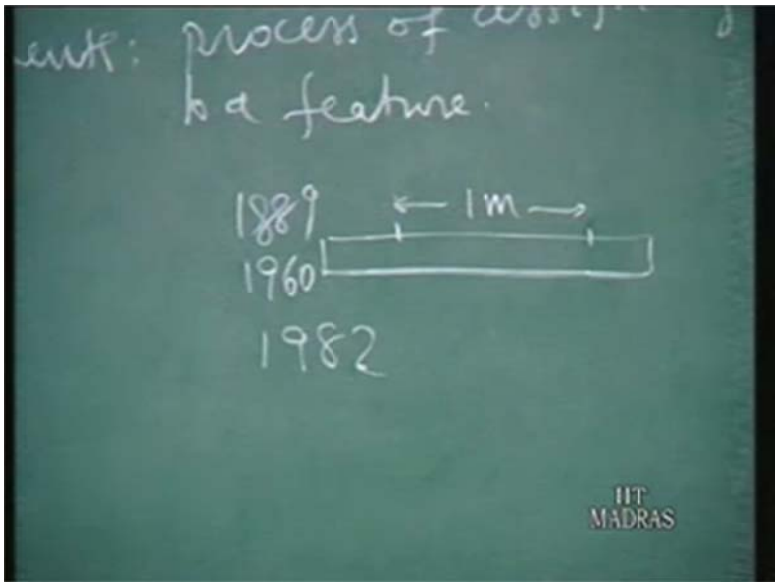
Principles of Mechanical Measurements
Prof. R. Raman
Department of Mechanical Engineering
Indian Institute of Technology, Madras
Lecture No. # 01

Namaskaram to all of you. We are going to talk about the subject mechanical measurements which is one of the basic subjects for both engineers and scientists. Before we see how the subject is important, we would like to see what these two words represent, before we see mechanical let us see what are measurements.

(Refer Slide Time: 00:01:54 min)



A measurement is the process by which we assign a number to any parameter. What is a parameter? Parameter is one which is surrounding us mainly feature, say it may be a displacement or any atmospheric condition also say temperature or the pressure. When we say temperature is too high or too low, people may not be able to appreciate how high or how low it is. So it is important always that we assign a number, so the process of assigning a number to a parameter is called measurement.

That is process of assigning a number to a feature, this is the process. Suppose we are unable to give the number then what does it mean, then what we should do? We should say probably the earlier man was also doing like that. He was telling that the weight is too high or the distance is too much or the depth is too shallow. So that means he was telling qualitatively that a parameter is high or low because probably he did not know how unique by which you can measure a parameter. Later on we know for example, in length the standard was accepted by all countries as meter. It is around 1889 that is at the end of the 19^{th} century the unit for distance is accepted for all countries that is the meter. What is the meter according to the definition? Meter is a distance between 2 markings in a bar.

That is something like a bar was there, even today it's there somewhere near Paris, 2 markings was there. This bar is made up of a material which will not expand or contract. It's very stable material and in that 2 markings where made in which the marking looks very thin and it was made and the distance between them is as agreed as 1 meter. Once you have got a basic unit like this, any distance can easily be given a number in terms of meter. That is multiplication of or sub multiple of this basic unit. That how we assign a number to any distance, that is for a distance.

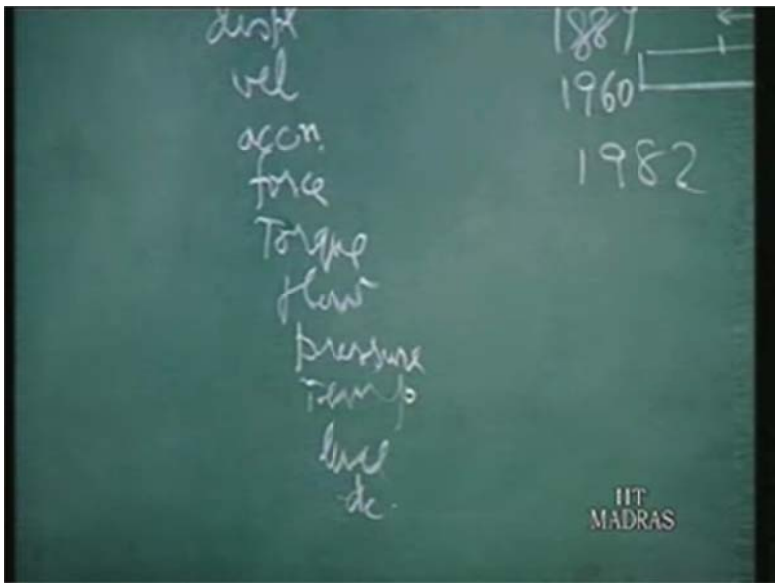
For example if you want to give a number for temperature, previously he was telling that I cannot touch, it is too hot or ice is too cold. I cannot have it for so long; actually it was called a qualitative statement. For assigning number what it was accepted is, they measured the 0 to 100 degree water boiling. What is the total distance then divide it into 100 parts and each part is the unit. So we call the temperature in terms of degree centigrade so this is the basis of assigning a number. For assigning a number that means you have to have a standard unless we have a standard we cannot assign a number. So 1 meter that is what was defined earlier but problem is we cannot go to Paris where the standard is kept.

