze the performance of axial turbines, in a very similar manner as we carried out for axial compressors. So, we will look at multi-staging of axial turbines, the exit flow conditions and very important aspect of turbine flow is the turbine blade cooling. So, we will spend some time in understanding the various mechanisms, which are used for a cooling of turbine blades, because as we know that a higher turbine inlet temperature is always desired for better efficiency and thrust of an aircraft engine for example.

But it is the material that limits very high temperatures from being used in axial in in turbines in general. So, one of the ways or methods of extending or enabling higher turbine inlet temperature is to use certain cooling mechanisms, and so, it is necessary that we understand, the various types of turbine blade cooling mechanisms, which are used.

We will then spend some time on understanding turbine blade design, and we will start with airfoil design, and it is profile construction and so on. And then, we will extend that theory to 3-D blade design, the same way, which we carried out for the axial flow compressors. So, this would complete the second module of this course, which is an axial turbines. So, once we have covered the axial compressor and the axial turbines, we will then move on move towards, the other components, the other counter part of these the the centrifugal compressors and the radial turbines.

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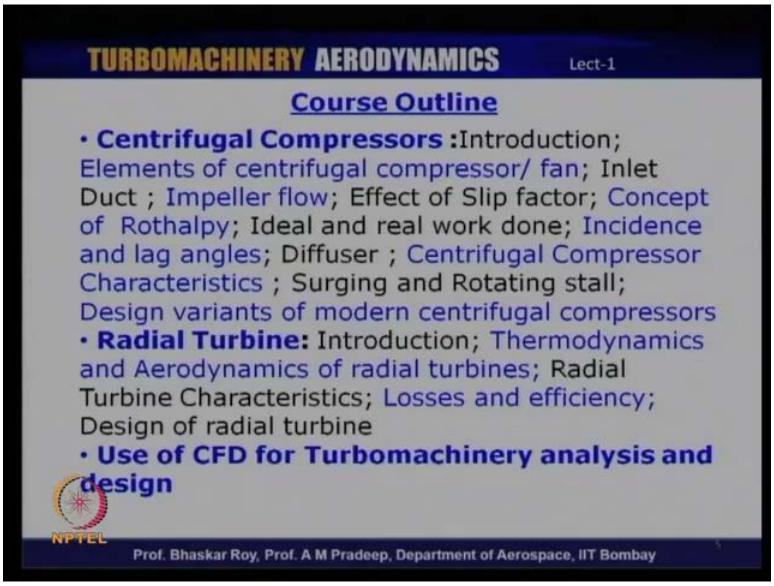

So, the third module that we are going to cover in this course is on Centrifugal Compressors. So, in Centrifugal Compressors, we will start with some fundamentals of centrifugal compressors and we will basically be talking about the different components of centrifugal compressors; the Inlet Duct, the Impeller and of course the inducer and related components. We will then understand, what is meant by Slip factor and its effect on the performance. We will be discussing about the Concept of Rothalpy and the Ideal and real work done. We will also spend some time discussing about the incidents and the lag angles, and the different types of diffusers, which are used in centrifugal compressors.

And subsequently, we will spend time discussing about the centrifugal compressors characteristics, and we will be talking about the serge margin, which is an important performance characteristics characteristic associated with centrifugal compressors. We will then be discussing about serge and rotating stall in detail, which we also covered in terms of the instability mechanisms in axial compressors. We will also be discussing about the similar instability mechanisms, which affect a centrifugal compressor and then we will also discuss about the different variants of centrifugal compressors of modern day centrifugal compressors. So, this would complete the third module of this course, which was on centrifugal compressors.

And the fourth module is on radial turbine. So, we will begin with some introduction to radial turbine. Then, we will also talk about the Thermodynamics and Aerodynamics of radial turbines and of course, the Radial Turbine Characteristics; Losses and efficiency; and Design of radial turbine. So, radial turbine as you can see will also complete some elementary aspects of radial turbine.

But, we would probably not be spending too much time on radial turbine, as compared let say axial turbine. Primarily, because of the fact that we would be dealing with axial turbines more commonly than radial turbines; and towards the end of this course, we will also spend may be a lecture of two on discussion of on the use of computational fluid dynamics in turbomachinery design and analysis. So, this is a computational fluid dynamics or CFD is increasingly being popularly used in design, as well as in analysis of turbomachines, and the computational tools are getting better day by day, in terms of their accuracy and ability to accurately predict the complex three-dimensional flow in turbo machine. So, we will discuss some of the aspects associated with the use of CFD in modern day turbomachine design and analysis.

So, these are some of the topics or the modules that we shall we covering in this course on turbomachinery aerodynamics. As you can see the discussion is purely on aerodynamics of these components, we shall not really be discussing the mechanical design aspects of turbomachines. So, that is purely out of scope of this particular course, which is also evident from the title of the course, which is turbo machinery aerodynamics. So, we will only be discussing about the aerodynamic aspects of design, as well as analysis of these components, and the mechanical aspects of design will not really be covered in this course.

So, before we move further, it is necessary that also mention that the that there is a certain Pre-requisite required for those of you, who plan to take the take up this course, because it is dealing with aerodynamics of turbo machines.

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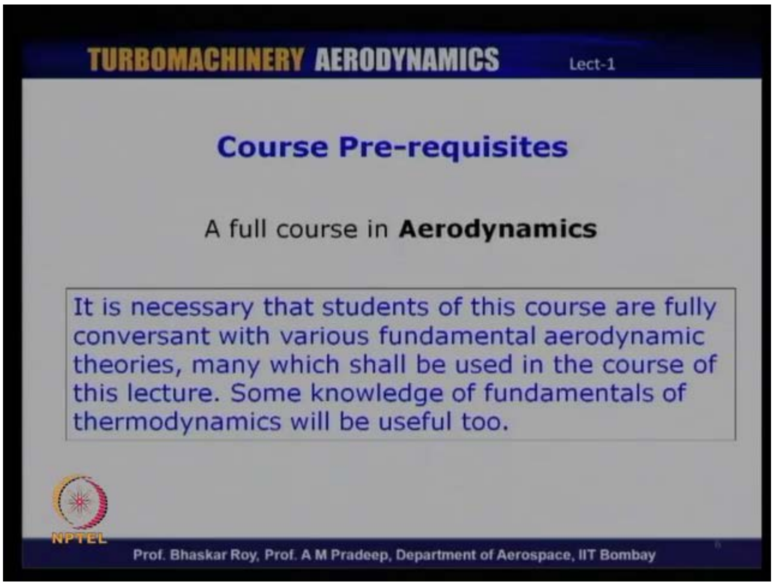

It is necessary that one should have undergone a full course in aerodynamics, before attempting to take up this course. So, the Pre-requisites for this course is essentially a full course in Aerodynamics, and therefore, it is expected that students would be conversant with the various fundamental aerodynamic theories, many obviously or directly used in this course. And it is also desirable that you have undergone some course in the fundamentals of thermodynamics, because that also would be part of many of the discussions that we are going to take up in this particular course.

