Experimental Methods in Fluid Mechanics
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Module
Lecture 15
Pressure measurement using 3 holes probes

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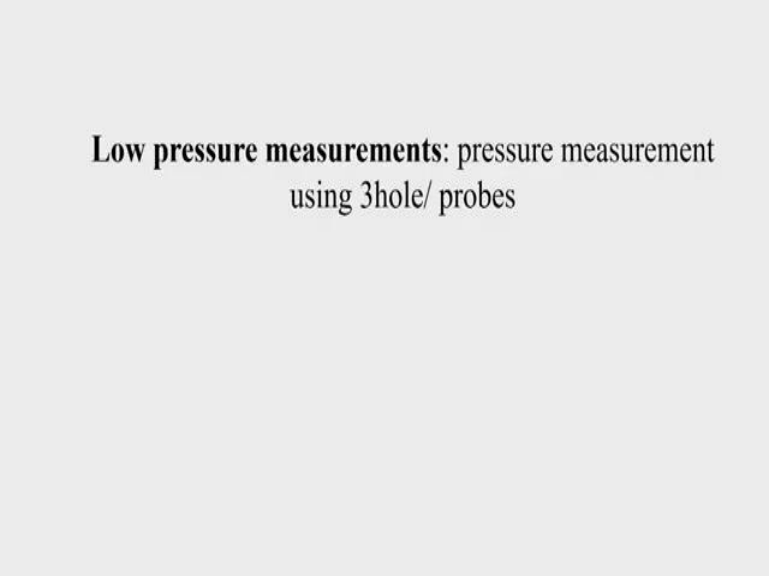

Good afternoon, I welcome you to this session of Experimental Methods in Fluid Mechanics. Today, we will discuss about pressure measurement using probes, how we can measure pressure using multi-hole probes. And we have discussed in my last few lectures, the measurement of pressure using gauges and we have seen that we can measure pressure using gauges and that range of pressure which you can measure maybe very small to very large, and for that, we have discussed about the operational principle of different instruments.

So, today we will discuss about another instrument which is used to measure pressure. And we will see today that this instrument rather I mean, this probes multi-hole probes are used in the area of fluid mechanics, in the area of experimental fluid mechanics to be precise with having some advantageous features. So, we should know that if we use measurement probes, why these proofs are important rather why these probes are very common in measuring several flow parameters that will know.

Multi-hole probes has become very common to determine different flow parameters like total pressure, static pressure, flow velocity, and most importantly the flow angles even in a 3 dimensional flow field. So, not only that, the probes we have seen that using gauges we can

measure pressure, gauge pressure we can measure, but the use of probes allow you know us to measure simultaneous detection of total pressure, static pressure, flow angles, flow velocity.

Now, and these mechanical probes are having a few advantageous features over other pressure measurement, pressure measurement instruments like the simple in operation, then low cost and also their maintenance is not very difficult. So, today, we will see that we can use pressure using multi-hole probes, but we will restrict our discussion in using 3 hole and 4 hole probes.

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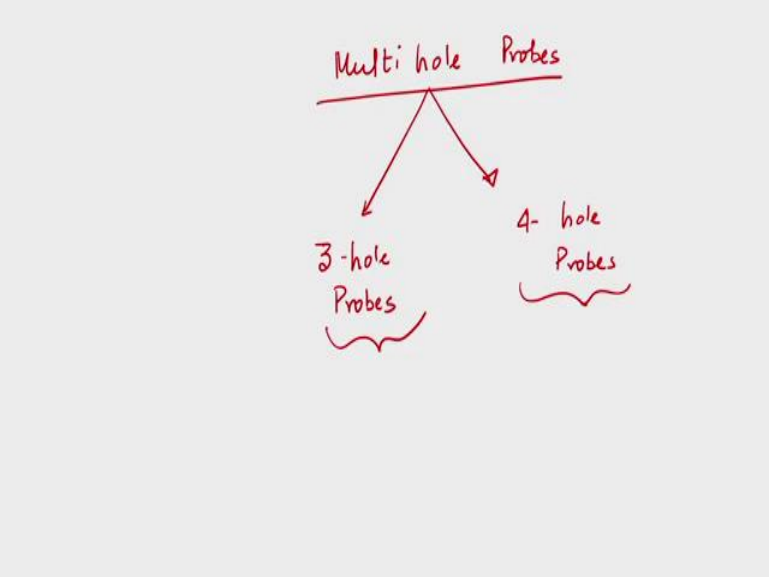

