Experimental Methods in Fluid Mechanics
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Lecture 35
Measurement of Torque by dynamometers, Straingauge, Transducers

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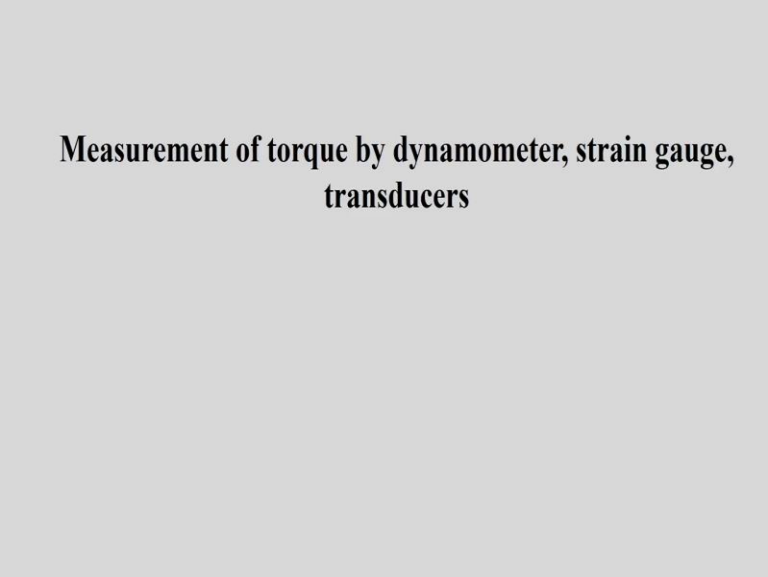

Good afternoon we will discuss today the Measurement of Torque by a dynamometer. And in the context of the experimental methods in fluid mechanics, the torque measurement is an important aspect and considering that aspect today we will see if you would like to measure torque then what is the role of the dynamometer and what are the difficulties associated with the dynamometer we will also discuss.

If we try to recall that measurement of torque, which is important, that we have studied in the context of internal combustion engine. Also, if we look at the hydel power plant, we have studied that hydraulic turbine which are used to rotate the shaft of a generator and from there we can produce electricity. So, the amount of torque which is produced, which is very important to know.

And to know that means, if we design that means to obtain a particular power output, we need to design the turbine, we need to design the electrical motor. So, if we do test, then in a lab scale, then we need to measure the torque which is being produced by the

hydraulic turbine or the electrical motor, then we can at least predict that the electricity generation would be this much. So, accounting this aspect, it is important to know the principle of measuring torque using a dynamometer.

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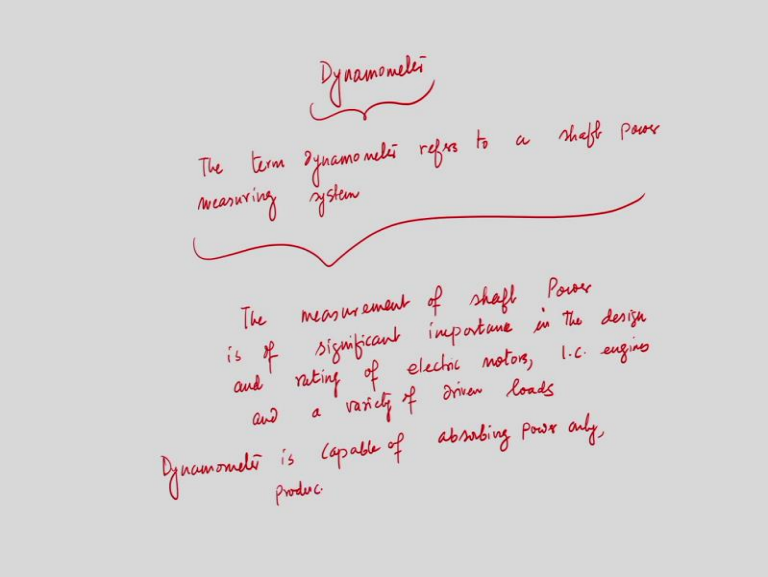

So, today we will focus our attention on the dynamometer. Now, the term dynamometer which is very common, and I can say that we have studied this for the test of the internal combustion engines, which is used and this is, I can say an important part. The term dynamometer refers to a shaft power measuring system and that is what we have studied in our undergraduate course curriculum where we had to, we have tested the performance of the internal combustion engine.

