Acoustics & Noise Control
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Module – 01
Lecture – 01
Introduction 1

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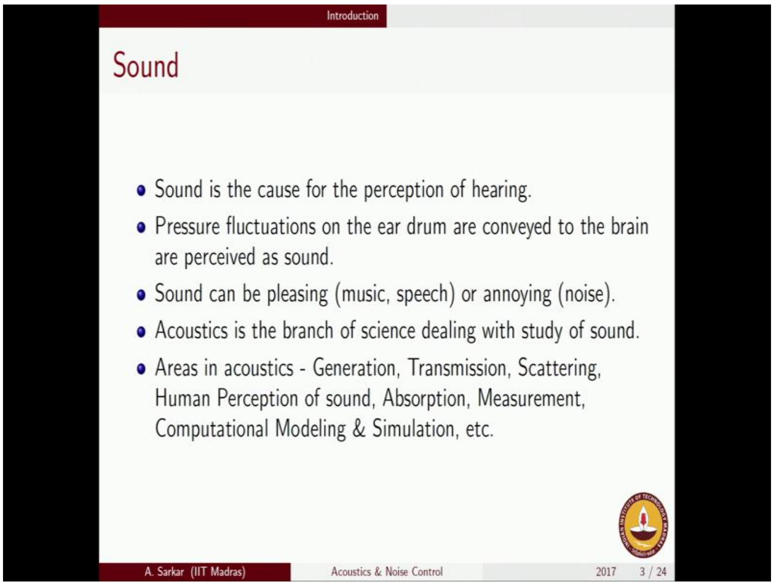

Hello friends, welcome to this first lecture on Acoustics and Noise Control. The title of the course has this two very important words acoustics and noise control. So, this introductory lecture is about a brief description of these two words acoustics and noise control. So, see what acoustic means.

Acoustics is obviously as you may be aware is the science of sound and sound in turn is the cause for which we have the perception of hearing. So, it is a very important attribute, it is a very important sensory human sense that we are able to hear different kinds of sound it has great implications in terms of our behavioral as well as biological existence. So, that part of it is obviously, not engineering, but what is engineering we will come to it in a moment time, but before we do that let us try to understand what causes this perception of sound. So, the elementary physiology that we are going to stick with in terms of that it is very clear that it is some kind of pressure fluctuations which hits your eardrum. And these pressure fluctuations in turns excite a fluid which is there in your ears which is called the cochlear fluid that gets into some excitation and those excitations are picked up by the nervous system present in the auditory canals and it is interpreted as sound by the brains.

So, at complex physiology is something that possibly we are not going to do in this course, but we are going to non and the same stick to this important idea that the perception of hearing is because of the fact that there is a certain sound pressure which is fluctuating sound pressure rather which is causing the eardrum to vibrate. The eardrum is just like a structure just like the tabla or the drum it is a membrane if it is subjected to some fluctuating pressure force. Please understand what the difference between fluctuating pressure force and a standard atmospheric pressure. If it is a standard atmospheric pressure like 101 kilopascal pressure then you will not have any sensation of hearing because of that because it is going to cause only a static deflection.

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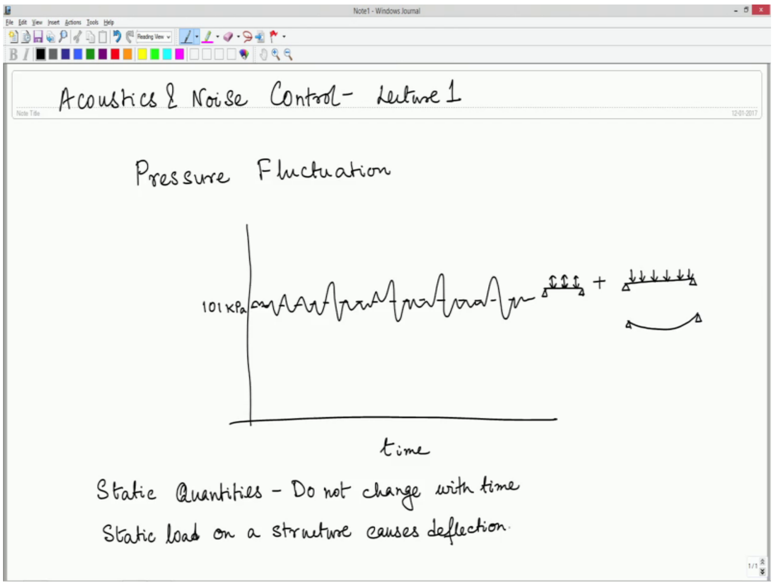

So, let us make this clearer. So, there are this term of pressure fluctuation, so as the name suggest fluctuation means there is in time axis if you had to plot the pressure there is a mean pressure and the mean pressure does not change much in the scale of our interest. So, let us say the standard atmospheric pressure is 101 kilopascal at some conditions of temperature, humidity and so and so forth; then usually this does not change in the scale of seconds or minutes or even in an hourly scale.