So in order to reproduce the distance in laboratories in 1960 they had another definition for meter. That is so many wave lengths of krypton 86 whatever it is, an atomic resonance of that with so many wave length, if you can make in a laboratory that distance is equal to 1 meter. But that is also a better version of that definition, which they got now around 1982. That is first one is 1889 and 1960, second definition. Now third definition for meter is a distance traveled by light in a fraction of second that fraction is 1 over 3 into 10 to the power of something like that. So in that fraction of a second whatever the light travels in vacuum that distance is 1 meter.

So that is now the basis for distance is we have time during the time whatever happens for the light the distance traveled by the light is the unit for meter. Coincidentally you will fine even today in Indian villages, people used to say how much distance one has to walk. If you enquire somebody they may say, you walk through a better (Not understandable) (Refer Slide Time: 00:06:59) time, that is time is taken as basis for telling distance. That is whatever we were using earlier in our villages now that has become the basis for the most modern definition for displacement. So thing is for making measurements we should have unit, without unit you cannot make measurements.

Similarly you have got unit for weight as Newton or for second we know there is again second. In many wave lengths the duration is one second. So we have got standards for different parameters. So measurements are the process of assigning number, numbers is in terms of basic units. Now what is mechanical? Mechanical is telling the number of features generally a mechanical engineer comes across. For example displacement, velocity, acceleration, force, torque, flow, pressure, temperature, level etc. are the mechanical quantities.

(Refer Slide Time: 00:07:57 min)

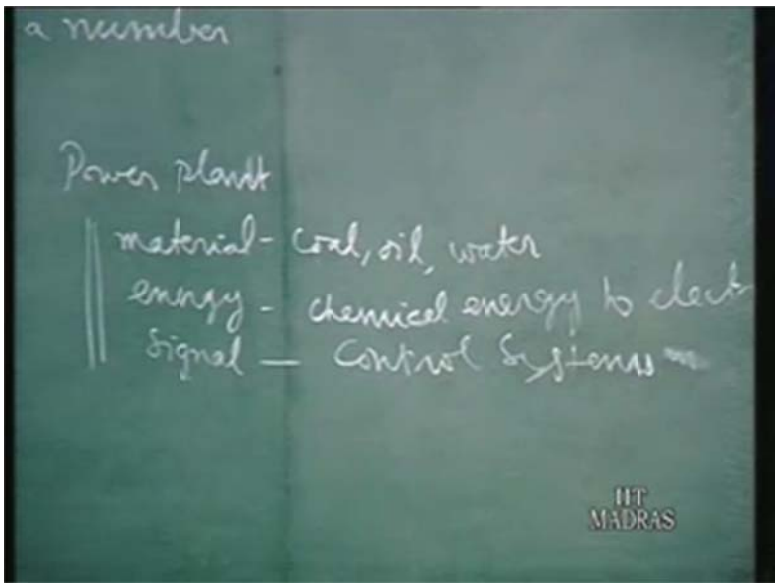


Whereas in electrical engineering you have got current, voltage, electrical power, flux density, gauss all these things are electrical quantities. So in order to differentiate the field of measurements that pertains only to mechanical engineering we call the topic as mechanical measurements. That is how the topic has evolved and under this topic we are going to learn so many parameters and how important the topic is? How it is important for an engineer or a scientist? For an engineer when he wants to select an instrument for measurement naturally he should know how to select an instrument from the available instruments in the market and for example if you want to make displace measurement there are about 10 or 20 different type of instruments available where you have got different ranges, different accuracies and working with different principals and among them if you want to select any one instrument naturally you should know the characteristic of the instruments, so in that respect you should learn the topics.