So, that means I am writing the term dynamometer refers to a shaft power measuring system so, that means we need to measure, we need to calculate the power produced at the shaft. Now, then, knowing fully that a dynamometer can measure the torque or the shaft power, we now will discuss the operational principle.

So, this is important and in this context I would like to mention that the measurement of shaft power is very-very important to the practicing engineers, to the designers who are responsible, who are associated with the design of generator, electrical motor and also the heat engines.

So, keeping that in mind at least we should know, if you would like to measure the output power, knowing the output power rather keeping in mind that the particular machine whether it is an electric motor, electrical motor or it is an internal combustion engine, if we need to produce, if we need to obtain this much amount of power from this particular machine, what will be the design, what will be the dimensions of the different components of that particular machine.

So, keeping that in mind I am writing the measurement of shaft power is of significant importance in the design and rating of electric motor, internal combustion engines and a variety of driven loads. So, this is important. That means, this is not the trivial aspect of measuring power.

So, this is really an important part of the measurement system that we should know a priori the information about the power then only we can test, we can calibrate a particular system, whether that system is capable of producing that much amount of power or not and to do that we need to go for the measurement of the shaft power and dynamometer will play an important role for this particular case.

So, that means, dynamometer is capable of absorbing power only, producing that power that drives the load and both. So, this is what is important. So, now, we will try to discuss the constructional feature that we have seen, if we can recall our undergraduate (())(9:19) where we have tested, we have performed engine efficiency, rather we have conducted a test on the internal combustion engine essentially to measure the engine performance.

So, today we will focus our attention to check the measurement of rather to see the measurement of the power, shaft power using the Prony break which is an important type of the dynamometer.

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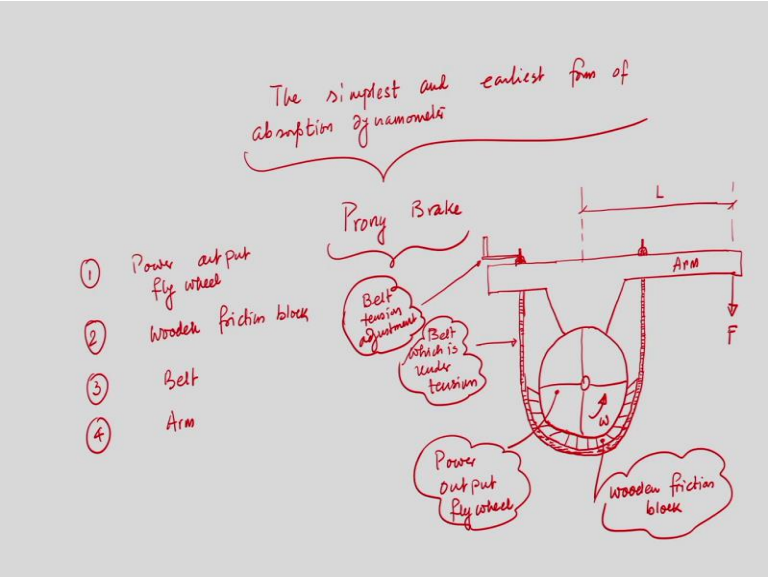

So, our discussion will be today. So, today our discussion will be on the operational sorry constructional as well as operational principle of the prony break, which is the simplest and earliest form absorption dynamometer. So, the simplest and earliest form of the absorption dynamometer is the prony break, prony break, so, we will discuss today the constructional feature as well as the operational principle of this particular instrument, which is used to measure the shaft power.

So now, we will try to draw the schematic of the prony brake and from there we will try to explain the function of different parts, integrated with the system and their operational process. So, prony brake if we try to recall the prony brake will have several other parts then, this is the belt. So, this is the belt which is used to measure so, this is the, and these are, this is connected with screw, so these are fixed over here and this tension can be adjusted using one lever.

So, this lever which is used to adjust the tension in the belt and this is the load F and this is the moment arm, this is L and this is arm and this is the power output flywheel, power output flywheel. This is the intermediate part which is wooden block, wooden block to provide friction and I am writing wooden friction block and this is rotating with omega and this is the belt which is under tension.

So, this is the and this arrangement that is what I was telling, what we can see from the schematic is that this is the schematic of a prony break, which is a very simplest and earliest from of the absorption type dynamometer. What are the different parts of this particular device is that we have one, what are the different parts of this instrument? One is the power output flywheel.