So, if there is a membrane, this is a membrane structure let us say and if you have this pressure acting on to the membrane structure then the resultant of that is going to be a static deflection. So, the membrane structure is possibly going to deflect like this and that is it nothing else will happen. So, it is like as I sit on the chair the chair being spring like, the chair shots of reflex into a static deflection position and nothing else. But if instead of a standard atmospheric pressure on a static atmospheric pressure, we have a fluctuating pressure something like this. We do not quite declared what the type of fluctuations are, but all that we say is over and above this mean level there is some fluctuating or oscillatory components if you may like which is acting.

So, on top of this what is now going to happen is that there is going to be an oscillating component and I will show these oscillating component in this fashion, because it is both upward and downward with reference to a mean which is now not zero, but at 101 kilopascal. The mean has been shifted, the mean is no longer 0 pascal or in term if you work in terms of gage pressures, you can still think that the gauge pressure is zero. But in terms of absolute atmosphere absolute pressure quantities, the quantity which is the mean pressure is at 101 pascal, but over and above the 101 kilopascal there is a positive pressure and a negative pressure which is what it means as a fluctuating pressure

To continue the analogy of me sitting in to this chair if I just do not move around and nicely comfortably sit statically onto this chair, I can understand the chair has deflected by a few millimeters probably because of my weight. But then if I start sort of jumping around in this chair then I can feel that this chair is also oscillating along with me, this is true for any structure not just for a chair. You can try this in your car seat you can think about the car itself any structure when it is subjected to a dynamic, this is what we call a dynamic forces. A static force is that which does not change with time. So, you will note this down, static quantities are those which do not change with time. You could have a static weight; you could have other forms of static dead load or so on. So, static the effect of static load onto a structure causes static deflection.

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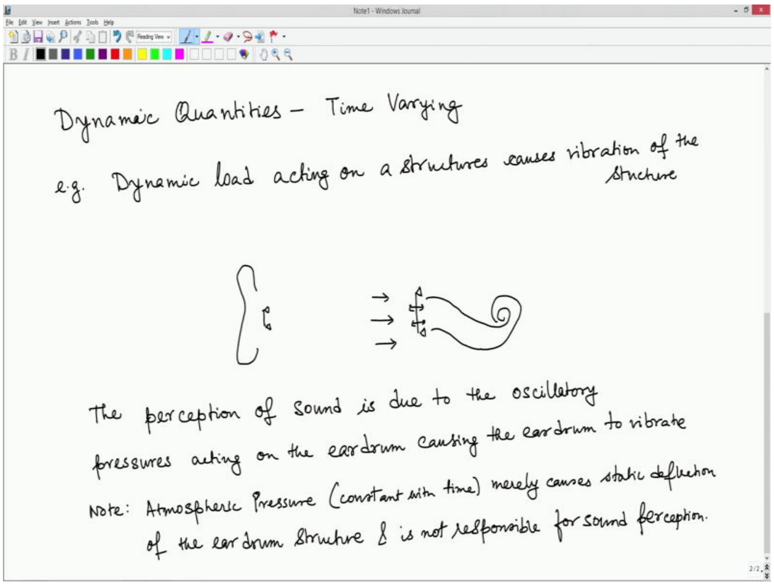

However, when you have when I say dynamic quantity, I basically mean time varying quantities. So, dynamic quantities basically are time varying that which is not constant with time. So, in this course, we will be interested about dynamic quantities, time varying quantities and as an example a dynamic load acting on a structure causes vibration of the structure. How to calculate vibrating structure due to a given applied loading that is the subject matter of theory of vibration, some of you may have had exposure to that, but even otherwise do not we do not need too much of theory of vibration at least for this course. But we just need to appreciate this fact that once you have a dynamic or a time varying load acting onto a structure, the structure will vibrate. So, again as an example of this we have the physiology of acoustic.

So, let us take this to be our ear and internal to the ear there is a structure as I said which is the eardrum. So, now, if I looked at just the eardrum, this is being subjected to some kind of atmospheric pressure that is for sure. But on top of the atmospheric pressure the fact that I am talking to you it basically implies that on top of the atmospheric pressure my voice is a able to create some fluctuating components and these fluctuating components are going to cause the ear membrane to oscillate. And this oscillations will be picked up by some fluid which is called the cochlear fluid, and it goes in some spiral fashion. And from there onwards using some complex nervous, I mean sensory pick up it is interpreted by the brain as a voice or as the sound or whatever you think music or noise and so on and so forth.

So, the basic cause of our perception for hearing is the fact that our ear drums are vibrating and why are the eardrums vibrating just like any structure would any structure would vibrate because of the presence of oscillating forces acting onto the structure. So, eardrum is no different mechanical structure than a plate or this chair on which I gave you the example. So, accordingly the eardrum vibration is setup by fluctuating pressure components which are caused because of the sound generation mechanism, this is what we will take up in more details as we go along. But the moral of the story is this, the perception of sound is due to the oscillatory pressure forces oscillatory pressures acting on the eardrum causing the eardrum to vibrate.

