Experimental Methods in Fluid Mechanics
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Lecture - 09

Pressure Measurements Definition of pressure and Dynamic response considerations

Good afternoon, I welcome you to the session of Experimental Methods in Fluid Mechanics.

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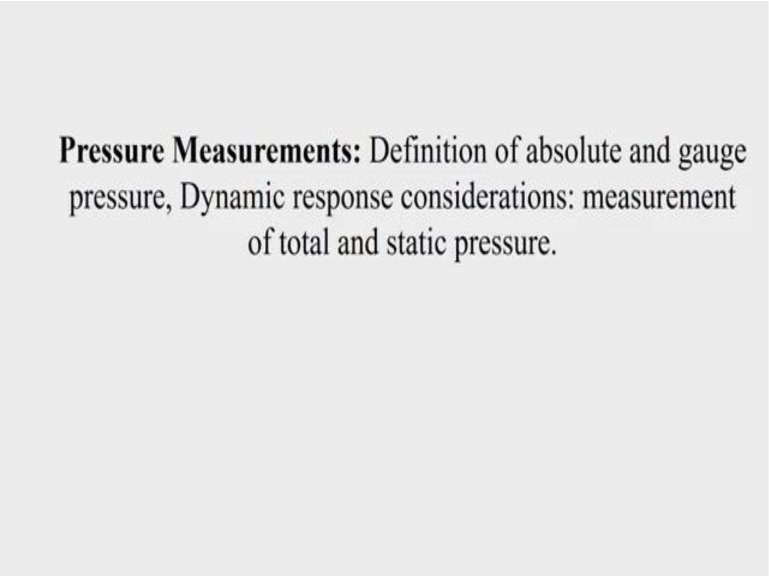

Today, we will discuss about different pressure measurement techniques and in this module we will be discussing about the important part of the, this pressure measurement techniques that is dynamic response consideration and then we will slowly move to see how, what are the different methods available to measure pressure.

But, before I go to discuss about this dynamic response consideration, we will briefly review the definition of pressure and the different types of pressure that we have learnt from our school days. As such, the pressure measurement techniques we have learnt from our undergraduate fluid mechanics course, but we will briefly review a few of them which are common in use.

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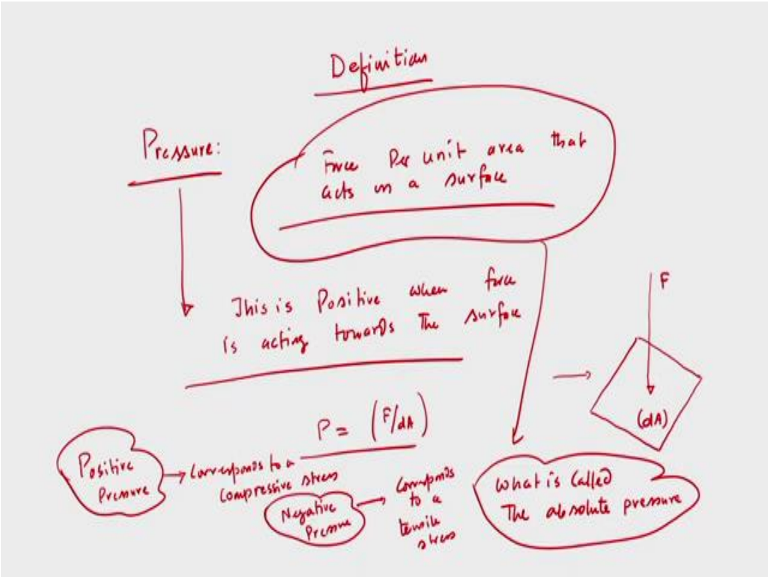

So, we start with the definition of pressure that is what we would like to measure and pressure is one of the important flow parameters we need to measure and in most of the fluid dynamic applications we measure pressure in dynamic condition, that is whenever fluid is flowing in a fluidic pathways, then we measure what is the pressure. Many a times we are interested in to measure pressure in the dynamic conditions.

So, now we can discuss that what is the definition of pressure? So, pressure that is what we know that pressure is defined as the ratio of force per unit area on a, acts on surface. So, now I am writing that again this is what we know from our school days that force per unit area that acts on a surface. So, this is the pressure that we have learnt. Now, see, this quantity is positive when the force is acting towards the surface.

So, this pressure this is positive when force is acting towards the surface. So, I mean I can define this with the help of a schematic depiction, say, we have a surface and say force is acting on the surface and the area is dA and this is force. Therefore, this pressure P is F by dA or I mean small dF, dF by dA, I can write that is F by this small area, so that is the definition.

Now, this quantity is positive whenever force is acting towards the surface and this definition of pressure gives us what is called absolute pressure. So, from this definition, from this definition that is force per unit area that acts on a surface from there we can rather this definition gives us what is called the absolute pressure, so what is called the absolute pressure, that is what will see.