So, I am writing one is power output flywheel, output flywheel number two, that is the golden frictional block, wooden friction block number three, that is belt and number four, arm and finally this is the belt tension adjustment, so this is very important. So now, the power output flywheel that means a flywheel will be definitely connected to the shaft. And since shaft is rotating, the flywheel will rotate.

So, as you can see from the schematic that the force F is shown and the force will be required to balance I cannot say the force so, this force will be required to the balance of the load or power which is being produced. Now, knowing this force we can estimate what is the amount of power being produced, what is the amount of torque being produced. Now, we will discuss slowly the operational principle.

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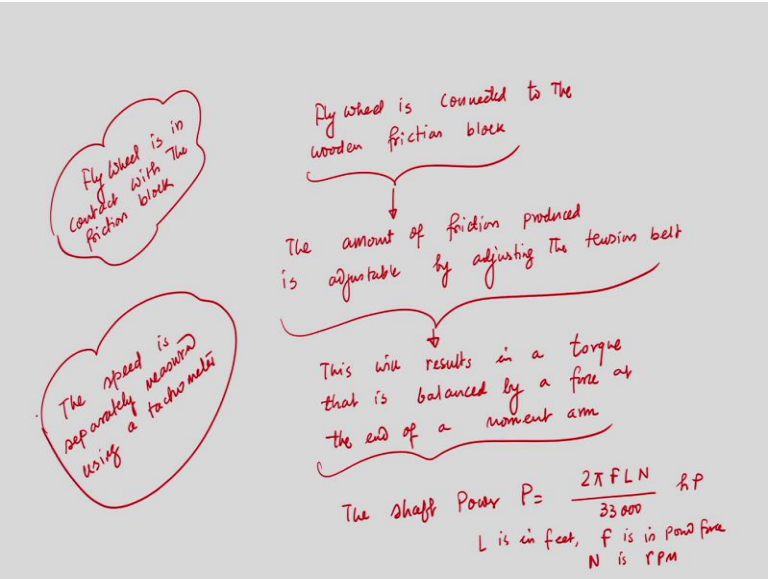

So, what we can see that so, we have seen that in this case prony break what you can see that flywheel is connected, the flywheel is connected or I can write to the wooden friction

block and this is typically made of wooden. So I can write that it is not mandatory that always the blocks should be wooden. That is the flywheel will be in contact with the frictional block and that friction block which is typically made from wood.

So that is why I have written the wooden friction block. Now, what will happen so in generic I am writing flywheel is, flywheel is in contact with the friction block and the friction block which is typically made of wood, made from wood? So that is why I have written the wooden frictional block.

Now, the amount of friction, amount of friction produced is adjustable by the adjusting or by adjusting the tension belt, by adjusting the tension belt and if we adjust this that means now I am writing the operational principle. So, if we go to the previous slide, we have drawn the schematic, we have identified different parts which are integrated with the system. And next we are trying to explain the operational principle including the function of each part.

Now, the amount of friction so, flywheel is in contact with the friction block that means when it is in contact with the friction block flywheel is rotating at an angular speed omega. So, the friction will be developed. Now, the amount of friction produced or developed that will be, that can be adjusted, but I can say this is adjustable by adjusting the tension belt and this wheel so, when we are trying to adjust the amount of friction using the tension belt, this will result in a torque, torque and that is balanced by a force at the end of a movement arm.

So, you have seen from the schematic that the amount of friction that will be produced that will be balanced, that will be balanced. So, the amount of friction that will be produced can be adjusted by the tension belt and the process will results a torque and the torque will be balanced by a force which is acting at the end of a momentum and that is shown in the schematic.

So, from there we can, now an important point, so, we can write this shaft power, the shaft power P that will be equal to twice pi FL. So, F that we should know what is the amount of forces required to balance the torque which is developed because of these

frictional effect and L we know the distance of the, the momentum and these two pi FL into N divided by 33,000 and that will be in horsepower.

So, here L, here L is in feet, F is in pound force and N is RPM. So, we can convert the unit accordingly that is not an important matter. So, this expression which gives us the amount of shaft power and that is what is very important for the design of the prime movers that is what I was discussing, that is the electric motor, internal combustion engine.

Now, of course, the hydraulic turbine now, P is the two pi f L and L n by 33,000 and L is in feet and this unit is horsepower, L is in feet, F is in pound force and N is RPM. So, what we can see from this figure that if we would like to calculate or if you would like to measure shaft using dynamometer, we need to measure another important parameter without this, we cannot calculate power, what is that?