Again please note that the atmospheric pressure which is a static which is assumed to be static or constant with time merely causes static deflection of the eardrum structure and is not responsible for sound perception. So, this is the most important trigger as far as human perception of sound is concerned. And we will take it up from here that there are some oscillating pressure forces which we will try and understand how these oscillating pressure forces are generated in the or taking birth or originating. And then another very important aspect is how they are getting transmitted from the point of it generation to your ear drums, how is it getting transmitted.

So, accordingly we will have different topics to talk on, but the fundamental point which I wanted to emphasize is that it is the pressure fluctuations which is acting on the eardrum which is the basic trigger for the perception of our sense of hearing. Again another human aspect of sound is that sounds could can be pleasing or it can be annoying; and obviously, there are lots of human subjectivities involved in this criteria there is no hard and fast rule that what appears as music to a certain individual can appear noisy to the other. So, in general now sound is not subjective, sound is the perception of hearing, you have sound, you have it fluctuating pressure, you will you are going to hear sound But whether that is pleasing her whether that is annoying; obviously, depends upon the individual concern.

So, the discrimination between what is music or what is an intelligible speech in comparison to what is not is or what is an annoying sound, annoying sound will be called noise. So, this distinction is actually there are subjectivities involved, but in this course we are primarily going to be concerned about machine noise. We are not going to worry about music or speech because that is basically outside the scope of our discussion here.

Being mechanical engineers, we are interested in machines we are also interested in machines which are quieter, and I will emphasize why we need quieter machines in a moment time, but usually when it comes to machine any sound that is emanated from the machine is basically not intelligible. So, it is of no use, it is definitely not soothing. So, it is best avoided, it is annoying, but in certain instances as again I will probably emphasize in certain instances, you may like to have a certain kind of noise, but more often than not all machine noises are annoying and all machine noises in terms of good machine design perspective. It is an objective that this noise is best got rid of.

So, from sound we come to noise and the objective in this course will be to understand not only sound, but to be able to at least in some through some examples to be able to appreciate how all this theory can help us design quieter machines. So, obviously, there are a lot of machines that are there we would not talk about all machines. But hopefully at the back of our mind we will keep this in mind that how different machines make noise and what is it that one can do to sort of contain this noise or bring this noise to the minimal possible levels.

So, generalize definition of acoustics could be stated as it is the branch of science which deals with the study of sound. So, we are going to study sound and noise control in a more specialized branch of acoustic which deals about how to apply this theory behind sound in order to design better machines in terms of its acoustic performance, and there are good reasons why we should do so I will have some motivation for you in the following slides. There are different areas within this very broad field of acoustics. We could talk about how sound is generated in the first place and that we will do in the part of this course.

A more important factor is how sound is transmitted from the point of generation to the point of reception. So, we could do something more often than not again the generation is very difficult to tinker with and there are engineering reasons which I will come to. But the transmission path from the point of generation of the sound to the point of reception of the sound has lot of scope where in an engineer can use his or her ingenuity in order to reduce the sound as perceived by the receiver. So, the transmission path analysis turns out to be very important. Scattering well scattering is once there is a sound getting transmitted any blockage that happens is called scattering. I will just probably quickly explain to you these ideas through the writing.

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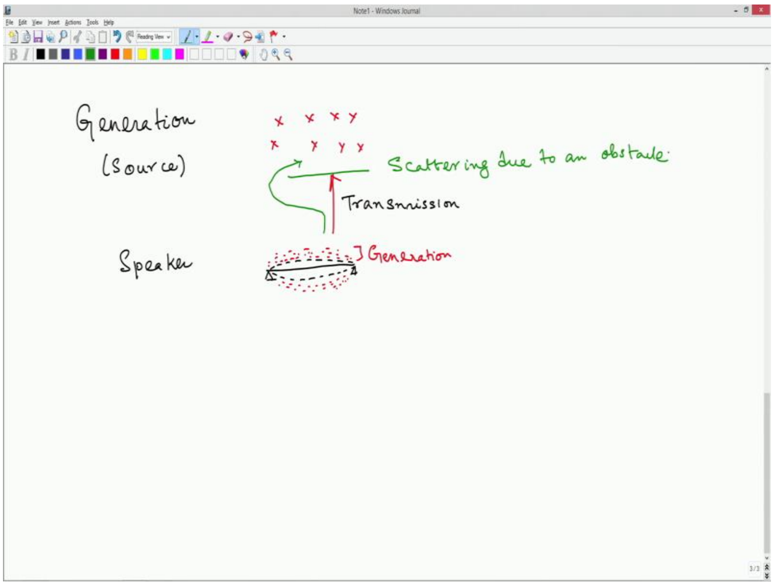

So, generation is one aspect which happens at the source. So, for example, as I am talking the sound is getting generated from my vocal cords, you may wish to understand how is my vocal cord vibrating. And then how the air around the vocal cords is actually moving such that this pressure fluctuation is created and then right from my mouth as you will do the mouth is going to serve as a resonator for the acoustic. So, the sound that is getting generated from my vocal cords is actually getting amplified at my mouth which is serving is an acoustic resonator; we will discuss all these in details as we go along and from there on it is getting transmitted right.