Now, from this schematic that we have drawn here this schematic, from this schematic we can say that a positive pressure corresponds to a compressive stress while negative corresponds to the tensile stress. So, from this schematic it is clear that a positive pressure corresponds to a compressive stress, while the negative pressure corresponds to a tensile stress.

So, that means from the schematic we can write that a positive pressure which corresponds to, which response to compressive stress, while negative pressure corresponds to a tensile stress. This is the basically definition of pressure and which gives us what is called absolute pressure.

Now, in practice recognise it is often more convenient to define pressure with respect to another datum pressure that is what we have, we have seen rather in our fluid mechanics course, the undergraduate fluid mechanics course we have learnt that. It is often convenient to define pressure with respect to a another datum pressure that is atmospheric pressure and the measured pressure which is known as gauge pressure.

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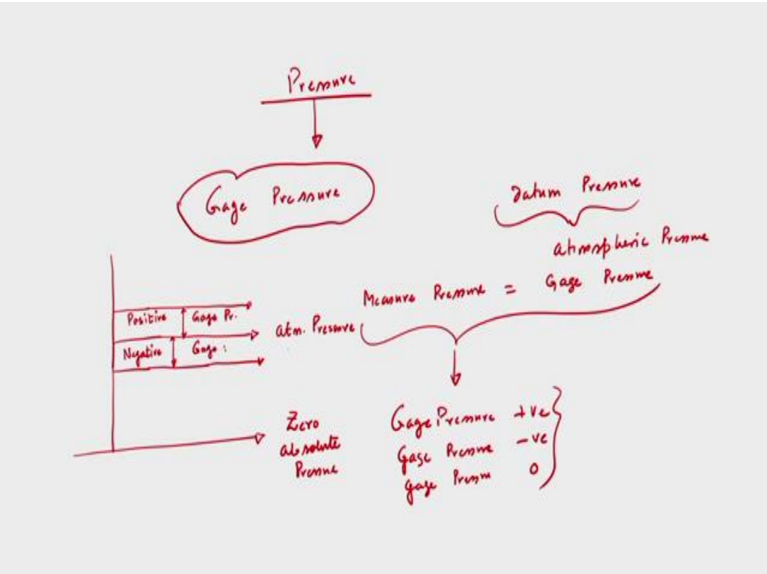

So, pressure that we have defined in the last slide that it is convenient to define with respect to another datum pressure that is atmospheric pressure and the measured pressure is known as the gauge pressure. So, basically gauge pressure that is another pressure we have now introduced.

So, gauge pressure we have now introduced, the absolute pressure, the concept of absolute pressure that is coming from the definition of the pressure itself and the gauge pressure that is mostly used in fluid dynamics applications and we measure many a times rather it is convenient to measure pressure with respect to another datum pressure that datum pressure is this datum pressure is the atmospheric pressure. And the measured one, measured pressure is gauge pressure.

So, we can say from this if we measure pressure with respect to another datum pressure that is atmospheric pressure the measured quantity is known as the gauge pressure. So, from this we can say that gauge pressure positive, gauge pressure negative, or gauge pressure 0. So, these three values we can have when you are measuring pressure in terms of gauge pressure.

That means, now, again we can show it through a schematic depiction that we have, this is a datum level and now this is the atmospheric pressure. So, this is atmospheric pressure and this is zero datum or absolute pressure. So, zero absolute pressure. Now, if the measured pressure is above atmospheric pressure, then it is called positive gauge pressure, but if the measured pressure is less than atmospheric pressure then it is called the negative gauge pressure.

And if we, if the pressure is measure is equal to the atmospheric pressure then gauge pressure is equal to 0. So, that means the pressure we measure is higher than the atmospheric pressure then this is called positive gauge pressure, positive gauge pressure. If the measured value is less than the atmospheric pressure then this is negative gauge pressure. But if it is equal to atmospheric pressure then gauge pressure is equal to 0.

In this context, I can tell that in most of the fluid dynamic applications we are interested in pressure difference, not the absolute pressure rather we are interested in the gauge pressure. But in thermodynamics applications, we are interested in the absolute pressure because we would like to calculate the density of a gas, not using a gauge pressure rather using absolute pressure. And also we will look up the data in the thermodynamic table which are obtained using (gauge), absolute pressure, not the gauge pressure.

So, with this we have briefly reviewed our understanding on pressure, the pressure which is, what is the definition of pressure and then what are the, what is the absolute pressure, what is the gauge pressure and since in this course we will be largely focusing on different techniques which are important in the in fluid dynamic applications. So, that is why I told you that in fluid dynamic application gauge pressures, gauge pressure is commonly used rather measurement of gauge pressure is commonly used. And but in thermodynamic application we are interested in measuring the absolute pressure.