So we will discuss multi-hole probes and we will discuss about two different probes that is 3 hole probes and 4 hole probes. So, as I said that these probes are important, because using this instrument we can have simultaneous measurement of static pressure, dynamic pressure, flow velocity as well as, which is very important in the area of experimental fluid mechanics is that the how we can measure flow angles. So, these parameters can be measured simultaneously using multi-hole probes.

So now, as I said that we can measure static pressure, we can measure total pressure, then measuring this total pressure we can measure the flow velocity, we will see how we can. Now before that, just we will try to recapitulate, you know we have learned from our undergraduate fluid mechanics course, what is static pressure, what is total pressure? And now, in continuation of that, today I would like to discuss about that you know, what is static pressure probe, what is stagnation pressure probe?

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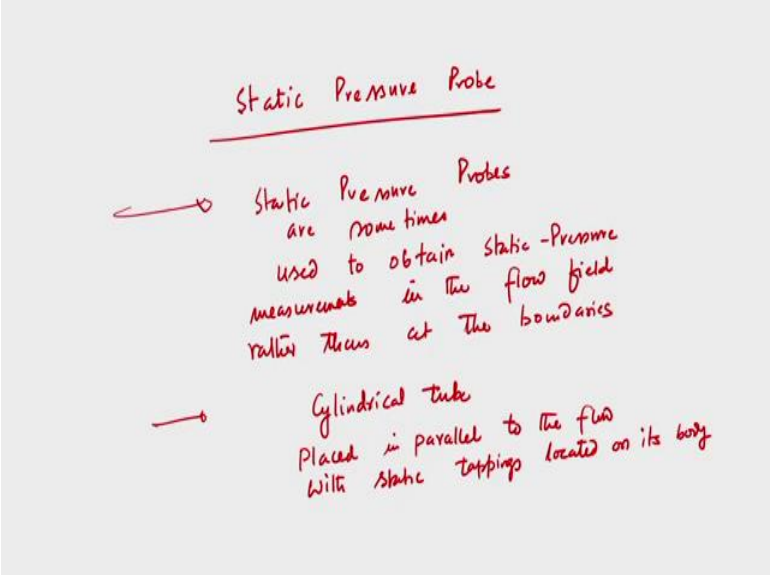

So, first of all I would like to discuss about static pressure probe. So, I will write the, you know, what is static pressure probe and what are, the name suggests that we can measure static pressure and we will see that if we I mean the problem is having facilities so that we can measure static pressure, stagnation pressure, flow velocities and flow angles. So, this static pressure if you would like to know the static pressure using probe then perhaps how we can visit rather what will be the construction of the probe and the operational method I mean principle by how we can measure static pressure that is what I would like to discuss now.

If you would like to measure static pressure, so I am writing then it will help you to understand the operational principle of the probes in a better way. So this static pressure probes are sometimes used to obtain static pressure measurement that is obvious that is obvious because the name itself suggests that we can measure only the static pressure. So, that static pressure probes are sometimes used to obtain static pressure measurement where. So, we can use this in the flow field rather than at the boundaries.

So, this is one aspect so if you would like to measure static pressure using probe we cannot measure at the boundaries rather we can measure at the place which is far away from the boundary that is in the flow field. Now, this static pressure probe largely in cylindrical shapes, I mean these probes are cylindrical tubes and these probes are placed basically these probes are placed in parallel to the flow with static tappings located on its body.

So, we have to place the probes, which is I mean placing should be in parallel to the flow field and the probe itself should be having static tapping. A variety of configurations are

available with shapes conical, cylindrical, but the objective is that we should place the probe which is in parallel to the flow field and we should have a pressure tapping otherwise we cannot measure static pressure.