So, you could have a source which could be let say the speaker the speaker could be a human speaker or it could be the instrument speaker that you are well of both of both the human speaker as well as the instrument speaker work on the principle of vibration induced noise sorry vibration induced sound. So, there is something which is vibrating in our vocal cords or even in a speaker there is a membrane which is vibrating and ones that vibration happens that sort of. So, I will make myself a little more clear through this drawing. So, if you have a structure, which is vibrating. So, let us say this structure vibrate within these envelope it goes up and down up and down what will happen to the neighboring fluid particles.

Let say there are some fluid particles and I will indicate them in a different color. So, these are the neighboring fluid particles just some random fluid particles I am drawing right. So, as the structure is going to vibrate, it is going to throw out these neighboring fluid particles and it is going to cause motion of the neighboring fluid particles. So, once the neighboring fluid particle is set into motion or what happens to the fluid particles which are faraway nothing is going to happen because these fluid particles do not yet know that there is a structure which has started vibration. The neighboring fluid particles will immediately know because they are being pushed around and shafted around by the structure they will immediately know that the structure is vibrating.

So, they will sort of get cramped for space as a result you will have a region of localized build up of the pressure within this fluid particle which is basically called a region of condensation that is you will have a region of buildup of the local pressure and the local densities. So, this is the source of sound right. And this is more categorical speaking this is the vibro acoustics source of sound speakers being one very good example of that right, but there are other sources of sound also and I will talk of them as about them as we go along.

But then when you talk about transmission, let us understand that you are a little further away from at least my vocal cord right. So, you do not get to hear what you are exactly my vocal cord is producing, it gets amplified firstly, in my throat because of the resonance effect which as I said will be detailed out in the later classes, but what reaches you is the transmitted sound. So, this localized pressures will actually get transmitted all the way up to the point where the reception is occurring. So, this part is generation, whereas this part is transmission from the point of generation to the point of reception whatever changes are taking place is studied under the heading of sound transmission.

Now, here one crucial assumption that we have taken is that in this world there is only the vibrating structure and nothing else that is not true right, there are obstacles. So, now, let us complicate the picture a little bit and say that there is a certain obstacle here it could be a wall, it could be a fat man standing between me and you, it could be anything right. So, obviously, the transmission path will now get distorted it cannot have a there is no direct path of transmission just like in the terms of optics, there is an obstacle between me and you, you are not going to see me right, but that it is not so very easy in terms of sound. Even if I play some obstacle and sort of hide myself behind that obstacle, my sound can still reach you. So, there is a way in which the sound will now travel in some strange manner.

So, any distortion to the path to the direct path would be called as scattering. So, this effect is that of scattering due to an obstacle. We will talk not of all kinds of scatters, but one very important rather an easy obstacle to talk of is when this is a completely rigid barrier and it is sort of reflects the sound back. So, even an ideal reflector in that sense is a scatter right, but typically we will not get into the business of scattering because I do not think we will have time allotted to that much details. So, it is just for you are awareness that what is the scattering.

So, then there are lots of issues associated with the human perception of sound. And you know the evolution of the decibel scale for one thing is lead from this trigger that it is the human perception which matters. And once you get into this human perception issues, you understand that you cannot quantify sound in the usual run of the main type of unit. So, one needs to evolve the units which are decibel scale and you will have decibel a weighted scale, b weighted scale and so on and so forth these are all related to human perception of sounds because finally, what we are interested in is to understand how we can have less annoying machine less noisy machine right. So, if you have a machine which makes less perceptible noise then it is all the more better for us in terms of our machine design perspective.

We will also like to touch up on the topics of absorption. There are different materials which are there which can absorb sound, and what is the basic underline philosophy of sound absorbing being materials if time permits we will try and touch on those things also. We will talk about sound measurement techniques some of these will be these materials will be uploaded in the appropriate web page for the course. We will just create some awareness about the different computational modeling and simulation tools that are available for acoustic. This course is not about computational acoustics in particular, so we will not talk about detail formulation aspects of these computational approaches, we will just create an awareness is to what are the ways and means by which different computational modeling can be done, so that being slide one.