Now, while we have identified what is gauge pressure, what is absolute pressure and we have identified that gauge pressure is important in fluid dynamic applications and absolute pressure is important for thermodynamic application to define or to calculate density of a gas or different other properties which are there in the table. Now, we should know that gauge pressure, how we can measure and if we would like to measure gauge pressure then what are the difficulties associated with the measurements, can we measure absolute pressure, if we cannot then why we cannot measure absolute pressure.

And then we will briefly review our, we will review up different techniques which we have learnt from undergraduate fluid mechanics course. And then we will move to see, how we can measure using techniques if their pressure difference is very small, that is very important in different fluid dynamic applications. Now, what I can say that the gauge pressures are relatively very simple rather I mean they are very (sim) easy to measure and they can be measured accurately using any pressure transducer or differential manometer.

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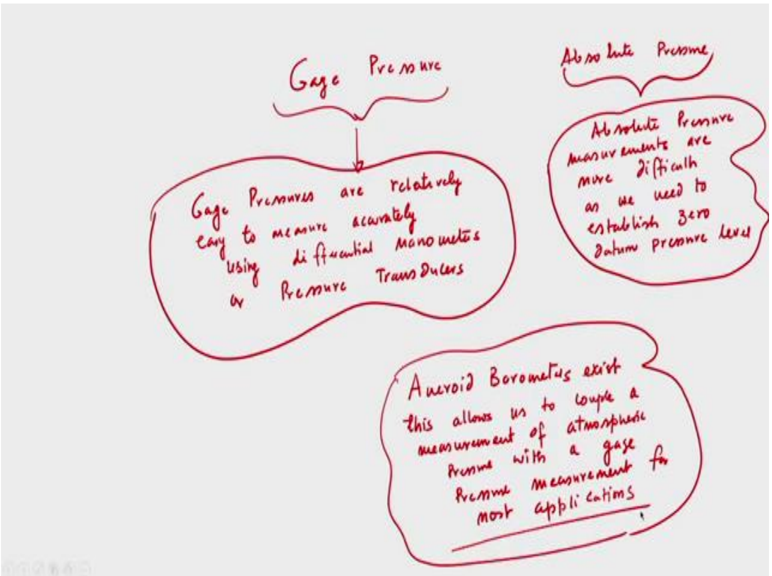

So, gauge pressure that is what we have defined, gauge pressure and we have also defined the absolute pressure, gauge pressures are relatively easy to measure using any differential manometer or pressure transducer, not only that they can be measured more accurately. While, absolute pressures are very difficult to measure. So, I can write, this is very important that you should know and because largely we will be focusing on different methods, different techniques which to obtain gauge pressures.

So, basically the gauge pressures are relatively easy to measure accurately using differential manometer or pressure transducer. So, this is the gauge pressure measurement, we will discuss that different techniques which are common in use briefly review those. And then of course we will discuss about other measurement techniques, pressure measurement techniques which, from where we can measure, we can get even a small pressure difference in different fluid dynamic applications. While absolute pressure is more difficult rather measurement of absolute pressure is more difficult.

So, absolute pressure measurements are more difficult in the sense that we need to establish a zero datum level. So, this is more difficult as because we need to establish zero datum level. So, this is more difficult as we need to establish zero datum level, pressure level. So, this is not so easy, but fortunately we have aneroid barometer, rather we can say aneroid barometer exist that allow us to measure absolute (measu) pressure with a gauge pressure measurement in most of the applications.

That means through aneroid barometer we can obtain absolute pressure rather this aneroid barometer allow us to couple the measurement of absolute pressure with a gauge pressure measurement in most of the applications. So, I am writing although it is difficult to measure because we need to establish a zero datum pressure level, but aneroid barometer, aneroid barometers exist and this barometer allows us to couple the, a measurement of atmospheric pressure with a gauge pressure measurement for, with gauge pressure measurement for most applications.

So, this is there, so using aneroid barometer we can, this barometer allow us to couple the measurement of a atmospheric pressure with the, with a gauge pressure measurement for most of the applications. So, even though absolute pressure measurement is very difficult but still we can have, we can measure because of this aneroid barometers.

So, with this, so we have understood what is gauge pressure, what is absolute pressure, why gauge pressures are relatively simple to measure and we can measure accurately using differential manometer or pressure transducer. But absolute pressure measurement is not, is not a easy task rather it is not an easy task, we need to define, we need to establish zero datum, zero datum pressure level.

But because of this aneroid barometer we can measure because the barometer, aneroid barometer allow us to couple the measurement of atmospheric pressure with the measurement of gauge pressure in the most of the applications. Now, as I said that we will discuss rather we will review different pressure measurement techniques, pressure is one of the important flow variables in most of the (appli) fluid dynamic applications we need to measure pressure.

But we will review those which are common in use, which we have understood, which you have studied in undergraduate fluid mechanics course, but we should know different other techniques through which we can measure even a very small pressure difference. And we will identify that there are many other applications, fluid dynamic applications where you need to measure very small pressure difference and that will see.