So, now question is, if we do not place the probe in parallel to the flow field then what will happen? If we do not place the probe which is you know in parallel to the flow field, we will not get the correct results. Now, another important condition is that since we need to place, rather we should place the static pressure probe in parallel to the flow field, so we cannot use this probe in places where the velocity gradients are very large and turbulence is there.

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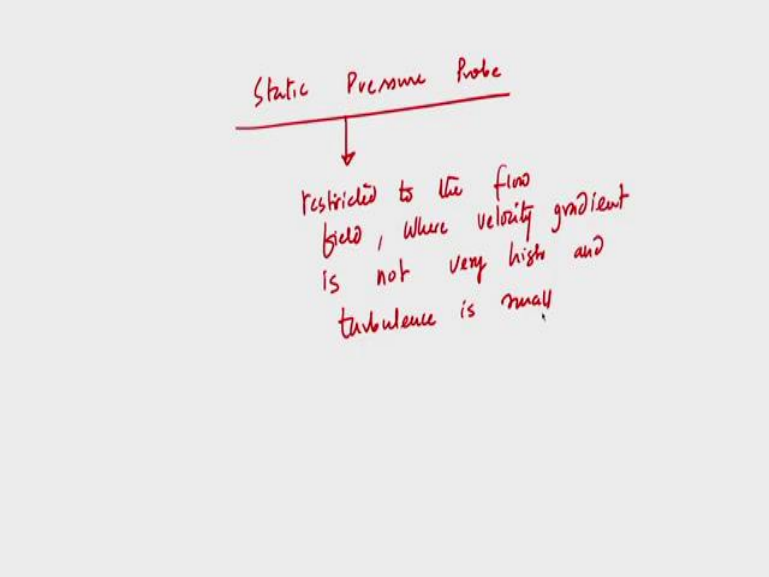

So, basically this static pressure probe is having restriction that means, this probe is not suitable for the places where flow field is highly chaotic and there exist a velocity gradient, so this is not suitable. So that means, I can write this is restricted to the flow field, where velocity gradient is not very high and turbulence is small, so this is what is static pressure probe.

Now, so we have seen that static pressure probe is used to measure static pressure and important condition is that we need to place the probe in parallel to the flow field, the probe axis should be in parallel to the flow field. And since we cannot place it in perpendicular to flow field then we can see rather we can understand that the use of static pressure flow is restricted to the flow field where velocity gradient is not very high and turbulence is small. So now, we will see what is stagnation pressure probe?

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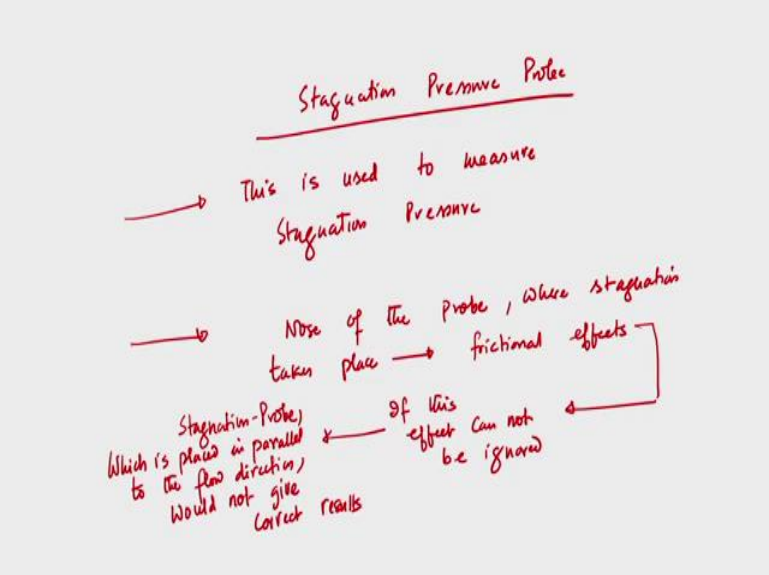

Now, second is stagnation pressure probe. So this probe is used to measure stagnation pressure, the name suggests. Now, this is used to measure stagnation pressure, another thing is that see since it is used to measure stagnation pressure so again, we have to place in a flow field where that means axis of the probe should be parallel to the flow field? And now question is at the point, I would like to measure this stagnation pressure, the positioning of the probe will definitely disturb the flow field, there is no doubt about it.