So, we will be assume that you have already undergone a course in aerodynamics, and you also have some fundamental understanding of thermodynamics, because these are going to be used very frequently throughout this course. Now, let us now take a look at what are the text books that we recommend, that you read while taking up this course, you will also suggest some additional reading material, which you can take up as in when you required the need for that.

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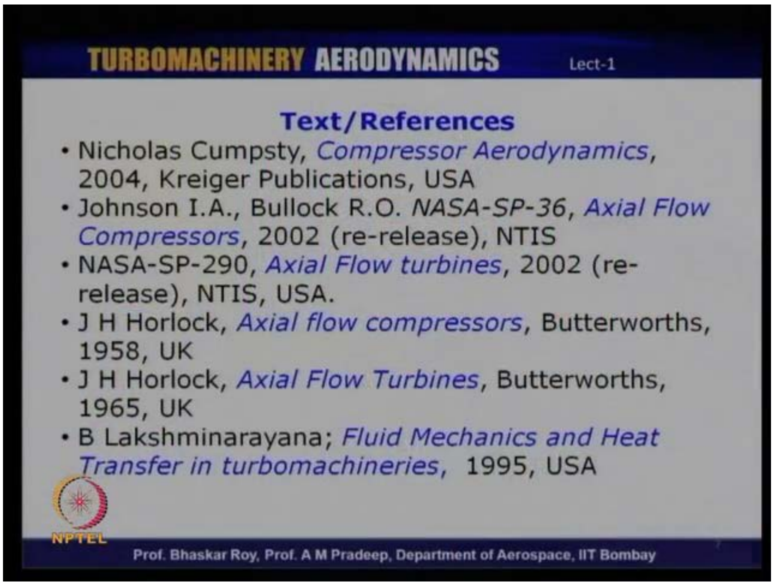

So, Text book and References, because we will begin with compressor. The different types of compressors, one of the very fundamental text books, which deal with Compressor Aerodynamics in great detail is by Nicholas Cumpsty, on Compressor Aerodynamics published in the year 2004 by Kreiger Publications, USA, this another book on Axial Flow Compressor, which is basically kind of a report published by NASA, and it is by Johnson I.A., and Bullock. The report number is NASA-SP-36 on Axial Flow Compressors; this was released in the year 2002, and similarly for turbines we have a NASA report NASA-SP-290 on axial flow turbines; this was also released in the year 2002. There are two classical text books, if I am I call this on turbo machines Axial Flow Compressors by J H Horlock, this was published as you can see way back in 1958, but it is still considered as a very good book dealing with the fundamental aerodynamics of compressors.

Another book which was published by the same author by J H Horlock is on axial flow turbines, published in the year 1965. A text book, which deals with both the aspects of Fluid Mechanics, as well as the Heat Transfer in turbomachineries was published in the year 1995 by B Lakshminarayana, and this is also considered as a very good text book, which can give you a great in depth analyses of many of the fundamentals of turbo machines in terms of both the aerodynamics as well as the heat transfer, and also this book will also give you some idea about, how to use computational fluid dynamics or numerical techniques, how they can be used in analysis design an analysis of turbo machines.

So, Lakshminarayana's book is also highly recommended in terms of not only as a text book for covering fundamental aspects of aerodynamics of flow, as well as heat transferred, but also for understanding of the use of numerical techniques in design and analysis of turbo machines. So, these are some of their fundamental text books that we would recommend that you should try and read as you undergo this course.

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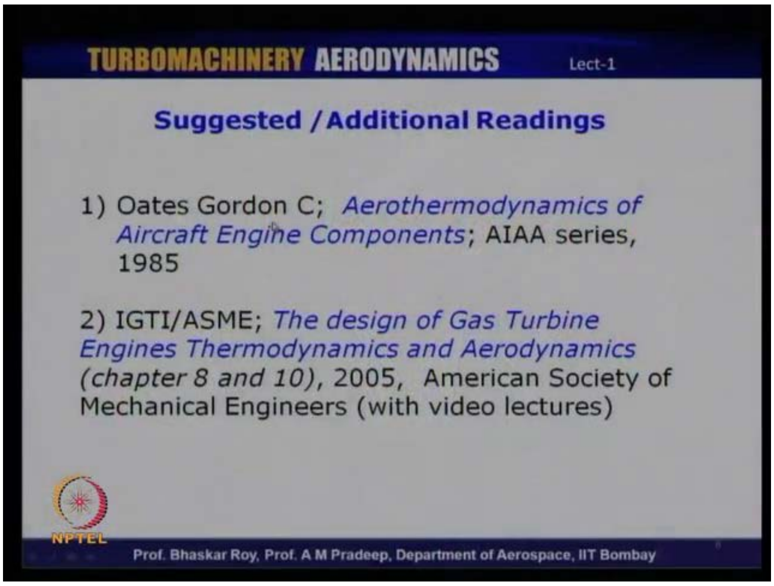

Besides, this there are a few additional text books that we might suggest two of them are listed here. One of the books is by Gordon Oates; it is on Aerothermodynamics of Aircraft Engine Components and it is AIAA series publication; which was published, in the year 1985. Another series of, another text book on aerodynamics of gas turbine engines was published by the international gas turbine institute, which is affiliated to the American Society of Mechanical Engineers (ASME). The design of Gas Turbine Engine Thermodynamics and Aerodynamics, basically chapters 8 and 10, which are of interest to us; this was published in the year 2005 by ASME and of it also comes with few video lectures, on covering various aspects of these courses.