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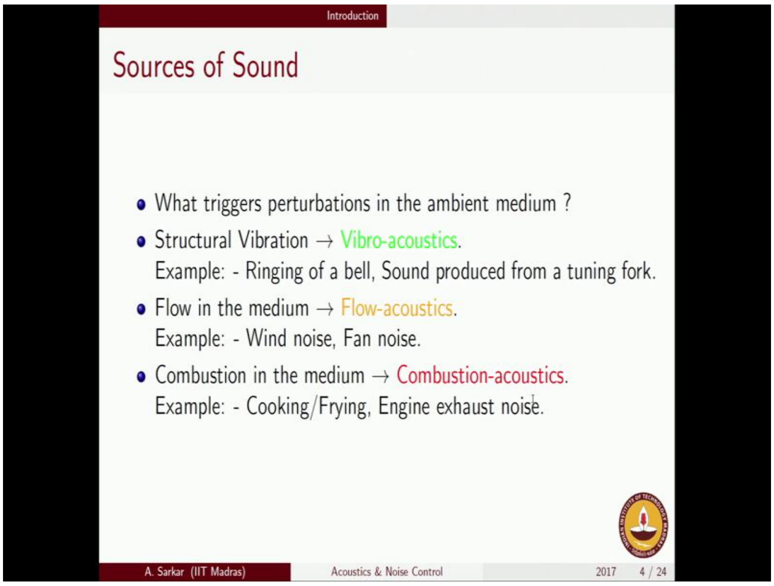

So, here I again start talking about the sources of sound some of which I have actually demonstrated in notes that I was writing for you. So, the question was what triggers perturbations in the ambient medium, what triggers this fluctuations or perturbations if you may so. By perturbation, I simply means small fluctuations. So, this small fluctuations are triggered by a source and as I said one way in which these perturbations are these fluctuations could be triggered is the structural vibration. The structural vibration is a very good example and all sources which creates sound because of vibration are called as vibro-acoustic or structural acoustic sources.

So, examples being the good old bell jar experiment where well not the bell that we have in our door these days, but the traditional ringing of a bell, if you say it is just a hammer which is impinging on a plate like structure circular plate like structure. So, this finally, makes the plate vibrate. And once the plate vibrate, the ambient air is thrown out is set into motion and that motion of that ambient fluid particles is communicated from the point of generation to the point of reception, so that is how a ringing bell or a tuning fork or my voice or a guitar actually makes sound. So, most musical instruments which are either of percussion type let say drums, tabla all of them are vibro-acoustic instruments.

On the other hand, if you have flute in flute nothing vibrates actually no structural rather vibrates you could have a flute which is made up of very very rigid structure yet I mean the vibration of the structure could be (Refer Time: 26:25) minimal. So, there is nothing that vibrates, but yet you hear the nice sound of a flute, so that is caused because of the flow right. Another very nice example of flow induced sound, it is probably you guys have experienced last month when there was cyclone what the striking us then there was huge noise a shrill noise was like deafening noise was being carried through. So, the motion of the air as it passes through different structure is able to cause noise also.

And the reason is quite simple because if you recollect the motion of the air especially at high velocity is when it comes to talking about you know cyclonic weather. When the wind was really blowing at nearly 100 kilometer per hour then you could expect that the as the wind this airflow was happening through the building through the trees, there were boundary layers that would be created. And since the velocity were very high, the Reynolds number was very high and it would go to turbulence right the motion was turbulent. If you recollect turbulence also has the same idea that there is a mean component and there is a fluctuating component on top of a mean component.

As you know in the turbulent flow example we will have a mean quantity and associated with the mean quantity is also a fluctuating quantity. So, what happens is that this fluctuating quantities are transmitted from its point of generation too far away in points and that process is also process in which sound can get transmitted. So, the point is this the source of noise this time is the turbulent fluctuations which happens in the turbulent boundary layer, but then these turbulences induce the fluctuations the fluctuations are eventually conveyed or transmitted through large distances in the form of acoustic wave propagation that is the source how the turbulence induced noise can be generated. This is an example of flow-induced sound

It is the same process if you have heard engine noise let say in an air breathing engine which is basically your aeroplane engine. Aeroplane engine also makes the sound because of exactly the same process; it is a very very high velocity flow which is happening through an air breathing engine. And once you have such a very high velocity flow, definitely you are inducing turbulence at some point or the other. And once you induce turbulence the fluctuations are naturally there, the fluctuation can be of a different kind between the flow induced noise and the structure induced noise, but none the same they are fluctuations over the mean value. And once you set up these fluctuations, you will be able to hear. You have a generation mechanism from the generation mechanism there is a transmission mechanism which basically is the wave propagation idea and from there on, it hits your eardrum and your eardrum perceive it as noise, so that is flow acoustics for you right.

So, flow acoustics is another very important branch of acoustics probably more important than vibro-acoustics in certain applications such as aerospace whereas, vibro-acoustics is all pervasive. Flow acoustics a lot of research work is being actively done to understand different mechanisms of noise. Computation inflow acoustics is really demanding, you have to run your CFD simulations very intensively in order to predict the flow acoustics correctly, so but none the same you should be aware that there are different mechanisms of generating sound.