So, basically, if you would like to measure stagnation pressure at the point using this probe, so the positioning of the probe will definitely leads to a disturbance in the flow field. And if it disturbs the flow field, then the measurement which we will take, that may not be the correct one. So, we need to be careful while we are using this flow to measure stagnation pressure.

Now, I will try to discuss what are those, the you know, special attention rather what are those precautions we need to consider while we are placing this probe to measure the stagnation pressure. We are going to measure standards and pressure, so there will be you know the point how we would like to measure the stagnation pressure. So, we will see through a schematic depiction that these are probes multi-hole probes.

So, which hole is used to measure stagnation pressure and as I said that the positioning of the probe will try to create disturbance in the localized flow field. So there is a possibility of having heating this is because sudden stop of the flow velocity so that is known as in the zone which is nose, nose of the probe where stagnation takes place and the effect of measuring this stagnation pressure will results in a frictional heating or I can write frictional effects.

But this frictional effect can be ignored, if it is no uniform steady flow, but always we cannot ignore it. So if this effect cannot be ignored, then this stagnation probe which is placed in parallel to the flow field to the floor dejection, flow field is not the correct word rather the axis of the probe is parallel to the flow direction would not give correct results.

So, that means what we understood that in most of the cases if the flow field is uniform and steady then if we place the probe, whose axis is parallel to the flow direction, then we can ignore the frictional effect, but in most of the cases we cannot ignore the frictional effect that means, the nose where the probe is placed hole is placed where the stagnation takes place because of the frictional effect the flow field would disturb locally will not be able to measure the pressure correctly. Now, if that is the case, then what we can, we should consider to get the correct measurement using the probe we should know.

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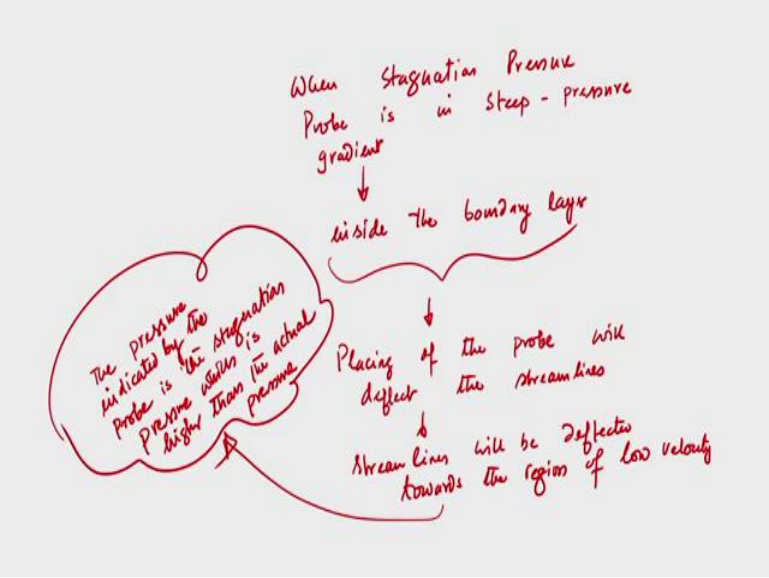

So, when stagnation pressure probe is in the, you know diff in the flow field I can write that in the steep stagnation pressure gradient, is in steep pressure gradient which is very common, we know rather you all know that the typical example is inside the boundary layer. So, inside the boundary layer what will happen? So, if we place a stagnation pressure probe in the region where we have steep pressure gradient, a cover example is inside the boundary layer, then what will happen?

The positioning of the probe will try to deflect distort the streamline and the streamline will try to deflect towards the region of low velocity. So, this if we place this probe knowing fully that in that region velocity pressure steep pressure gradient exist when we are placing the

probe then the positioning of the probe will try to deflect the streamline and streamline will get deflect towards the region of low velocity. Eventually what will happen?