So, we recommend and suggest that some of these text books, obviously are would be of great interest to you can also go through some of the advance text books, specially by Lakshminarayana of some of these additional text books that we have suggested would be of interest to you as you as undergo this course. So, you may want to go through these courses, these text books as you undergo this course and various chapter of this particular course.

So, what I am going to do now is to take you through the lecture wise schedule of this course and what is it that we shall be covering in each of these of lectures, during this entire lectures series.

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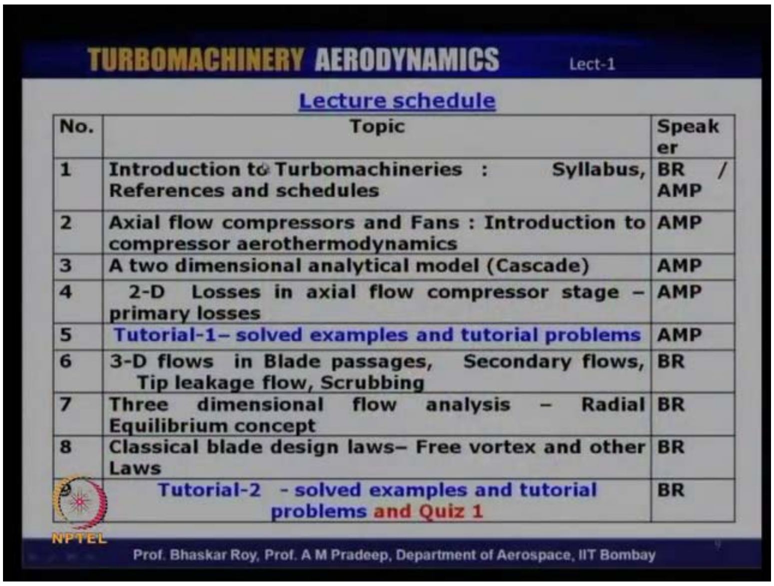

So, let me go through the lecture schedule, we will start with lecture number 1, which is basically today's lecture, primarily to do with introduction: Syllabus, References and this schedule. So, I am as I mention professor Roy is going to take up some of the fundamental and introduction to turbomachineries.

The second lecture is on is where we will start with the Axial flow compressors and Fans. The first of that lecture would be on Introduction to compressor aerothermodynamics, which will be covered by me. The third lecture would be on the two-dimensional analysis of axial flow compressors and fan basically the cascade aerodynamics, which will also be covered by me. Next lecture would be on the loss estimation, 2-D Losses in axial flow compressor stage - the primary losses and what are the loss mechanisms, which will again be covered by me.

So, the next lecture we shall be taking up a tutorial, we will solve certain examples, and also I shall give you some tutorial problems, which you can solve later on. The next lecture would be to do with the three- dimensional flows. We deal with 3-D flow in Blade passages, Secondary flows and Tip leakages, blade Scrubbing and so on.

So, Professor Roy is going to take up this course of this particular lecture. The next lecture, lecture number 7 would be 3-D flow analysis-the Radial Equilibrium concept, which will be covered by Professor Roy, and then we will take up the Classical blade design laws-the free vortex and other Laws, which are used in design of axial flow machines; professor Roy is going to again take up this particular lecture. So, end of this the next lecture, lecture number 9 would be devoted to a tutorial. The second tutorial of this course solid examples and tutorial problems, and we will also have a quiz, during this particular lecture that would be lecture number 9.

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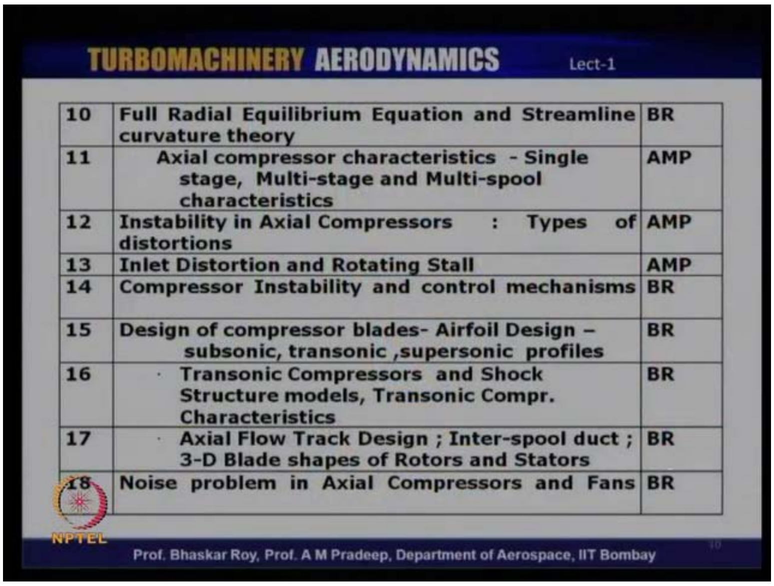

10	Full Radial Equilibrium Equation and Streamline curvature theory	BR
11	Axial compressor characteristics - Single stage, Multi-stage and Multi-spool characteristics	AMP
12	Instability in Axial Compressors : Types of distortions	AMP
13	Inlet Distortion and Rotating Stall	AMP
14	Compressor Instability and control mechanisms	BR
15	Design of compressor blades- Airfoil Design – subsonic, transonic ,supersonic profiles	BR
16	Transonic Compressors and Shock Structure models, Transonic Compr. Characteristics	BR
17	Axial Flow Track Design ; Inter-spool duct ; 3-D Blade shapes of Rotors and Stators	BR
18	Noise problem in Axial Compressors and Fans	BR

And then on lecture 10, we have the radial equilibrium equation, the full radial equilibrium equation and the streamline curvature theory, which will be covered by Professor Roy. Lecture 11, which I shall be handling would be on axial compressor characteristics-Single stage as well as multi-stage and multi-spool characteristics. So, basically lecture 11 is on compressor characteristics of both single as well as multi-stage types.