Secondly, not always the instrument is available in the market and some research purposes he has to design his own instrument. Unless he knows the field of instrumentation the problem of designing doesn't arise at all. So it is very important for an engineer to know the measurement topics either to select or to design himself the instrumentation. So thus there is a necessity for an engineer or scientist to learn the topic. One more point is how this field of instrumentation is important in engineering field?

If we take any power plant which processes 3 quantities, a power plant processes material, energy and signal. These are the three quantities a power plant or any engineering system deals with. How important these three quantities are? Now if you take a power plant itself, we find material is coal which is to be transported at different stages. So from storage to cleaning, to remove the foreign materials from coal and then it is to be transported to the top of the furnace, blast or some furnace whatever it is.

(Refer Slide Time: 00:10:20 min)



So it has to be properly transported and also during transportation, it has to be measured what is the flow rate. So any how the coal is to be handled properly that is one material coal or oil whatever it is, depending upon the power plant. In a hydraulic plant, water is to be properly transported and energy is to be extracted. These are the material dealt by that power plant and energy. Now energy is converted from say chemical energy to electrical energy that is what is being processed in a power plant. Chemical energy of the coal is burnt in the furnace and then it is converted into heat energy that is being absorbed by the steam and from steam it is made into mechanical energy by the engine and the engine drives an alternator or generator and electrical power is made. So the energy is changed from one form to another form.

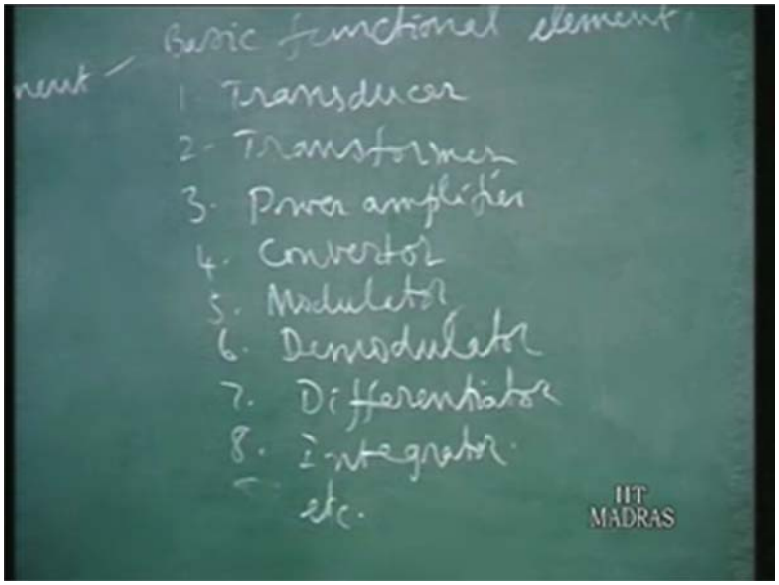
Now what is signal? In both of the above cases signal plays a vital role. The size of the coal which is being taken to the furnace should be a proper size of proper distribution and it should be at particular flow rate, the measurement should be made that is signal. Signal processing is nothing but measuring. What is the size? That is the signal, it is to the measured and oil flow rate for different power generations, a water inlet to the turbine should be controlled. So all these things controlling of different parameters is dealt by signal also energy. Energy conversion, amount of energy that is coming out its also measured how much energy we give inside and say if steam boiler is there in the power plant then we see that pressure and temperature of the boiler should be maintained constant. So control systems are based on the measurements or signal.

Unless we properly measure the size or the pressure or temperature of steam turbine or steam boiler we cannot have the proper control over the energy output. So controlling the temperature and controlling the pressure and all is achieved by control system which is again based on measurement. In order to maintain a parameter at a particular level naturally you have to measure that level unless we measure it, we cannot maintain it. Thus you find measurement is the basis of any control system.

How control system is important in these power plants or any engines? Just like human body the nervous system is important for you to actuate any muscles. Suppose I want to move my hand the signal comes from brain to the muscle and then the muscle acts. That is the signal coming from the brain to the nervous system. Similarly you find control system which measures and controls maintains every parameter there is analogous to our nervous system. Suppose the nerve fails here in our human system then muscle stop functioning. See this side of the brain controls all actions on the opposite side, so when something happens due to accident you will find the other side is paralyzed. That is signal is not taken which means the nervous system fail, the power system fails or energy system fails.