This is the N. So, we need to measure it the speed and the speed is separately calculated, measured using a tachometer, this is what we have done. Again, I am repeating, in our undergraduate course, where we have performed, we have conducted tests, internal combustion, test on internal combustion engine and we have measured the engine efficiency.

So, we need to measure the speed or speed of the prime mover separately using a tachometer. Knowing the speed of the prime mover we can calculate shaft using this dynamometer which is the prony break. Now, this is the operational principle. So, we have discussed about the constructional feature, we have discussed about the operational principle, procedures that we have studied in our undergraduate days but again today we have recapitulated.

Finally we should know, what are the problems, what are the difficulties associated with the measurement process and that is very important to the experimentalists, who are using this not only this device, who are using equipment, instruments in measuring several parameters, several flow parameters, then what are the precautions should be taken, at least to get error free result.

We cannot say that the result which you are getting from the experimental investigations are completely error free, but our objectives should be to reduce the error and if we would like to reduce the error associated with the measurement methods, measurement techniques, at least we should be aware about the difficulties, problems associated with the measurement technique to be precise, the instrument itself. So, that means, our awareness should be there while we are going to use any particular instrument in measuring any flow parameter.

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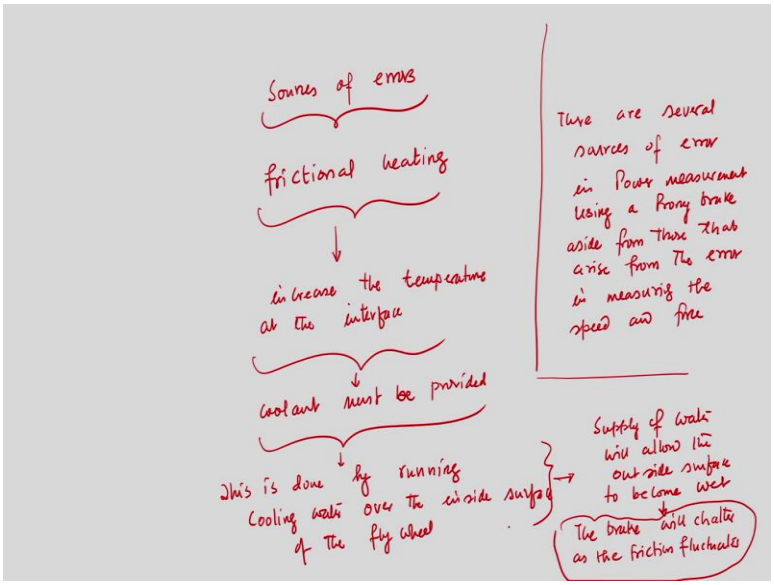

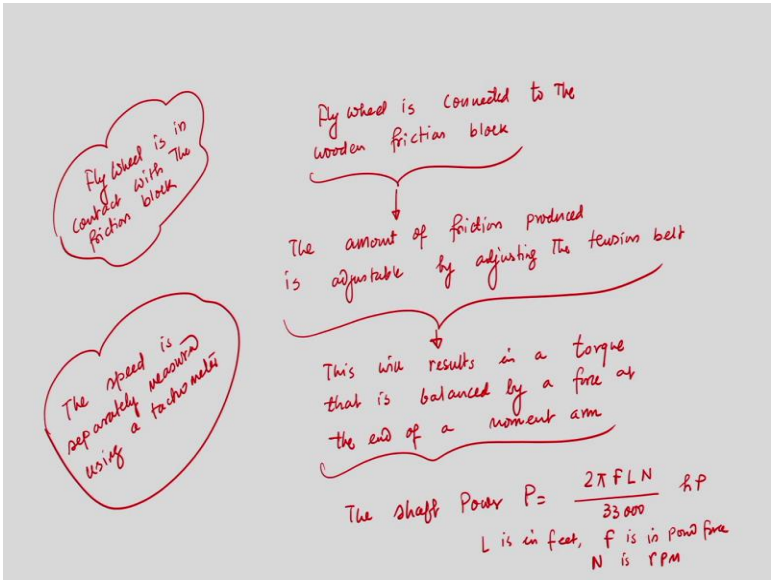

So, now, the difficulties rather I can say several other sources of errors. So, at least this we should know what are the sources of error because if we now try to go back to the previous slide, what we can see from the schematic that the flywheel is rotating at an angular speed omega and we are trying to produce, we are trying to keep the belt under tension by adjusting the belt that belt tensor adjustment part that means by tuning the knob of this tension adjustment part, we can create tension in the belt.