But before we go to discuss those techniques, today I would like to discuss another important point which is inevitable with the pressure measurement techniques that is called dynamic response consideration. That means this dynamic response consideration is inherent with all the pressure measurement techniques available, but we cannot completely eliminate this, there are few issues with the measurement techniques of dynamic pressure as I said you that in most of the fluid dynamic applications we have to measure dynamic pressure.

And while we are measuring dynamic pressure then there are a few issues which we cannot eliminate but we can reduce the effect of those issues while measuring pressure. One of the important consideration is that dynamic response consideration. Many times we call it transient response considerations.

So, today I will discuss about what is dynamic response considerations and why you need to know this, we need to know this to design a pressure sensor, pressure transmitter, pressure transducer and also we need to know it while you are measuring, while you are using any pressure measuring device equipment to measure pressure.

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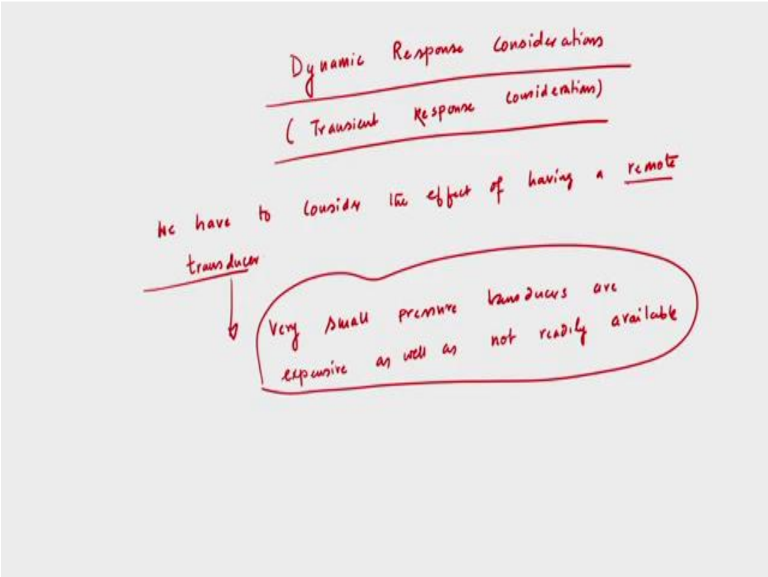

So, that is why today we will discuss about rather we should know about the dynamic response considerations or it is also known as transient response considerations. Now, as I said that why you need to study it? It is important to design the pressure sensor, pressure transmitter but also it is important, equally important to know when you are using those transducer, transmitter to measure pressure in fluid dynamic applications.

See, we measure dynamic pressure, now, so in a fluidic confinement, in a fluidic pathway fluid is flowing and we want to measure pressure. So, what will do, we will take a pressure tap. Now, if I somehow mount a pressure transducer or pressure transmitter exactly at the place where you would like to measure pressure, perhaps we can eliminate the possibility of having a few issues which may, which lead to error in the measurement or calculation of the pressure.

Now, it is not always possible that we can mount the pressure transducer, pressure transmitter at the place or at the spot where I would like to measure pressure rather we need to have remote pressure transducer. Now, I said that there are a few issues and which are very important, one issue is that pressure fluctuations.

So, basically a pressure whenever we are measuring dynamic pressure, pressure fluctuations will be there, we cannot trivially note them, we cannot eliminate them, but our targets would be to reduce the pressure fluctuations and we need to take several preventive measures so that we can reduce the fluctuations essentially to have accurate measurement of the pressure.

Now, if we can rather we have small, very small pressure transducer and which can be mount at the place where you would like to measure pressure. So, that means we have very small pressure transducer, very small pressure sensor and which can be mounted at the spot where I would like to measure pressure.

And then perhaps the issues of dynamic fluctuations, I mean issues which are responsible for creating developing fluctuations in the dynamic measurements can be minimised. But, in many cases we cannot have such small pressure transducer and rather small pressure sensor and we need to go for remote pressure transducer.

Because the small pressure transducer, small pressure transmitters, sensors are very expensive and those are not readily available. So, they are very expensive as well as they are not readily available and because of that we need to go for remote measurement that means we need to take a tap and from where we can measure pressure after that means we should have a (suffi), at a particular length of the pressure measuring device or pressure transmitter.

Now, I will discuss this taking example and then through a schematic depiction we will show that what is done in normal practice, how we can measure pressure and when we are measuring pressure using this kind of, these kinds of pressure transmitter, pressure sensors then how the dynamic fluctuations are coming into the measurement system and then what we can take (precau) what will be the, what will be our objectives to reduce those fluctuations, mind it we cannot eliminate those fluctuations.

So, to do that, now I will draw schematic and then I will explain from where the fluctuations are coming and if you really want to reduce the fluctuations then what we need to take what precautions we need to take. So, I can, I am drawing that a typical pressure transmission system that means is a remote pressure transducer. That means we have to consider the effect of having a remote transducer. That means we cannot mount the pressure transmitter exactly at the, rather at the spot where I would like to measure pressure. We have to have the effect which are because of the remote sensing.