Lecture 12 will be on Instability in Axial Compressors and whatever the different types of distortions, which can effect and compressor performances. Lecture 13 would be the discussion on Inlet Distortion and Rotating Stall and what is the effect of distortion on Rotating Stall. Lecture 14, which will be covered by Professor Roy would on Compressors Instability and control mechanisms. Lecture 15 would be Design of compressor blades, starting with Airfoil Design and then we also be covering subsonic, transonic and supersonic profiles, because a blades as you will see would be quite different as it goes it from subsonic to supersonic.

Lecture number 16 is on Transonic Compressors and Shock Structure models and also some characteristics of transonic compressors. Lecture 17 would be Axial Flow Track Design; Inter-spool duct; 3-D Blade shapes of Rotors as well as Stators. Lecture 18 will devote to Noise problem in Axial Compressors and Fan. The origin of noise and what is it that probably could be done prevent or control the levels of noise.

And then after we have covered the axial compressor in detail, we will move onto the axial flow turbines, as we have discuss during the syllabus. The second module is the turbine, axial flow turbine.

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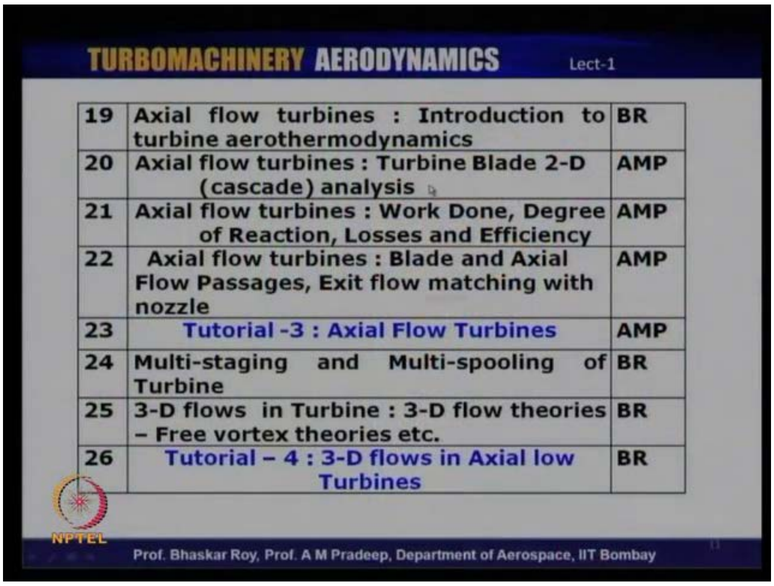

Axial flow turbine: the Introduction to turbine aerothermodynamics will be covered by Professor Roy and the 2-D analysis of turbine blades, the cascade analysis of axial flow turbines to be covered by me. And then lecture number 21 would be axial turbines, the the Work Done, Degree of Reaction, Losses and Efficiency. Subsequently, we will take up axial flow turbine in terms of the Blade and the Axial Flow Passages and the Exit flow matching with the nozzle.

Lecture 23 would be a quiz, a well a tutorial on axial flow turbines, which again will be covered by me. Lecture number 24 would be Multi-staging and Multi-spooling of axial turbines, to be covered by Professor Roy. Lecture 25 is 3-D flow in axial turbines: the 3-D flow theories-the Free vortex theories etcetera and Lecture 26 would be the forth tutorial, which would cover the 3-D flows in Axial low Turbines.

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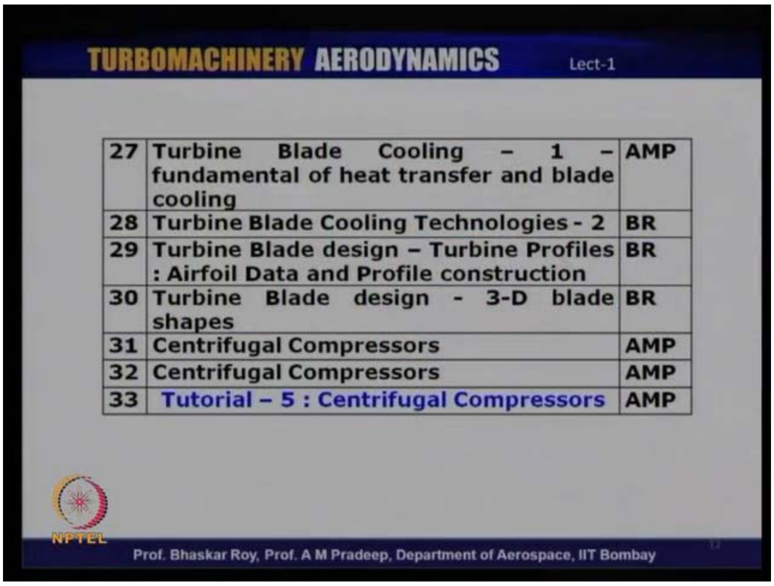

And then we will spend some time in understanding the cooling or the effect of blade cooling on performances. We will understand, what are different types of blade cooling techniques? The fundamentals of heat transfer and blade cooling and which will continue on the next lecture, that is lecture 28, we will continue with Blade Cooling Technologies.

Lecture number 29 is Turbine Blade Design - Turbine Profiles: Airfoil Data, profile construction etcetera, which will be covered by Professor Roy. Lecture 30 is Turbine Blade Design - 3-D blade shapes. And then from lecture 31 to 32, we shall be taking up centrifugal compressors in detail. Lecture number 33 is the fifth tutorial, which will be on centrifugal compressor, which again I shall be covering.