The other mechanism is combustion-induced noise. So, even if you have observed cooking right when you poured in your hot oil if you put your vegetables immediately you will hear a crackling noise that is happening because of some chemical reaction that is happening between the hot oil and the vegetables right. So, there is the primary factor there is a chemical reaction which eventually sets of fluid motion that is true even if you are cooking vessel does not vibrate. The cooking vessel if you have noticed is fairly rigid as the cooking process is going on you hardly have any perception of vibration of the vessel. So, it is not because of the vibration of the vessel that the cooking is happening. So, this is something you would have definitely seen as you or your mother probably was cooking in the kitchen.

But this believe it or not the same thing is happening when you are IC engine is undergoing a combustion process. Basically it is hot oil which is getting spread within the combustion chamber and the same crackling sound is obviously going to get generated due to the combustion process that is happening in the IC engine also. The only point is that you do not sit in inside an IC engine to hear that noise rather you sit outside your car and that noise will actually if you hear carefully in the exhaust side of the engine, you would be able to pick up some similarity between those sounds right. So, this is what the primary driving factor in this case is the combustion process and the chemistry associated with the chemical reaction of the combustion process which is the driving factors. Eventually it will trigger of the fluid motion and the ones the fluid is set into motion, it will get conveyed from the point of generation to your ear drums, so that is combustion acoustics for you.

So, we are not going to talk much in details about combustion account or flow acoustics; we are going to remain fairly generalistic in our study of acoustics persevere. We not going to specialize towards any of this topic but none the same you should be aware there are different ways in which sound does get generate.

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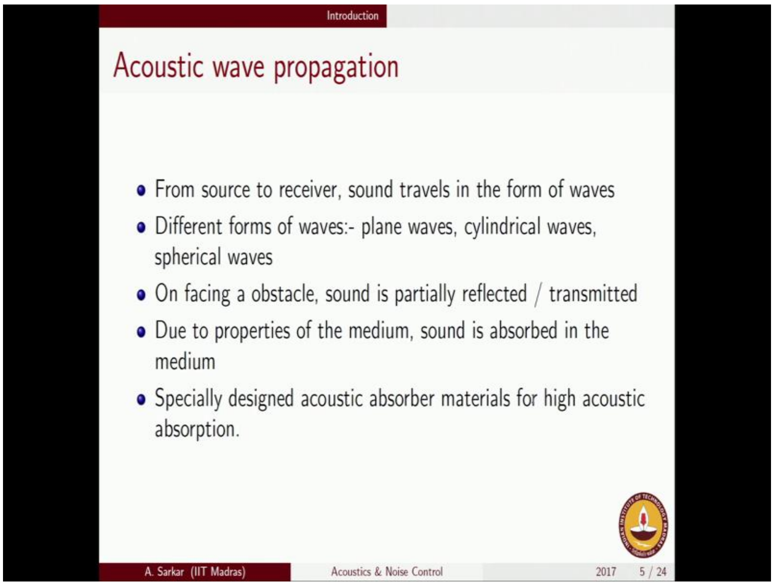

So, from the generation process let us now talk about the transmission process. After the sound gets generated at its source the question is how does it reached the receiver. So, as will be shown in very much details is that the transmission from the origin to the point of reception is through a form of waves. So, waves maybe as a child, you would have played with different types of you know by throwing stones at pond, you would have seen some waves. But we will formalize these arguments as to what really a wave is how do you mathematically describe our wave and there are very nice interesting mathematical tools to study waves, this is what we will do predominantly in this course. At least the first part of the course we will try and (Refer Time: 33:08) the foundations and try to understand how waves propagate in a given medium.

So, the reason why we will study waves is because we understand that the transmission of sound from the origin to our eardrums or to the microphone for that matter is in the form of waves. And as I said that you know in most cases as a noise control engineer, this is the place where you have to target. Because again getting back to my IC engines example, the combustion process is sort of fixed by the engineer who owns the engine in the sense that you know a certain combustion setting maybe the best in terms of the flow efficiency of the horsepower rating or the torque rating. So, as a noise control engineer, you are really not expected to tinker with the engine because that will offset the design objectives for the engine. But what we will show and in through this course is that that you could really do a lot in containing that noise in the transmission path between the source which is the engine and the human ear which is outside your car. So, the transmission path is through the exhaust pipe.

So, what we will do is we will put a silencer or a muffler in that exhaust pipe and we will try to contain the noise as that the noise does not reach the outside let it get generated in the engine. You do not want to tinker with that because that may sort of cut off the best efficiency of designs for the engine in terms of fuel consumption horsepower rating, torque and so on and so forth.