So, now I can write, we have to consider the effect of having a remote sensor, the effect rather I can say effect only, not effects, effect of having a remote transducer. Because the remote, I am using this two word remote transducer because small, very small pressure transducers are there but they are not readily available and they are very expensive, are expensive as well as not readily available.

And because of this we need to go for a remote transducer. If we have a small pressure transmitter then we can just put that transducer exactly at the place where we would like to measure pressure and then perhaps the effect of the remote sensors, remote sensing that will be there and we can have accurate measurement. Now, so in the next slide we will discuss that the pressure measurement through a remote sensor.

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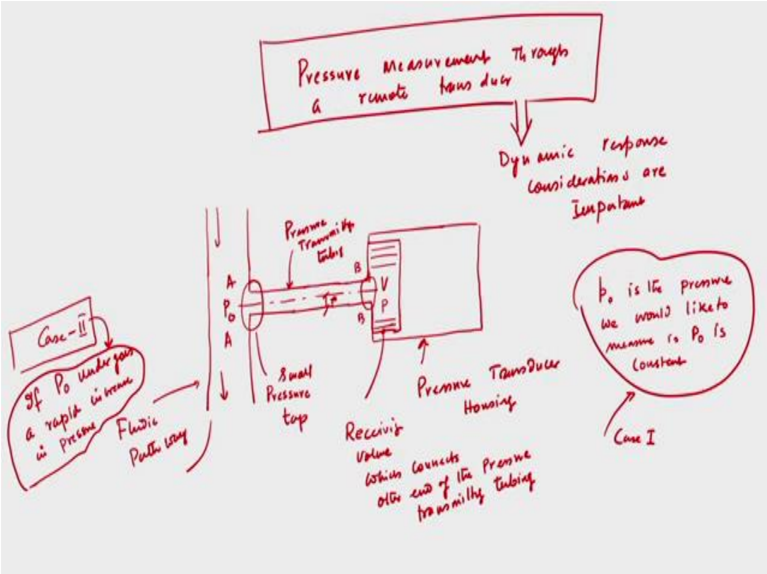

So, pressure measurement through a remote transducer and while we are measuring using, while you are measuring pressure using remote transducer then the dynamic response considerations are become important, considerations are important. Now, we need to know why, why it is important.

So, I will draw a schematic say we would like to measure pressure where fluid is flowing in a tube or fluidic pathways and what we can do, we can take a small pressure tap, so we can take a small pressure tap. And this tube which are tigan tube or other tubing. So, one end of the tube which is connected at this pressure tap, so this is pressure tap, small pressure tap.

And other end of the tube is connected with the receiving end of the transducer and this is like this. Now, so this is receiving, small receiving volume and this volume is V, this volume is V and pressure is say P and this is the transducer and this is actually known as, this is known as pressure transmitter housing, so this is pressure transducer housing, pressure transducer housing.

And this is basically a small volume, this is a receiving volume, receiving volume of the fluid which connects other end of the pressure transmitter tubing, pressure transmitting tubing. So, this is basically pressure transmission, transmitting tubing and this is radius R, so this is pressure transmitting tubing.

And this is receiving volume and this transmitting tubing has two ends, one end is connecting say this is A A end, this is B B end. Now, this is one rather most commonly used, all pressure transducer have this kind of structure that it is having three different parts, on its pressure transmitting tubing, which is correct, which, one of which is connected to the small pressure tap, other end of this tubing is connected to the receiving volume which actually you know collect liquid volume, fluid volume.

And then this receiving volume is integrated with another big parts which is known as and these two constitute together to form the pressure transducing housing. Now, if the pressure at the (())(34:47) in a pressure tap is P naught and if you would like to measure pressure, then transducer is there so that will measure pressure, if the pressure at the end A is P naught, we can measure, and that is constant.

So, now question is if P naught is the pressure that we would like to measure, pressure we would like to measure and P naught is constant. So, this is the case 1, so this is case 1 that P naught is the pressure that we would like to measure and which is constant. We can measure that pressure using this pressure transducer without any problem. But we have to wait until the equilibrium is (())(35:48).

If say, another case, I am writing another case 2, that if rather now consider what happens if P naught undergoes a rapid increasing pressure that means this is fluidic confinement we really do not know because fluid is flowing, say, this in this fluid is flowing. So, this is fluidic confinement, fluidic rather I can say fluidic pathways, fluidic pathway.

And fluid flow is taking place from top to bottom I do not know, if it is horizontal then fluid is taking place from left to right or right to left. Now, if P naught is constant that means flow velocity is constant and then you can safely measure P naught using this pressure transducer without any problem.