If the streamlines are deflected in the region of low velocity, the probe will definitely give you the measurement of the pressure. But, but the measurement that is recorded by the probes will not be the correct one rather it will give the higher you know measurement of the in the higher side. Then placing of the probe rather I can say will deflect the streamlines and the streamlines will be deflected of low velocity and this effect, the ultimate effect of this phenomenon is that the probe, rather I can write the pressure indicated by the probe is this stagnation pressure which is higher than the actual pressure.

So, this is the ultimate effect we will have that the pressure indicated by the probe will definitely be the stagnation pressure, but the pressure will be the higher than the actual pressure, so this is one aspect. Now, I said that stagnation pressure probes, the axis of the probes are normally you know, probe is placed which axis upon the probe is parallel to the flow direction. Now question is, if we place the probe which is perpendicular to the flow direction, then what will happen?

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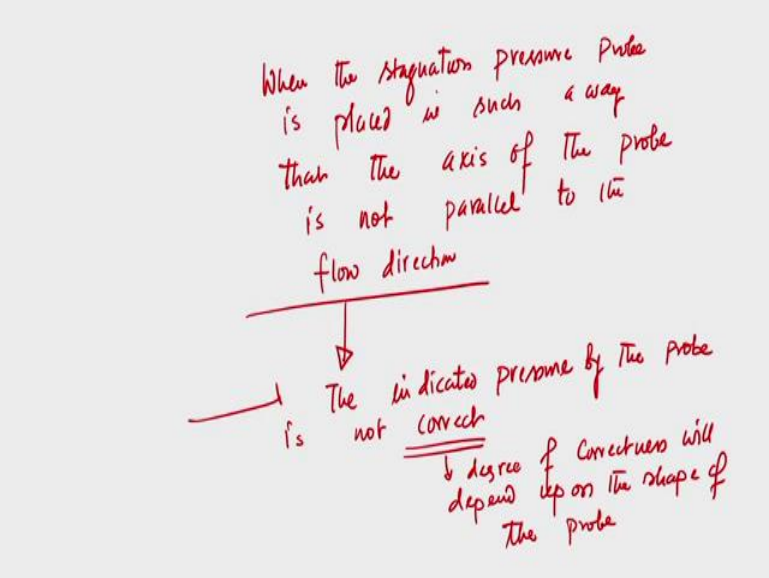

So, when the stagnation pressure flow is placed perpendicular or I can write in more generic way that when the stagnation pressure probe axis is placed in such a way that the axis of the probe is not parallel to the flow direction, then the straight answer is the measurement will be erroneous. So, the indicated pressure by the probe is not correct. So, that depends upon the

shape of the probe now the degree of wrong results rather not correct value that depends upon the shape of the probe.

So not correct I am underlining this word correct and the degree of correctness will depend upon the shape of the probe. See, most important advantage of having rather of using probe is that we can use we have seen that we can measure using gauges, we have discussed about different gauges starting from conventional one to the low pressure gauges which are used to low pressure measurement.

But this pressure probes as I said that these probes are used to determine simultaneous measurement of static pressure total pressure, most important is the flow angle because in the application in the turbo machinery. You know, hydraulic machines, we need to measure the flow angles. And in that case, the probes are very useful to measure those flow parameters because we can get all the measurement in the same platform.

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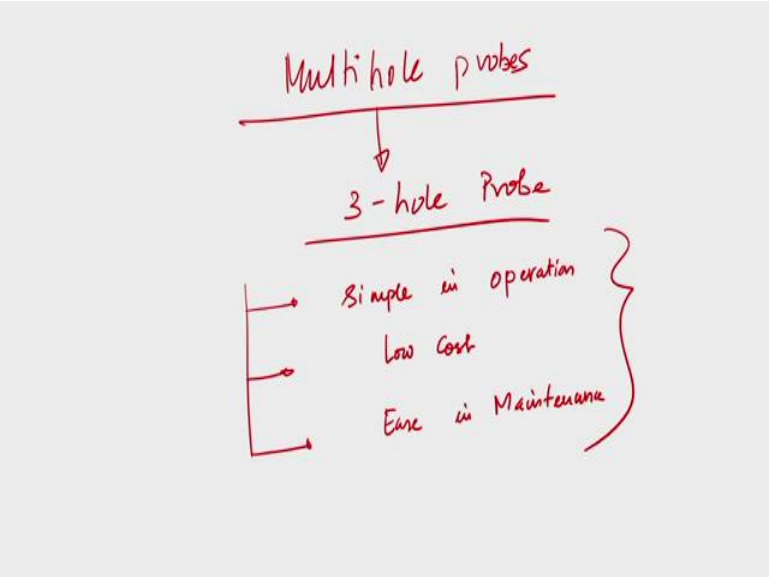