That means, we are trying to keep the wooden block in contact with the flywheel and that is how we have seen that we will have torque and that will be balanced by the force which is acting at a movement distance. Now, when friction, when the wooden block will be in contact with the flywheel, the outer periphery of the flywheel, then because of the frictional effect, because the wooden block will try to, we are adjusting the tension and the wooden block will be in closer contact with the flywheel and there will be development, generation of huge frictional hitting.

So, we cannot trivially ignore the frictional heating that is produced because of this frictional, because of this process. So the, frictional, so before I go to list down, another important point that I would like to mention that there are several sources of errors in power measurement using a prony break aside from those that arise from the error where in measuring the speed and force. So this is very important.

If we try to recall just five minutes back, we have seen that we need to measure the speed separately, independently. So, when we are measuring speed independently using a tachometer, we will have measurement error, when we are measuring force there also will have measurement error in addition to these measurement errors we will also have inherent error which is associated with the prony break or measuring the shaft is the frictional heating.

So, that is the significant amount of heat and this will increase the temperature at the belt, at the interface I can write, at the interface, at the interface and although we have used wooden block, but the shaft, I am in the flywheel is a metallic part and it is, we need to save, we need to ensure that the flywheel have, the flywheel will have a particular or

finite lifetime to ensure that the flywheel have finite lifetime, to save the flywheel out of the excessive rise in temperature because of the frictional or dissipative effect.

We need to provide cooling, we need to provide coolant. So, that means we need to ensure cooling will be there. So, coolant will be supplied, coolant must be provided and if you would like to supply coolant, there are ways that means, by this is done by running cooling water over the inside surface, inside surface of the flywheel. So, inside surface of the flywheel we can supply cooling water essentially to cool down temperature which is being developed because of the dissipative effect.

Now, when you are supplying cooling, coolant for this purpose, that is to reduce the temperature what will happen, you know this process, what will be the case that this will leads to that means, supply of water will allow the outside surface to become wet and if this happens, that means when you are supplying coolant it is a difficult to maintain that the outer surface should not be inverted.

So, that means the supply of water will allow the outside surface to become wet and the brake wheel, the brake will chatter and as the friction fluctuates so, that means, what will happen if the outside surface become wet, then friction will fluctuate and the brake will chatter. So, this is the problem that we should keep in mind.

So, these are the different issues we need to ensure not only that, so if this is the case that means, we need to supply coolant, essentially to reduce the temperature because which is produced because of the frictional heating while we are supplying water or coolant to reduce the temperature, then again what will happen?

The outer surface of the flywheel be wet, the outer surface of the flywheel will be wetted, that means we are essentially indirectly allowing the outer surface to become wet. Now, if the surface becomes wet then friction, frictional effect or friction will fluctuate and as a result, the belt will chatter. That is what I have written.

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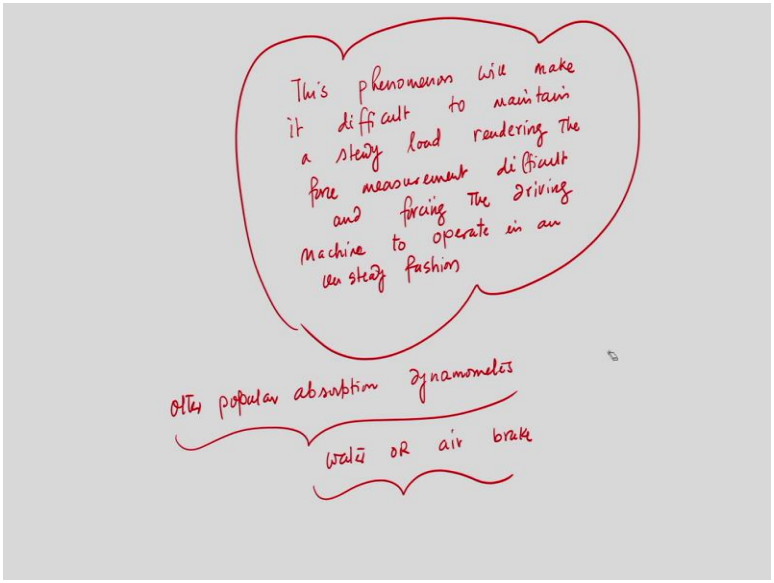