You do not want to tinker with these aspects rather you would be better off in controlling the sound by putting the appropriate muffler within the transmission path between the point of generation and the points of reception. So, therefore, and the reason why you will be able to design a good muffler if you understand really how the transmission works, transmission is in the form of wave and just to jump the queue. If you can induce some reflections in this transmission path and make sure that much of the wave actually reflects back to the source rather than get transmitted from the source to the receiver you will have a good muffler designs. So, based on these aspects we will be able to enlighten you as to how muffler design can proceed.

So, therefore, we will do all that as we go along, but then muffler design proceeds on the ideas of plane acoustic waves, but that is not the only kind of waves in which the acoustics wave propagation does take place. We also have cylindrical waves and spherical waves. Cylindrical waves you would have seen as you throw a stone on the pond, these waves are basically going on the surface, they go out radically, these are cylindrical way, whereas in the three dimension, you will be having spherical waves. So, some of these waves will be talking about plane waves and spherical waves for sure, cylindrical waves could possibly be some assignment for you.

So, we will talk about different forms of wave propagation, plane wave be the easiest and at least to visualize, and as I said there are interesting applications of plane waves. So, we will do a lot deeper in plane waves. We will also see how spherical waves can be analyzed and we will actually show you that you know there are very interesting cases where special cases where spherical waves can be approximated in terms of plane waves. So, in that way the study of plane waves will be very rewarding. So, as I said when there is an obstacle, sound will be partially reflected or transmitted. So, this is a very crucial idea. When you do not want the sound to reach to the human ear or to the point of reception, one idea would be to make an obstacle which typically is called a noise barrier or what is more technically called as inducer impedance mismatch, we will talk about all these terms as we go along.

But very loosely speaking this is an obstacle, if you put an obstacle then you are expecting that the sound will not get transmitted, but rather will get reflected back. So, if you do not want to hear me one idea is you put certain kind of barrier just like if you do not want to see me in front of you, you just put a barrier, I will not be visible to you. Similarly, it the optical barrier will not work efficiently as an acoustic barrier, but if you know the transmission analysis carefully and if you are aware of different issues associated with acoustic wave propagation, you could possibly design a very nice sound barrier, which actually has minimal transmission of my sound to you. So, how could you design all those things we could possibly think of as we go along.

So, one issue that is definitely there is all the medium will have certain losses. Associated with the properties of medium other than the process of sound transmission, there is also a process of sound absorption. Sound absorption happens due to two main features; one is that of the viscosity of the medium, as you know the fluid viscosities play an important role in the dynamics of the fluid, and the viscosity is are usually treated as a sort of head loss in the case of mean flow effects. Similarly, even in the case of acoustic propagation, the viscosities, which are inherent within the fluid do play a role of energy loss mechanism. So, these essentially create an effect because of which the sound which gets propagated within the medium is actually decaying as it is propagating. So, this phenomena is known as sound absorption.

Other than the fact that there is inherent viscosity in the fluid, there is also another important features that of heat conduction. What happens as we will come to know is that when the sound wave does travel within a fluid medium, then there are different zones having slightly different temperatures. It is not a very great difference in temperature which you could possibly measure with ordinary thermometer, but none the same there are differences in temperature between different zones in which the sound transmission is taking place. For example, the compression and refraction zone will have different temperatures. Now, once there is a temperature differential that is set up within the medium as you know there are heat conductions, which will take place because of the thermal conductivity of the medium.

Now, once this heat conduction takes place, this is also a sort of energy loss as far as the medium is concerned. So, for this dual effect of thermal conduction plane within the medium as well as the viscosity effects of the medium, there is essentially the sound that is getting transmitted through the medium also gets partially observed. And therefore, it slowly decays as it gets transmitted within the media. So, this phenomena is called sound absorption. Sound does not travel beyond a certain distance is because the sound essentially gets attenuated, so that is because the medium will have certain losses. So, all that is getting generated does not reach the point of reception because there is definitely a natural attenuation to associated with the medium. So, one aspect is that the medium is inherently having some absorption characteristics, but at times that is not sufficient. You want better absorption characteristics because you do not want the noise to reach the point of reception of or the associated human ear.

So, therefore, you would like to design absorbers which are better than what is naturally inherit in the air. So, therefore, those are called acoustic absorbing material. So, we could possibly I mean again depending upon how the course goes, we could branch out to understand how different acoustic absorber materials can be designed such that we have a better acoustic absorption. So, these are artificial materials which it is not like air or water in the sense that this air or water comes with its inherent absorption characteristics which actually may not suffice for our application needs. We will have acoustic absorbers usually made of fibrous materials. And once the sound is forced to pass through this fibrous materials, we will be able to get a lot of absorption out of this material, so that will again be something which will be very useful in terms of our objectives.