So now, we will see using, as I said that we are discussing about multi-hole probes. And multi-hole probes, so we will discuss about the 3 hole probes first, then we will see that using 3 hole probes rather 3 hole probes are having limitation and because of that, we need to go to discuss need to know the working principle of the 4 hole probe. Rather to overcome the limitation, which are limitations which are there in 3 hole probe to measure pressure and other flow parameters, the concept or the new design concept of 4 hole probe came and we will see that if we use 4 hole probes in fact 5 hole probes are there.

If we use 4 hole probes, we can eliminate the problem which is in having for 3 hole probes and how rather by suitability designing the 4 hole probe rather we can see the 3 hole and 4 hole in 4 hole probes we are having extra hole. So, with the inclusion of additional whole how we can eliminate the problem that is there with the measurement of pressure 3 hole probe. Now, but first we will discuss about 3 hole probes, but before that, as I said that multi-hole probes are more commonly used to determine several flow parameters.

Now not only that, this multi hole probes are having a few disadvantageous features as compared to other conventional pressure measuring instruments and those features are; one is simple in operation, low cost and easy maintenance. So, these 3 are the important advantageous features this multi-hole probes are having and because of that these probes are used.

Now, we will start our discussion using a 3 hole probe and we will see that if we would like to or we should know the construction of a 3 hole probe then only we will come to know what is the problem and if you would like to remove the problem, but we need another kind of probe then what will be the new design that the concept of 4 hole probe.

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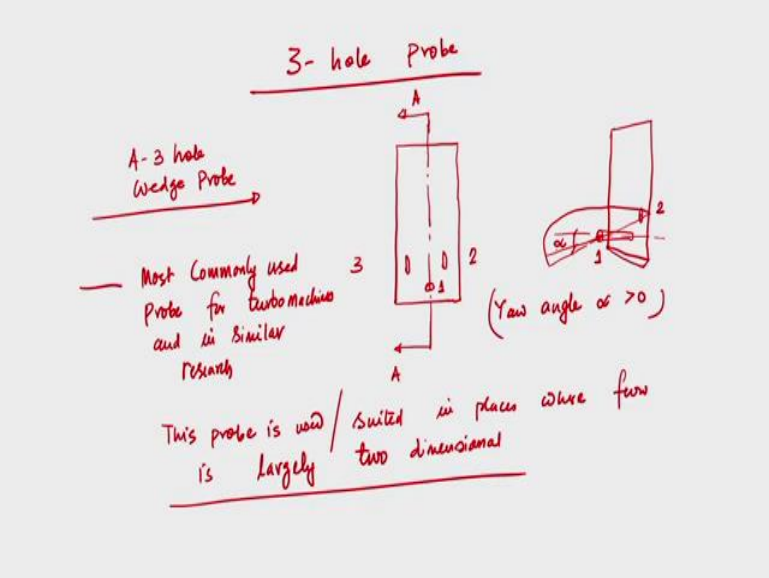

Now, the 3 hole probe I will tell schematically the construction rather the design of 3 hole probe and then we will discuss that what is the limitation of this 3 hole probe is having. This is well shaped 3 hole probe I am writing 3 hole Wedge probe. Now, this is one, this is two and this angle is alpha and this is known as Yaw angle, yaw angle alpha, which is greater than 0 as shown from the figure.

And so, see this is the construction of a 3 hole probe we can see, now there are 3 holes; 1, 2 and 3, one is the central hole and two and three are placed one his left side, other is right side about the axis of the probe. Now, alpha that is yaw angle because as I said that the probes are used to measure the flow angle. So two different angles we can measure that is yaw angle and the pitch angle. We will see that now the, you know this view is shown in the right side.