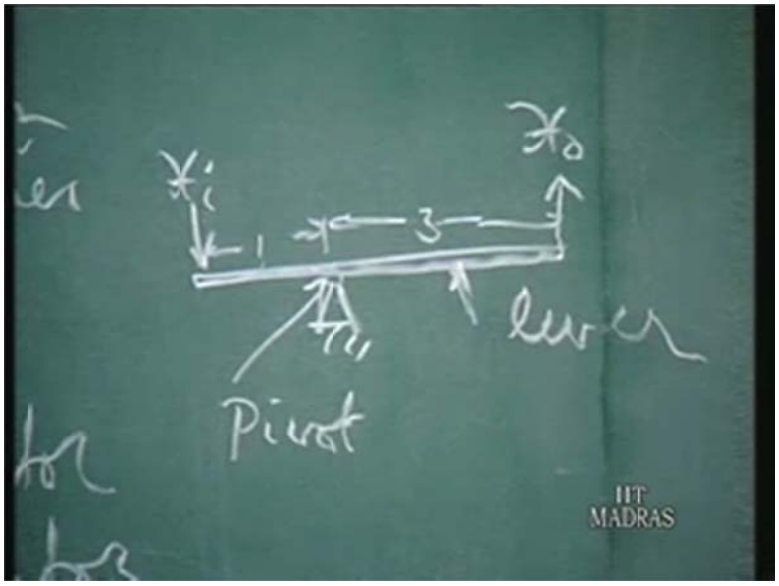
Similarly you will find in a power plant when its control system fails, the whole power plant stops that is the importance of control systems. Now control system is based on measurements hence we find the topic of the measurement is very important. So this is the introduction for the whole topic of mechanical measurements. Now we go into detail of some of the important parameters.

(Refer Slide Time: 00:15:38 min)



Now we are going to see the device what is made use for the measurement. The device used for measurement is called instrument. Instrument is the device used for measurement. Now what is it made up of? The instrument is made up of so called basic functional element. It is something like a brick which is used to build a big building. Big building is made up of arranging bricks and joining them together. Similarly you will find the instrument also is made up of by joining different basic functional element and here we have got different types of such basic elements. What are they? One transducer, transformer, power amplifier, converter, modulator, demodulator, differentiator, integrator, etc. What is the definition of the basic function element? It is a unit when we divide further, you cannot do any function. That is it is a basic I mean when we divide further for example if we take a lever mechanism.

(Refer Slide Time: 00:17:31 min)



We give input here we get output here; say x_i is input x_o is the output. The lever plus the pivot is a unit, this is the lever and this is the pivot. Pivot is nothing but a bearing; it allows the lever to tilt like this. So these two put together is the mechanism which achieves the function of changing x_i into x_o. Suppose we have got lever edge here 1 mm here, 3 mm from here and any distance given say about 1 mm we give at x_i it is made into 3 mm at x_o. This is the basic lever mechanism which you all know and in this case the lever and pivot constitutes the basic functional element. If we divide it further what will be there? Pivot will be in one place, lever will be in another place and it cannot achieve any function, pivot and lever individually cannot do any function. So we can divide the instruments until a basic unity is obtained which can achieve a function, if we divide further it cannot achieve a function that is called basic functional element.

So we have got so many types in such a basic functional element. So many types and more also in instrumentation and we are going to see what are these basic functional element, what do they achieve when they are part of a big instrumentation. Now the transducer is one which changes one physical quantity to another physical quantity. That is the transducer changes one physical quantity to another physical quantity. For example a thermocouple. What it does? It changes the temperature into a voltage. We know what is thermocouple, the voltmeter is there and this is wire A, this is wire B the similar materials, homogeneous material is immersed in one box T_1 and another box T_2. So temperature difference that is temperature is converted or changed into a voltage.

That is the temperature quantity is changed into a voltage quantity. Hence it is a transducer, a basic functional element. As per our definition can you divide this further? That is basic function element is one which cannot be divided further. Suppose if we divide further what will happen? Wire A will be different, B will be different they will not achieve; they will not achieve any function. Hence the thermocouple pair is a basic functional element converting the temperature quantity into a voltage quantity.