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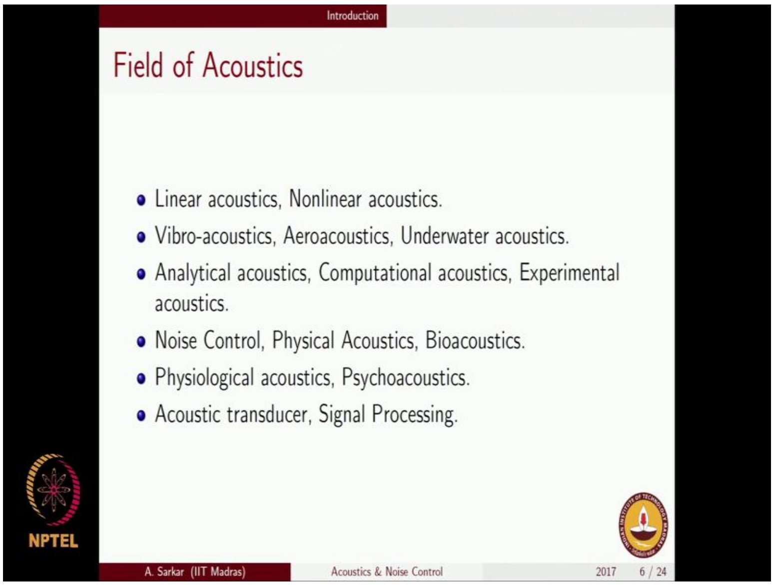

There are different fields associated with an acoustic, we will be interested mostly in linear acoustic because the sound which is not too intense will fall within this domain. However, if you have very intense sound as a rising in aerospace applications during the launch vehicle, take off, these intense sound which are like more than 100 dB or so should be analyzed as non-linear acoustic phenomena; however, this course is only about linear acoustics.

As I said in terms of generation of sound, we have vibro-acoustics, we have aeroacoustics. We also have a very important field which is underwater acoustic is very important for navel applications something that navy people are extremely you know for this topic is very important for design of stealth applications and underwater wall fair devices and so on and so forth. But we will predominantly not go in the direction of underwater acoustics, but this is a very important area which is a little advanced from this first course on acoustics.

The methodologies that could be adopted in the different solution processes could be analytical methods, it could be computational methods, it could be experimental method. So, my objective in this course would be to give you a brief overview of the computational and the experimental methods as well. We are predominantly going to fiddle around with some analytical tools, but understandably the analytical tools are very important to understand the preliminary and the fundamental concept. The computational tools are important in having an accurate estimate for a specific application, but the interpretation of the results will be done properly only if you have a good analytical background.

If you have learn the analytical background by which you have the interpretation at least for you know simple cases such as 1 D application, then you should be able to have a very good interpretations of your computational results also. Analytical results probably cannot be used to accurately predict us or accidentally estimate certain quantity of interest in three dimension. For that, we have to resort to computational methods, but the bit fall there is that if you only trance the computer and lose the insight then it will do more damages than help you solve the problem.

So, therefore, it is very imperative as students you should learn the analytical methods correctly, computational tools are there. And learning a computational tool could not would not be that difficult especially most of the commercial packages provide a very good help document using the help document you could learn your way how to work with those commercials software. But then the interpretation of the result will be based upon how well your theoretical foundations are how well you have learnt the basic theory for the learning the basics theory analytical acoustics is very important. And this course will be predominantly focusing on the analytical techniques certain awareness will be given about computational techniques also.

And experimental acoustics we will talk about the important instruments associated with the measurement of sound and other associated things some of these experimental techniques could also be part of your self-study which will be posted in the appropriate webpage. There are experiments available and I will post them in the course webpage as we go along. So, predominantly we are going to consult about noise control aspects. The other important areas could be physical acoustics. In physical acoustics, people are interested to know different physical processes associated with the acoustic phenomena. For example, in ultrasonic, we have a completely different physics associated with these wave propagation phenomena as they happen within elastic waves and so on.

Similarly, bioacoustics is concerned about the biological aspects of acoustics. We are not going to touch upon these topics in this course. Physiological acoustics and psychoacoustics are again interesting areas in their own right. There is lots of active research as to understand how exactly we perceive sound what I told you in the first part of this lecture today is that a basic sketching ideas as to how this thing is perceived. But even to this day there are lots of open question that how exactly is the sound perception happening. And what are the physiological ill effects of over exposure to noise, what are the psychological ill effects of over exposure to noise.

So, lots of experiments and lots of data has been gathered over the years with seem to points that over exposure to noise has its ill effects in terms of both physiology as well as psychology. So, but still a lot of active research is going on in this direction. If you pick up any journal on acoustics, you will see sections devoted to physiological acoustics and psychoacoustics, but again in this course we are not going to dwell on these topics any further.

Another very active area of research is how to design new acoustic transducer what is the associated signal processing and so on and so forth. So, there are lots of companies which are actively involved in making the different acoustic transducers and the associated acquisition system and the signal processing. So, this is a fairly active area of research. So, with that brief exposure, I will stop for the day here we will pick it up from here in the next class.

Thank you.