Now, question is, these three hole probes basically are not used nowadays because we found a figure itself it is saying that these 3 hole probe although they are most commonly used probes. So, this 3 hole probe I have drawn only the one shape but there are many other common sets available. Now, cylindrical and other things but these 3 hole probe which is mostly most commonly, most common used probe for turbo machine and in similar research.

So, this is nowadays it is not used, but it is I mean, it is most commonly used, but we will see soon that using this probe, we cannot measure one important flow parameters and because of that we need to you know modify the design of this 3 hole probe that is why the concept of 4 hole probe came now, but still it is most commonly used for turbo machine and similar other research. Not only the pressure, rather we also can measure the flow angle.

Now see, these 3 hole probe are suited in place where flow is are largely two dimensional, but we all have studied in fluid mechanics that two dimensional flow field again it is just like an assumption that we can consider that the other direction is infinitely large as compared to the other two direction. Now so, if we would like to measure flow parameters in places where flow is 3 dimensional and that is most you know common scenario.

So, in this places we cannot use the single probe. So, although it is most commonly used in for turbo machines and similar other research, but nowadays it is not used because of the limitation that this probe is used rather I can say suited, suited in places where flow field, where flow is largely two dimensional. So, one typical example is that in case of, you know, axial, multistage axial turbo machines where hub to tube ratio is large.

So, as I said that we can approximate, we can take assumption that the one direction is large an order large as compared to the other as compared to other two directions, dimensions and flow field we are approximating as if the flow field is two dimensional. In this process it is suited but this is not the common scenario we will see in most of the cases flow field is three dimensional largely chaotic, in those places, this 3 hole probe is not suitable, because, one important flow parameter that is the pitch angle cannot be or the pitch characteristics of the

flow cannot be measured using this probe, because from the schematic you can see the yaw angle cab be 0 greater than 0.

But now using this probe we cannot have the pitch characteristics, we cannot determine, so this is most suitable, but if we place this probe in a fully 3-dimensional flow field, then what will happen because we have understood that this is not suitable in for measuring flow parameters in 3-dimensional flow field, but if we place it by mistake or knowing fully that ok you can measure then what will happen?

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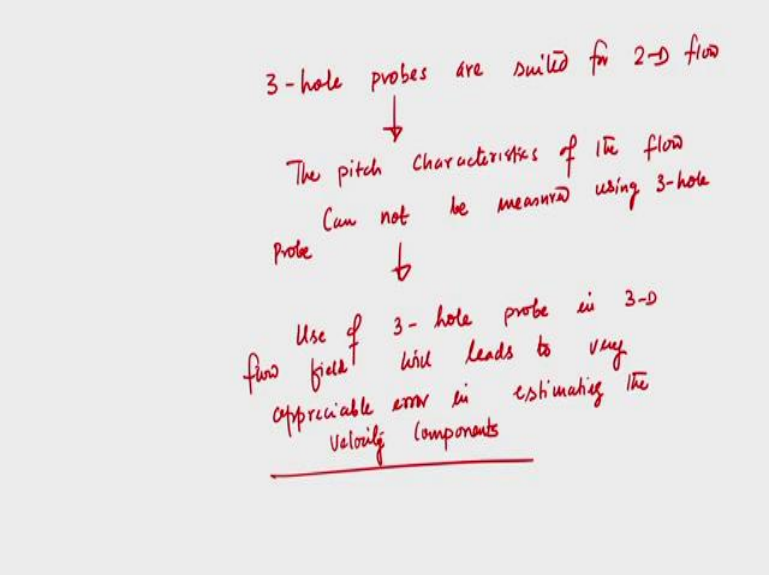

So, we have understood that this 3 hole probe are suited for 2 dimensional flow that means, the pitch characteristics of the flow cannot be determined. So, the pitch characteristics of the flow cannot be no measured using the 3 hole probe. So, if we place it for measuring flow parameters in three-dimensional flow field then what will happen? That means use of 3 hole probe in three-dimensional flow field will lead to a very appreciable error in what? Because flow field three-dimensional , we would like to measure the flow velocity.