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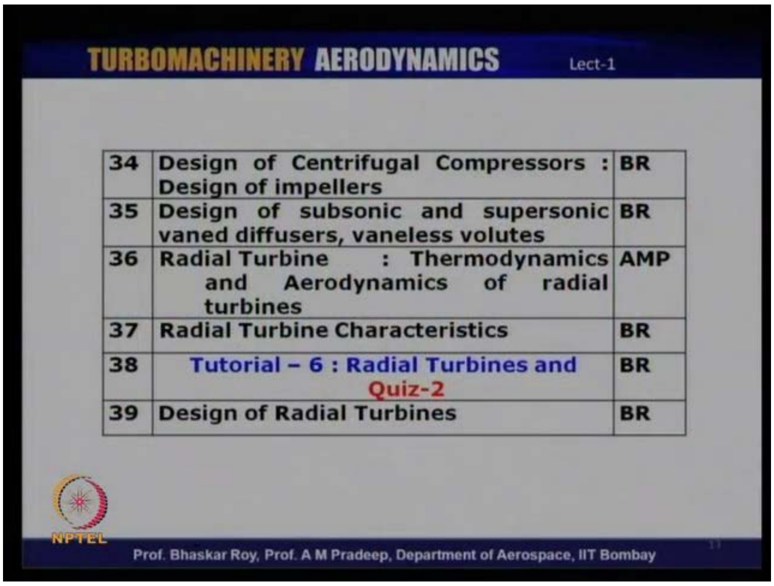

We shall also have some lectures devoted towards to Design of Centrifugal Compressors: the impeller Design. And lecture 35, we will take up the other components of Centrifugal Compressors, the subsonic and supersonic, vaned diffusers, vaneless volutes etcetera. Radial turbine, we shall start in lecture number 36, Thermodynamics and Aerodynamics of radial turbines followed by radial turbine characteristics in lecture 37. Lecture 38 is the sixth tutorial on radial turbines as well as a Quiz. Lecture 39 is on design of radial turbines.

And the next few lectures, as I mentioned, we also spend some time to look at the use of a computational tools, numerical techniques in the design and rancidez of axial flow well turbo machines. So, we will spend a few lectures on understanding, the basics of the numerical tools.

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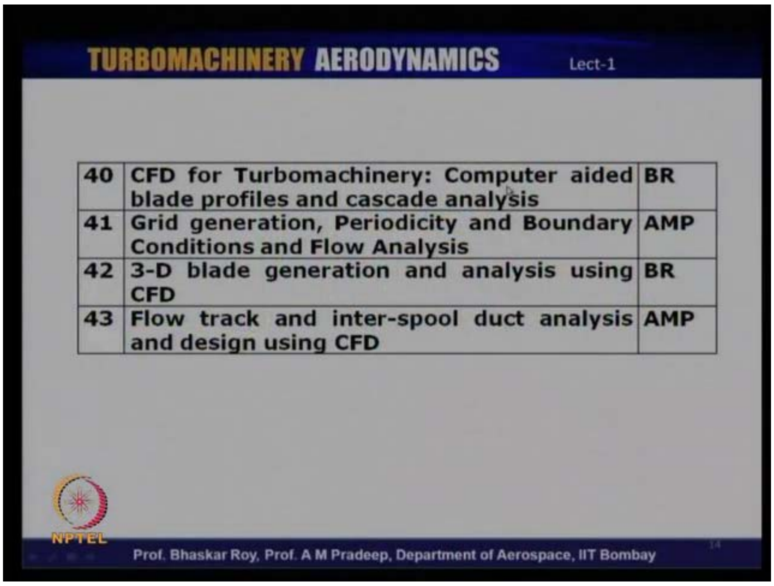

So, we will start with use of CFD for turbomachinery is basically Computer aided blade profiles and cascade analysis. We will then look at in lecture 41 Grid generation, Periodicity and Boundary Conditions as well as the Flow Analysis. Lecture 42 would be 3-D blade generation and analysis using CFD. And the last lecture of those lecture series would be the Flow Track and inter-spool duct analysis and design using CFD.

So, as you see the last few lectures, we have specifically set aside to introduce the concept of the, use of the numerical techniques in turbomachinery design and analysis. Because this is coming increasingly important in modern day, design of turbo machines. So, as you have seen about 43 are lectures in this lecture series, during which we shall be covering the fundamental aspects of the aerodynamic and of turbomachines. The different types of turbo machines, starting with axial flow compressors and fans, axial flow turbines, the centrifugal compressors and the radial turbines.

So, these the lecture wise schedule is what I had discussed in the last a few minutes and in next part of this today's lecture, which is going to be taken up by Professor Roy.

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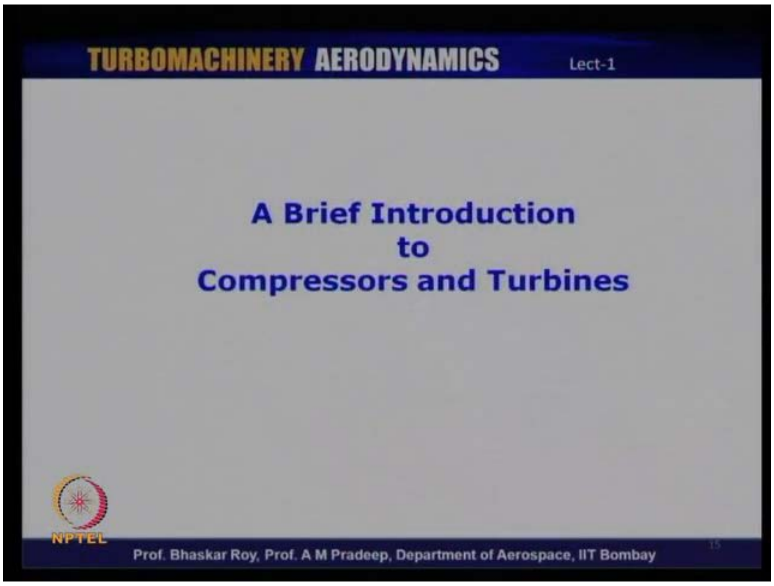

He shall give, an introduction, A Brief Introduction to the different concepts of the the types of Compressors and Turbine, basically, an introduction to this whole course itself. So, this second half of this lecture is going to be taken up by Professor Roy.

You are just been given a full details by Professor Pradeep, about the course content and the course coverage and all the details about how the course is going to be taken through the various lectures over this lecture series. He is also given you details about some of the books, very good books that you may have to acquire or you may have to ask your college library to acquire, because most of these books are published to abroad and hence you may have to take a little trouble to acquire those books, but those books are indeed a very useful for this course.