Of course we have to wait until the (sys), until the system comes in equilibrium condition, rather comes to the equilibrium condition. But what will happen if P naught the pressure which we would like to measure, if P naught undergoes a rapid increase in pressure. Then, because of rapid increment that is highly possible because, because of the condition, where, because of fluid flow condition dynamic evolution of the fluid flow, dynamic condition of the fluid flow that may, that is highly possible.

So, now if you would like to measure that pressure that when P naught suddenly increases to a value, then what will happen if we construct the system physically? Because of this incrementing pressure that is P naught plus delta P naught, what will happen. The receiving pressure, receiving unit is always receives liquid and the pressure P will come.

See, if we consider now the first case, case 1. So, pressure is P naught, receiving unit will collect volume and the P pressure eventually will come to the P naught after sometime and then we can record. Now, case 2, that it P naught undergoes a rapid increase in pressure. So, if P naught undergoes a rapid increase in pressure, rapid increase in pressure, this is case 2, then what will happen?

So, because of this pressure we could system, because whenever we are measuring P naught then of course receiving volume, receiving fluid also will have P naught. Now P naught plus delta P naught if that is there at the end A, then because of this pressure difference some fluid mass will try to flow form A A end to B B end.

So, whenever the fluid mass is flowing by virtual pressure difference from end A A to from B B and it will be the fluid mass will be collected at the receiving a part of this pressure transducer unit, what will happen? This is very important that the mass of the fluid will vibrate, but the rapid increase in the pressure, so fluid mass will move but it will vibrate, but the fluid friction will try to dampen out the vibration.

So, because of that there will be fluctuations, but that fluctuations you cannot reduce, you cannot element that is there in the situations, I mean we have to accept that and the pressure transmitter will be capable to measure pressure even in that condition when this kind of situations will be there, I mean because of sudden increment in pressure.

So, fluid mass will enter, it will vibrate while the fluid friction will try to dampen out the vibration. Now, we need to know, also very important is that the fluid mass try to vibrate and the fluid mass will try to move towards the receiving unit and the process requires certain amount of time and to come in equilibrium condition the time which it will take by that time it will the system will fluctuate.

So, it will take some time to come in the equilibrium, come to the equilibrium state and that time period is very important and the time period there will be fluctuations. So, we need to minimise the fluctuations because of this movement of the fluid mass and now the time which the system will take to come to equilibrium that will depend upon the fluid and also the geometry of the system.

Because that is what I would like to emphasize through this, in this discussion that this is not a system that because is remote sensing. So, we should have pipe, we should need a particular length of the tubing, we cannot make them 0. Because we cannot connect the transducer at the spot itself, this is not possible.

Now, so, now depending on the geometry of the system as well as the fluid properties the time required to come to the equilibrium will depend, I mean will defend. Now, if we allowed a system to come to the equilibrium by that time it will fluctuate, the fluid in the transmitting tube will start fluctuating and because of that we may not get the correct results. Even if you get the signal that single will be the, you will get signal which is fluctuating through the transducer.

Now, we need to know how we can minimise the signal even knowing the fact that we can, the pressure transducer has to face this kind of situations very often. Now, what I said that the fluid mass will try to vibrate, fluid friction resistance will try to dampen out the vibration. And the friction which is very important.

So, the time period that the system will take to come to the equilibrium by that time the fluctuation will be there. So, we need to measure what is the amount of friction and that will depend upon the fluid properties, fluid properties of the, field of the transducer. So, now can be measured using the friction which is required to dampen out the vibration and that can be measured using lemina frictional resistance. And this analysis leads to the one pressure amplitude ratio between the measured pressure and the true pressure.

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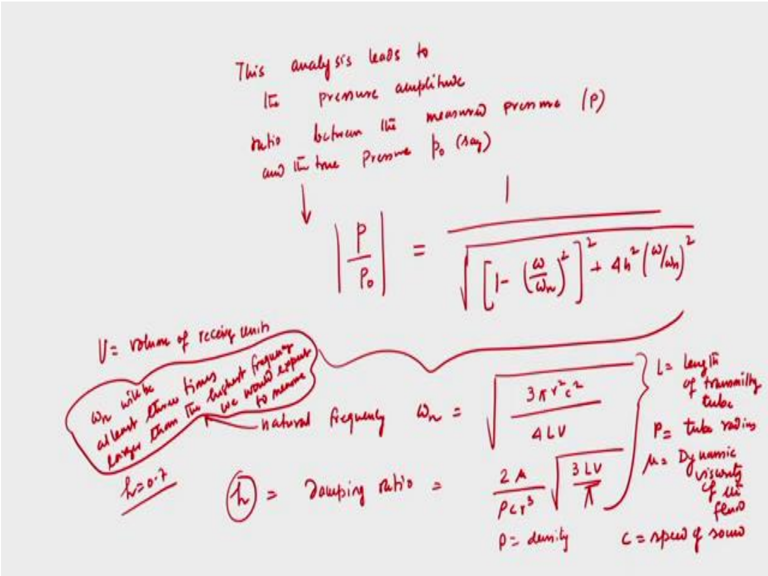