And pressure we can find but we would like to measure flow velocity, but the probe is not irresponsible to measure to give any information about the pitch characteristics of the flow. So, if we use this probe either by mistake or by knowingly that ok we can get it. So, eventually, the measurement will lead to a very appreciable error in calculating the flow velocity components in calculating rather I can write in estimating the velocity components.

So, this is what is the most important drawback of using 3 hole probe. So, since central hole is there, another 2 holes are there; one is in the left side other right side. Now, if we connect

the, we will see that when we will discuss about the constructional feature of the 4 hole probe then we will discuss that these pressure probes are drilled radially and they are connected to the lead, those leads special leads, the leads are connected to the manometer.

Now, connecting this probe through leads to the manometer we can measure pressure but since the pitch angle, the pitch characteristics cannot be measured in 3 hole probe then, if we use it in the 3-dimensional flow field we will get results, but the results, the measurements, the calculation, what we are getting will have appreciable error because the components of velocity, velocity components are not the correct one. So, now, to circumvent this problem associated with this probe, the concept of 4 hole probe came into the picture.

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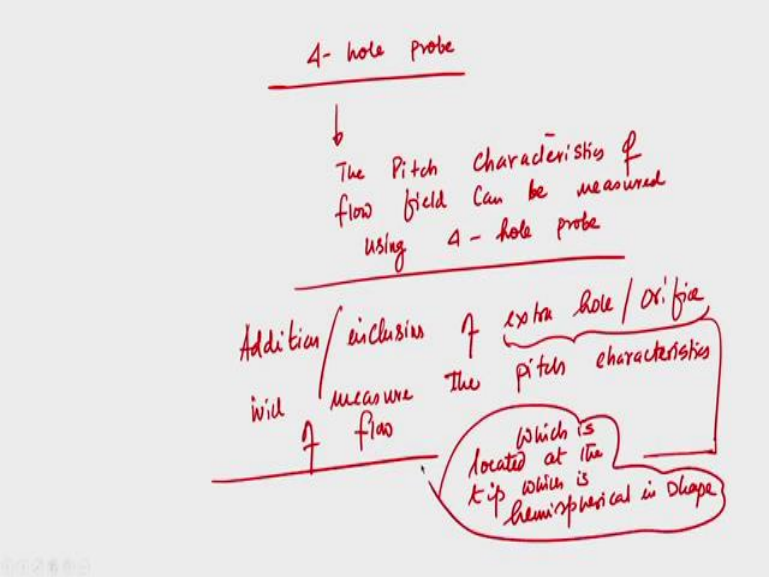

So now, this 4 hole probe which is nowadays used mostly largely defined as defined shape conical, cylindrical, well shape, but these probe limitation what we have understood that the pitch characteristics which cannot be measured using 3 hole probe can be measured using 4 hole probes. So, the pitch characteristics of flow field can be measured using 4 hole probe. So, that means, 3 hole to 4 hole inclusion of an extra hole is responsible only to give us the pitch characteristics, the pitch angle.

So that means, addition or inclusion of extra hole or probe will measure the pitch characteristics of flow, so that means a fourth orifice, a fourth hole which is located at the tip of the probe. So, I can say extra hole or extra orifice, this extra hole or extra orifice which is located at the tip which hemispherical in shape, so the extra hole, inclusion of extra hole

which is located at the tip and which is having hemispherical shape is responsible to measure the pitch characteristics.

So, in 3 hole probe we had one hole which is responsible of measuring the yaw characteristics. Similarly, the inclusion of another hole that is located at the tip is responsible for measuring the pitch characteristics. Now, we will discuss in detail that if we would like to include one extra rather, when you are including extra hole orifice, in the configuration of a probe then and that too which is placed at the tip of the you know, probe and which is having hemispherical shape and by placing that extra probe how rather by how you can measure the pitch characteristics that is the pitch angle of the flow, flow angle is very important.

And from there by measuring the, so we will measure static pressure, we will measure stagnation pressure and also we will measure the yaw angle pitch angle. So, these 4 parameters we will measure using 4 hole probes and the operation, the constructional feature of 4 hole probe together with its operational principle and from the measured value of pressure, how we can calculate the velocity components that part we will discuss in detail in my next class. So, with this I stop my discussion today and we will continue in the next class. Thank you.