So, if you or your college library can part these books, it will be really useful book addition to this course coverage. What I will do is, I will look at the basic elements that we are going to cover over this lecture series. I am trying to give you, a very brief sketch or what these elements are as for accept (Audio Not Clear). We will be looking at Compressors and Turbines, as essentially that are turbomachinery elements in this course. One may think of other turbo machineries like winter binds, but they those are not part of this course. We are looking at the elements that he is talked about, essentially the elements that are part of aircraft propulsion system or aircraft engines.

So, those are they elements that we would be looking at more closely an in in great detail in this a lecture series. So, i will we quickly look at these elements of the compressors and the turbines, to give you a very quick idea about, what we are really up to in this course. The first question is why do you need compressors and turbines in an aircraft engine or in an engine that produces thrust for aircraft to fly?

Now, this is the question that actually is answered, a little more precisely with a little help from thermodynamics. So, we will have a very quick peek at, what the thermodynamics indeed give us to begin with from which we have taken off to create these complex machineries called compressors and turbines. So, if you look at where the engine is come from understanding that an aircraft engine is fundamentally, a heat engine and this heat engine finally helps us produces thrust.

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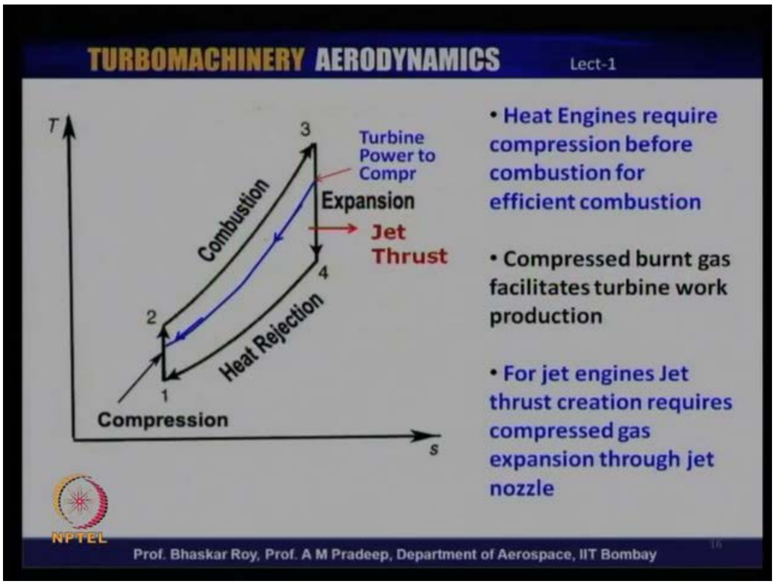

So, let us take a look at the basis of this heat engine, very quickly. If you look at this diagram is basically a temperature entropy diagram or a TS diagram. As it is popularly known and this TS diagram essentially encapsulates or captures, what is happening in an engine. Artificially in an engine, the flow goes through a process of a compression from 1 to 2 and then it goes through a processor combustion in which energy is a put inside the engine by burning of the fuel and having put in this energy; this energy highly energized flow is then used in an expansion process partly to run a turbine, which in turn is essentially runs the compressor, and then partly to take out the flow through the nozzle or a jet nozzle to create jet thrust.

Now, the question is what are the compressors and then the turbines indeed doing here? If you look at this diagram, you will see that if you have a compression. The thermodynamic diagram indeed goes from 1 to 2 and then it goes in the combustion from 2 to 3. The question is; if you do not have compression, what will happen is to reach that temperature 3, for example, you have to start your combustion process at one, and then go all the way along this and reach that temperature 3 along that path.

Now, that path as you can very imagine now is going to be a very long path of a burning of a fuel and the burning of fuel would then be done at a low pressure and not at a high pressure. So, the path of combustion would then be extremely large. To reach that same temperature levels from which you can hopefully do some amount of expansion. The point is for good combustion, you need to have a good compression.

Without a good compression, the combustion process of in and that being a very inefficient process. So, for combustion or for a good combustion, you do need a certain amount of compression to accomplished, before the flow is taken through the combustion chamber. Now, once the flow is taken through the combustion chamber, you have high energy gas. You have compressed gas and you have high temperature gas, which is then fed into the expansion system.

Now, the first expansion system as you see here is actually the turbine. Now, this turbine essentially is an expander indeed, and we will be covering turbine in grid detail in this course. This produces work or as it written here, the Compressed burned gas essentially facilitates turbine work production. Turbine is the work producer or work work exactor from the high energy gas and this work essentially extracted produced to run the compressor. So, the entire work produced here, in typical aircraft engine is transferred to the compressors, which then thus a compressor job to take the flow to high pressure.

So, turbine and compressor essentially are coupled and they work in a loop hoses certain amount of energy then actually is fed into the gas or into the air through the compressor and it is taken out through the turbine. So, that amount of energy is essentially going into this energy loop, which is between the turbine and the compressor, it goes to the combustion chamber again comes back to the turbine into the compressor and then remainder of the energy is fed into the jet nozzle to create the Jet Thrust.

So, you do need compressor to take the flow to high pressure, which facilitates the work of the turbine, and then it secondly facilitates the work of the jet nozzle for creation of thrust. So, compressor is a very important part of an aircraft engine, for most of the aircraft engine that we know of and as a result of which it has become integral part of aircraft propulsion system, right from the beginning of flying. Now, let us take a quick look at what an aircraft engine, a modern aircraft engine, typically would look like consisting of compressors, combustion chambers and turbines.