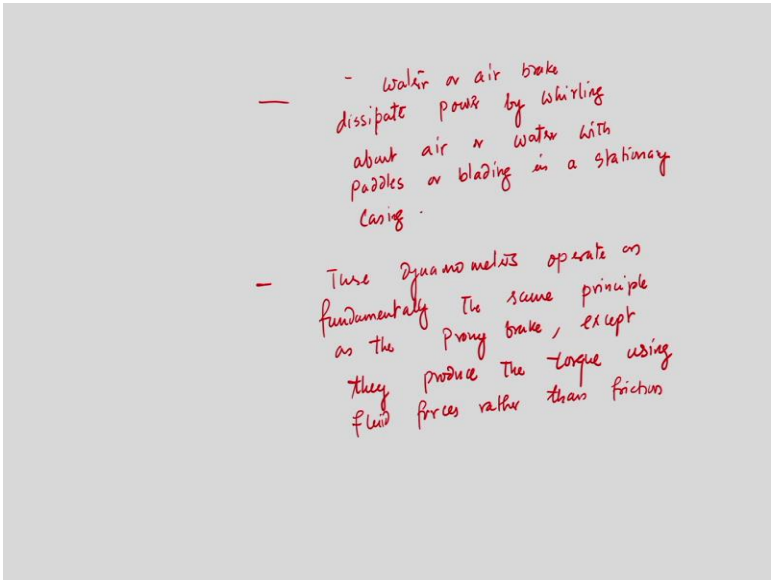

And this process, this phenomenon I am writing will make it difficult to maintain a steady load rendering the force measurement difficult not only that, and forcing, so not only that and forcing the driving machine to operate in an unsteady fashion. So, this is the very important problem which is associated with the dynamometers.

So, we have discuss about the why the shaft power measurement is important in the context of again in fluid mechanics research, we have discussed if you would like to measure shaft power, then most common types simplest absorption type dynamometer is

the prony break and that is what we have discussed today, we have drawn the schematic depiction of the prony break and then we have identified the different parts which are integrated with the system.

Then we have outlined the procedure of measuring shaft power, measuring torque using this prony break. Also, we have discussed about the function of different parts. And finally, which is very important to know, at least those who are working in the area of experimental fluid dynamometers, this would have awareness before any particular equipment, any device is used to measure any flow parameter that what are the, precautions, what are the, I can say possible sources of error associated with the measurement that is very important.

And today we also have discussed the different sources of error which are associated with the prony break. We have identified that, in addition to the speed and force measurement, the speed and force are measured separately. So, when they are measured separately, measurements, measurement errors are integrated with those measurement in addition to that another important point that is the frictional effect and you have identified to reduce the frictional effect we need to supply coolant.

If we supply coolant the supply of coolant again leads to another problem and that we have outlined. Now, finally, we will discuss other popular absorption dynamometers, at least we are not going to discuss but we will just mention other popular absorption dynamometer are the water and water or air break, water or air break.

Now, this water and air break here what is, I mean this two are, either water or air break are the other popular absorption dynamometer and in this two cases what is done, this water or air break, in I am writing in the next slide. In water or air brake rather water or air break dissipate, dissipate power by whirling about air or water with paddles or blading in a stationary casing.

And these dynamometers operate on fundamentally the same principle as the prony break, as the prony break except they produce the torque using fluid forces rather than friction. So, the prony break we have discussed, there are other popular absorption type

dynamometer are the water and air break, in water and air break it the dissipate power by whirling the, whirling about the air or water with paddles or other blading arrangements in the stationary casing.

The fundamental difference between these two dynamometers and, the fundamental difference between these two dynamometers that is water or air break and the prony break is that in case of prony break we have seen the torque is produced by the frictional effect, but for the water or air brake, they produce torque using the fluid force. So, this is only the fundamental difference.

So, to summarize today's discussion, we have focused our attention today on the measurement top shaft power, which is very important part of the fluid mechanics, experimental fluid mechanics, as I said again I am repeating, that to measure the output of the hydraulic turbine, to measure the output of, I can say internal combustion engine and also to measure the output of electric motor.

That is very important for the practicing engineer or I can say operational engineer which are involved in hydel power plant. To them it is very important to know rather to them very important to measure power which is being produced by the electric motor or the hydraulic power plant, hydraulic turbine.

Now, we have discussed about the prony break, constructional feature, procedure, then the possible sources of error and then finally we have discuss about another two popular absorption dynamometer and we have identified the fundamental difference between the prony brake and the water or air brake. So, with this, I stop my discussion today and we will continue our discussion in the next class. Thank you.