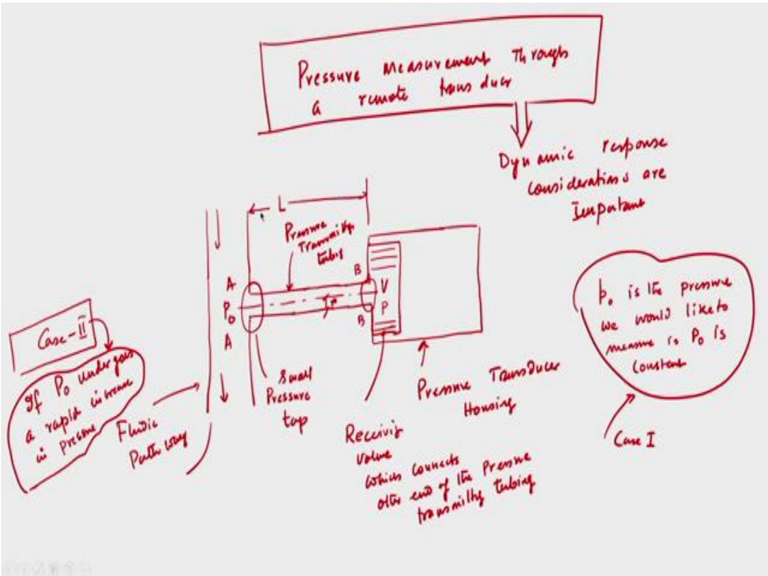

So, this analysis leads to the pressure amplitude ratio between the measured pressure and the true pressure, between the measured pressure say P and the true pressure and the true pressure say P naught say. And that is given by P by P naught mod that equal to 1 by root of under root of 1 minus omega by omega n square total whole square plus 4 h square into omega by omega n square.

Now, for your information that the derivation of this equations what I said that system will take certain time to come to equilibrium, by that time because of the movement of the fluid mass inside the transducer will leads to, the rather it will induced vibration, but the fluid vibration will be, but the fluid (resis) frictional resistance will try to dampen out the vibration and the frictional resistance which is required to the dampen out the vibration that can be calculated using laminar frictional resistance.

And that analysis leads to the (ampli) pressure amplitude ratio between measured pressure and the true pressure and that is given by this. The derivation of this equation is beyond the scope of this course, but I can say that this behaviour is typical of any second order system. So, that is beyond the scope of the course.

Now, in this this is the equation, where we can see that omega n which is the natural frequency. So, this is natural frequency omega n that can be given as 3 Pi r square c square divided by 4 L into V, where if I go back to my schematic then this L is the length of the, L is the length of the tube and R is the diameter that I have already indicated in the schematic, but so this is the natural frequency.

We will see this natural frequency has a big role to play to control the fluctuations that is appearing. So, essentially because of this fluctuations the signal that we will get from the transducer that will have fluctuations that single will have fluctuations, so but we need to minimise the fluctuations that is for accurate measurement of the pressure.

Now, and this h is the damping ratio that is twice mu by rho c r cube root 3 LV by Pi, where this L is the length of the tube of transmitting tube, r is the tube radius, mu is the dynamic viscosity of the fluid, and c is the speed of sound and V is the volume of the receiving unit, V is the basically we have already defined the volume of receiving unit, other things we have already defined. And what is, this is Pi, 3 LV divided by Pi. So, this is the expression between the measured pressure amplitude ratio between measured pressure and the true temperature.

Now, see, this natural frequency should be larger rather much larger than the signal frequency which will be measured, which we need to measure because ultimately we will get signal from the transducer that frequency of the signal will be much much less than the natural frequency of the system. And this is the damping ratio.

So, I forgot to write rho is the density, so rho is the density of the fluid, very important is that that if you look at the natural frequency expression we can see that if we increase r that is diameter of the tubing if we increase natural frequency will increase and that is very much important for this analysis to obtain the correct results that means to obtain that the signal which you will record from the transducer will not have any (signa) fluctuation.

Now, if we increase the radius of the tube then natural frequency can be increased that is important but if we reduce the length of the tube that is also important for the presence, rather this pressure transducer because we can increase natural frequency. So, here again I can tell you that if I can reduce the length that means I am reducing the tubing length. So, as if the transducer is, not remote transducer rather we are trying to have a transducer which can be located exactly at the place where you would like to measure pressure.

That is what I said that very small pressure transducer. So, if you reduce the length of the tubing natural frequency can be increased, if I increase natural frequency of course the disturbance vibration which is coming because of the sudden pressure difference, sudden pressure rise mostly certain amount of fluid mass will try to enter into the system and that leads to that will leads to vibration. So, we need to dampen out the vibration, if we would like to dampen out the vibration, I mean only way is that we have to increase the natural frequency of the system.