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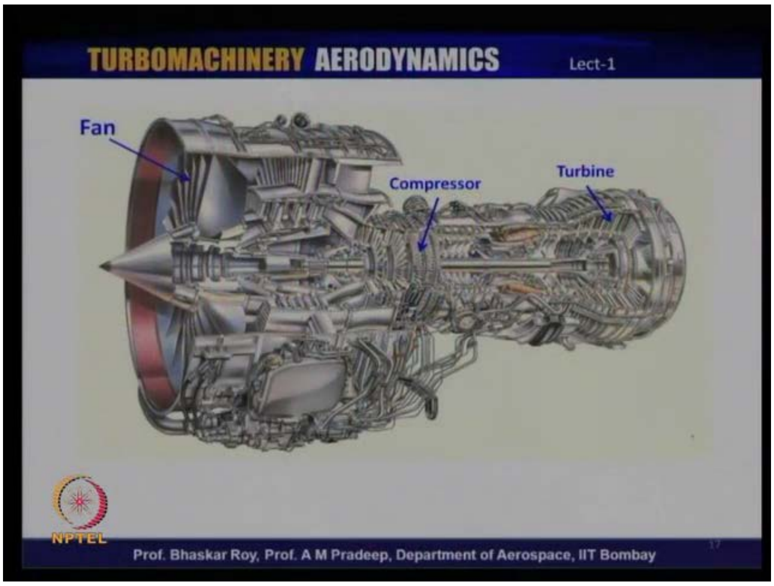

Now, if you look at this engine, you would see, there are so many parts, we would be dealing essentially with Fans, Compressors. So, the flow goes through these fans and then goes through these ducting system then into the compressors, and then through large amount of compression, through let us say various compressors stages and those various stages would be introduced to you and then fed into the combustion chamber, and finally the flow goes from the combustion chamber into the turbine, which extracts the work and through the shaft system runs the compressor. We will be talking about the multi - shaft system or multi - spool system by which various groups of turbines run, various groups of compressors or fans. So, those things would be introduced to you in the process of this lecture series. What we have here is very complex machinery of compressors, fans on one hand and turbines on the other hand, on calling these machineries, because these are fundamentally aerodynamic machines. These aerodynamic machines are essentially used inside their craft engine for creation of thrust.

So, these are essentially aerodynamic machines, make a mistake about it they are indeed machines, that work that produce work, that absorb work and finally that helps in creation of thrust. Let us take a closer look at some of these components, which make up an aircraft engine.

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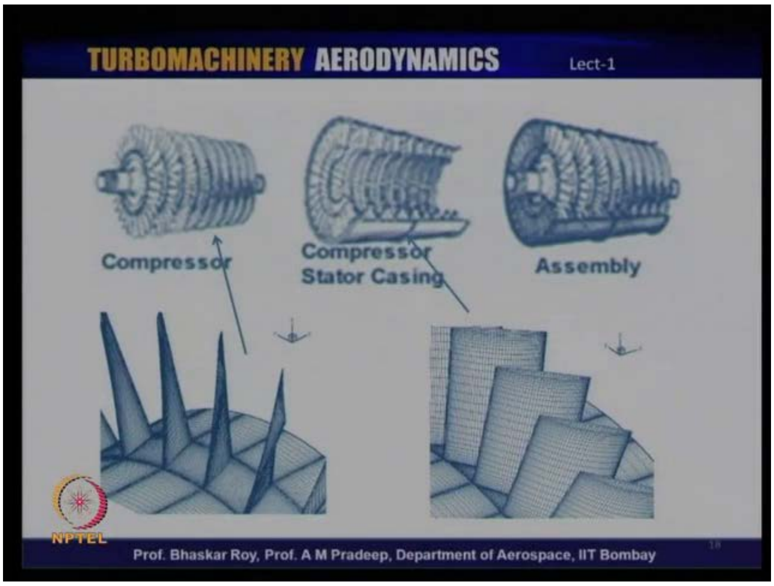

If you look at this components, you will see here compressors. The first picture on the left that you see here is indeed a multi - stage compressor. You can see here, so many rows of blades and one row of blade here, a router here is shown here, in a little more detail. It consists of so many blades. These blades as we go along, we shall see are indeed made up of aerofoils actions. And these aerofoils actions are the basses of which these blades are made, and then these blades are lined up.

First they are arranged a comparentially in a certain manner and then rows of these comparentially arrange rotors are lined up to make, what is called a multi-stage compressor? Now, in between these rotors, we shall see later on as we go along, we would have compressor stators; that means, another row of blades, which are stationary and hence they are called stators.

These stator blades again row or shown here in some detail and these are the blades that come in between two rows of rotors. So, we have 1 row of router and then other row of stator and here the final assembly shown, where rotors and stators surrounded and covered by a casing, which is the final assembly we shown here.

So, we have a compressor, which consist of a large number of blades, which are arranged in a certain manner and those manners are what we are going to talk about in great detail, and when you arranged them correctly. And when you arrange them in an appropriate manner, you have a compressor that produces compression and feeds the compressed here into the combustion chamber. So, this is what a compressor is whole about, we will take a look at a turbine. A turbine is typically made up of high temperature material.

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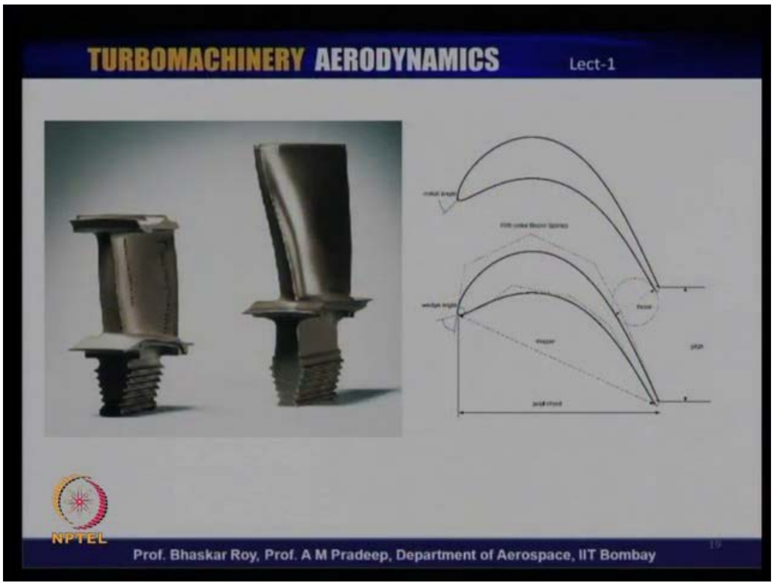

So, as you can see here in this picture. It shows that it is of a different color, because it is made up of very high temperature material, high temperature gas from the combustion chamber is going into the turbine. But these turbines are also made up of aerofoils slightly different kind of aerofoils, but indeed they are aerofoils and those aerofoils kinds are shown over here, on the right hand side.