How we can ensure that? We can ensure that by increasing the radius of the tube as well as by increasing the radius of the tube and by decreasing the length of the tubing. So, this is they are the very important points to note that while someone is designing pressure transducer because we know that in most of the cases we need to have a remote sensing, remote sensor.

And when we are having remote sensor we need to take into account the effect rather affects those may arise because of this remote sensing. And, today I have explained that one of the important effect is that, that is we cannot eliminate that is there, that because of the sudden rise in P naught there will be sudden fluid mass that will try to enter into a system because of the pressure difference.

And that will lead to vibration of the fluid mass in the tubing and that will leads to fluctuations in the signal and we may not get the correct results. But today I can write that this behaviour is as I said you that is not beyond, that is not in the, that is not within the scope of this course, but this is typical of a of any second order system.

And by analogy, we want the damping h this by analogy we want the damping h to be approximately 0.7. So, h to be approximately 0.7 for the system and natural frequency that is omega n, this omega n that should be much larger than the highest frequency at least 3 times, this natural frequency will be 3 times, will be, will be equal to 3 times higher than the natural frequency, will be at least 3 times larger than the highest frequency, larger than the highest frequency we would expect to measure, we would expect to measure.

So, this is, these are the two important points we should keep in mind. From this discussion I can tell another important thing that speed of the sound which is function of time and it can be readily, it cannot be readily adjusted. Now, similarly, fluid properties should be taken in such a way that the phenomenon that is there, so can be readily adjusted either through fluid properties or through the system parameters that is fluid properties means viscosity and density that is there again in the expression of damping ratio.

And the system parameters are geometrical parameters of the system that is striving radius and length and that is clear, that can be clearly seen from the expression that during radius has to be larger and length should be smaller. So, if we have very larger radius of the tubing and very small short length then it is good for the system rather it is good for the accurate measurement of the pressure using this transducer.

And lastly I would like to conclude that the transient response of the pressure measuring instrument depends upon two important points. So, today we have discussed about dynamic concentrations, transient concentrations, we have identified why it is important, then we have also identified that what are the steps we should know at least to minimize those, so that we can have almost accurate measurement of the pressure even in the dynamic condition. But before I conclude it, I would like to mention two important points and rather the transient response of pressure measuring instrument depends upon two important points, those are.

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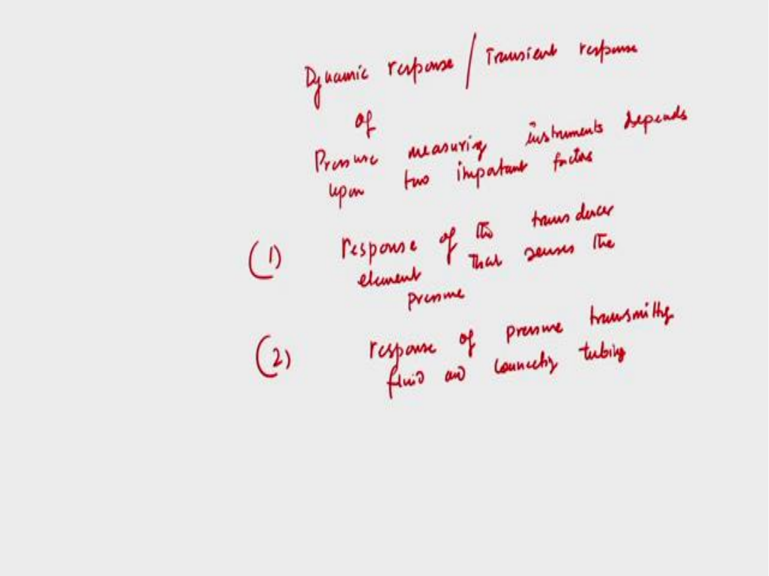

So, dynamic response or transient response of pressure measuring instruments depends upon two important factors. One is response of the transducer element that senses of the pressure. And number two, response of pressure transmitting fluid and connecting tubing. So, number two is very important and that is what we have discussed today that either through the fluid properties and the geometrical parameters that is length of the tube and radius of the tubes, those are very important for the dynamic response or transient response of the pressure measuring instrument.

So, at least the discussion on these dynamic response considerations or transient response considerations will help us to understand that when someone is designing a device to measure pressure or someone is using a pressure, any pressure transducer or pressure measurement instruments, he or she should know that these dynamic response concentrations are important you need to take into account.

And at least the sources from where the, these fluctuations are coming and we need to minimise those. And also discussed that by how we can minimise. So, next we will discuss about that pressure measurement techniques, different device, different devices, different instruments of course essentially to see how can measure gauge pressures.

And we will briefly review different instruments that we have studied in our undergraduate fluid mechanics course which are common in use and finally we will have to see how we can measure accurate or very accurately a small pressure difference of course gauge pressure using a special method of pressure or technique in the next class. With this I stop my discussion today. Thank you.