These kinds of aerofoils are used in turbine blades in rotors and in stators. The one you see in the right hand side is indeed a rotor and one on the left hand side is indeed a stator. You can see here, some very small row of holes drilled along the surface of this stator blade and these rows of small holes essentially or micro holes, essentially are the cooling mechanism that cools this blade internally and gives it sufficient life to work for few thousands of hours.

We will be talking about the mechanism of the cooling, their dynamics of the cooling and how the cooling essentially enhances, the working life of a turbine in a useful manner. We will be talking about those things as a part of all lecture series. So, this is what a turbine essentially would be looking like again it is made up of aerofoils and we will have to understand, how this aerofoils are arranged to make up turbine blades.

The other kind of compressors that we would be indeed talking about other centrifugal compressors, which Professor Pradeep mentioned and these centrifugal compressors indeed the other kind of turbines is the radial turbines, and we will see later on that the radial turbines and centrifugal compressors outwardly, they are not really similar. They work very differently, but looks wise they may look somewhat similar to each other.

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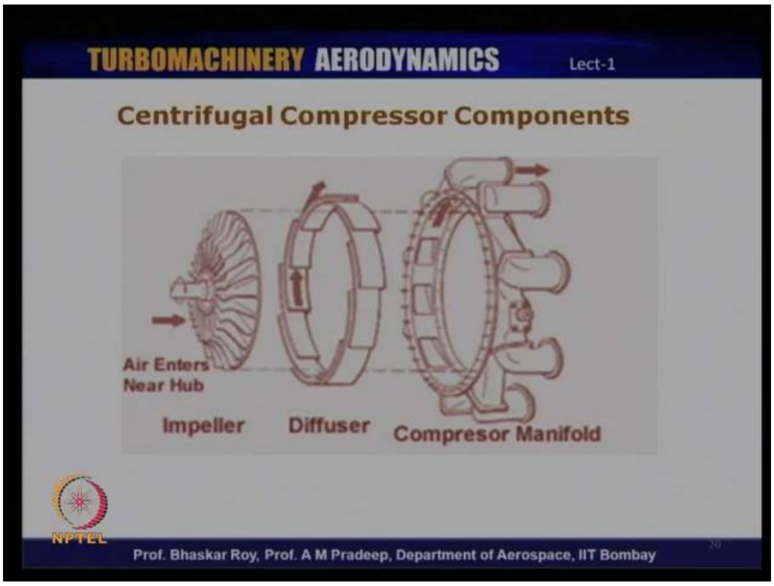

So, I am showing you here, a typical centrifugal compressor, which also does the job of compression and this flow here, it enters over here, it goes out from this side and then its surrounded by a row of diffusers, which is indeed equivalent to the stators that we talked about for actual compressors and when you put them together, the diffuser and the impeller together, you have a compressor.

In addition to these 2 units, you also have this compressor manifold, which essentially then take up the compressed air and supplied to the combustion chamber, as you can see here, there are number of supply manifolds, which are essentially supplying to various combustion chambers. So, a centrifugal compressor essentially consists of an impeller or diffuser and then of course, a set of manifold, which supply the compressed air to various combustion chambers.

So, these are the components with which, we shall be dealing with in great detail. We shall see, how these components are indeed made out how they are analyzed, exactly what shapes they are how do they work, and finally, we use CFD in the modern compressor analysis and design.

And we shall see, how these shapes are essentially created with an analyze with the help of CFD. So, that would be the course coverage in this particular course. I will round up today’s introduction with a comments that he would do need to have a good grinding, in the basics of aerodynamics.

We shall be using, those basic aerodynamic knowledge all the time and we will not have time to go back and essentially detail out those fundamental concepts all over again. We will be assuming that you are familiar with those fundamental concepts.

So, you may really need, to get yourself familiarized with those fundamental concepts and as I mentioned, that we will be using certain concepts of CFD. It may be useful, if you have a passing knowledge of CFD. So that when we come to towards the end of this lecture series and we get into using CFD for computational analyses of compressor turbines.

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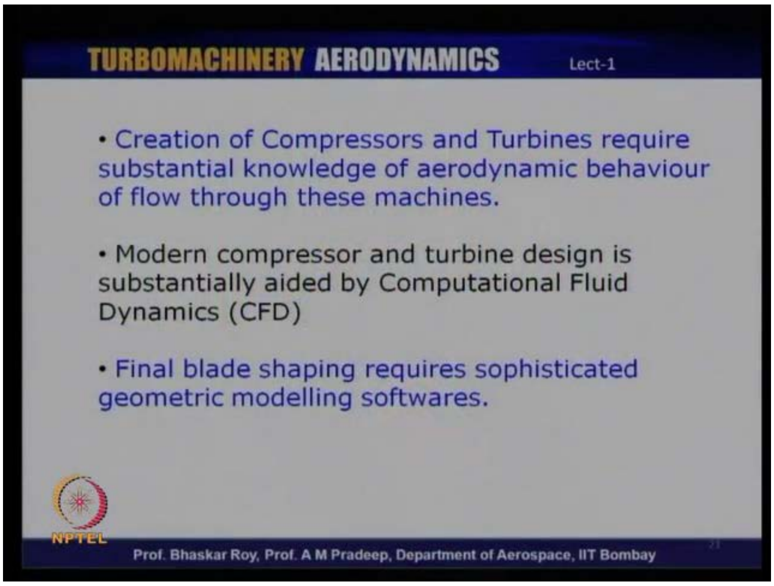

It is necessary that you have some passing knowledge of CFD; we will mention that when this blades and impeller shapes are created. It may be useful for you to have some knowledge of geometric modeling. The cad models, which are often used to finally give shapes to this complex shapes, which as I mentioned are essentially aerodynamic machines. You need to give them aerodynamic shapes for these machines to work in an efficient manner.

So, the this is what we would be doing in this lecture series, over a period of little more than 40 lectures and in the process, we hope that we will be able to introduce to you the fundamental aerodynamic details of compressors, turbines, how they are analyzed, how they are designed, and how they are finally created to go inside aircraft engines in modern aircraft engine for creation of thrust.