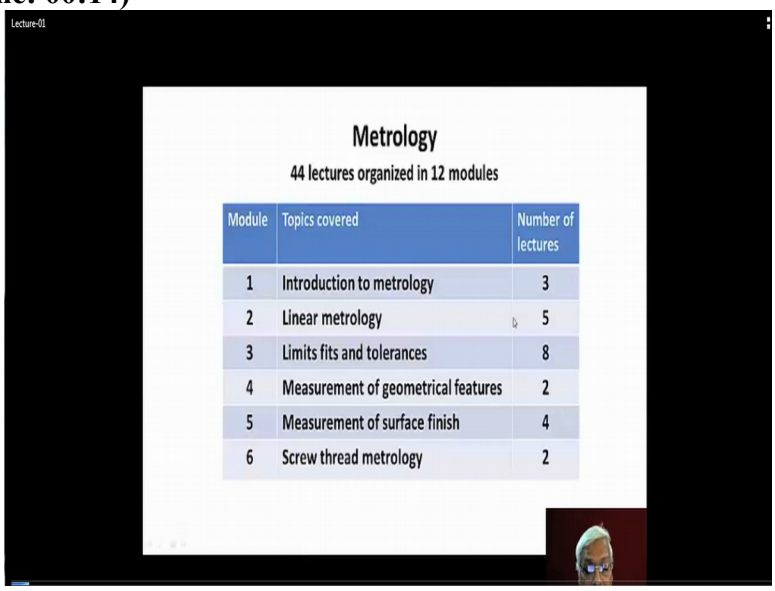
Metrology
Prof. Dr. Kanakuppi Sadashivappa
Department of Industrial and Production Engineering
Bapuji Institute of Engineering and Technology-Davangere

Module-1
Lecture-1
Introduction to Metrology

(Refer Slide Time: 00:14)



Hello everybody and welcome to this course on metrology. Before I am formally start telling you about metrology. I would like to introduce myself I am Sadashivappa, working as professor in Bapuji Institute of Engineering and Technology-Davangere. Metrology is the science of measurement which mainly deals with measurement of size, form and positions. In general for any kind of quantity to be measure that must be a unit of measurement and it should be possible to express the quantity in numbers.

Hence metrology is consult with the establishment of units of measurements and the standards, it is concerned with establishing methods of measurement and it also deals with different kinds of measuring instruments. In a broader sense it is concerned with industrial inspection, it deals with inspection of raw material to inspection of finished components with the help of standard measuring tools and gauges.

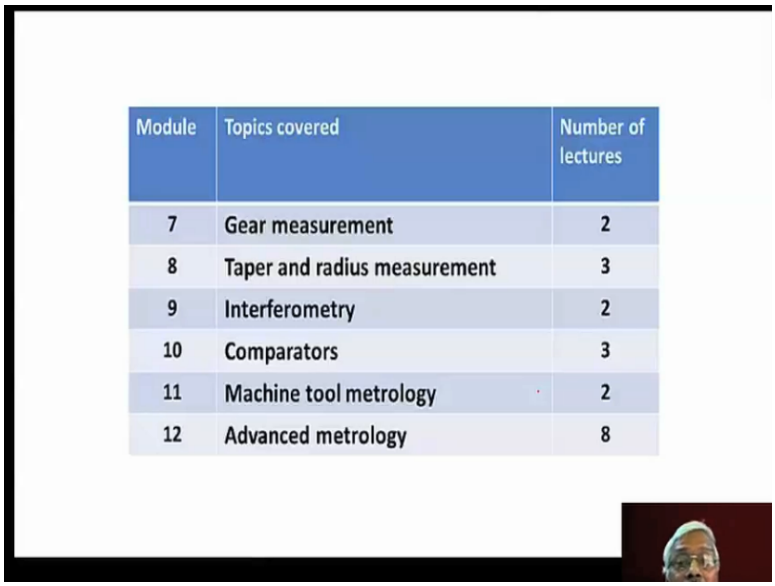
Metrology is used in many areas such as machine tool, the building, automobile engineering, biomedical engineering, space applications, building science, marine science and many other scientific and engineering fields. In the present course we will be mainly dealing with the

dimensional metrology where in we will be learning about precise measurement of lens, angles, forms and position.

This course is spread across 44 lecture arranged in the 12 modules, we will be learning about basic definitions and terminologies related metrology, different measurement standards, units, methods of measurement, errors in measurements and calculation aspects is module number 1 that is introduction to metrology and in module number 2 will be dealing with usage of different measuring instruments such as (()) (03:03), micrometre, angle measuring devices.

In module 3 we will be discussing about the limits, fits and tolerances, what is the need of tolerance, what are the different kinds of fits available, how to select a proper fit for the given applications such things we will be discussing in the module number 3 and in module number 4 we will discuss about the measurement of geometrical features mainly we will be discussing about straightness measurement and squares measurement.

(Refer Slide Time: 03:52)



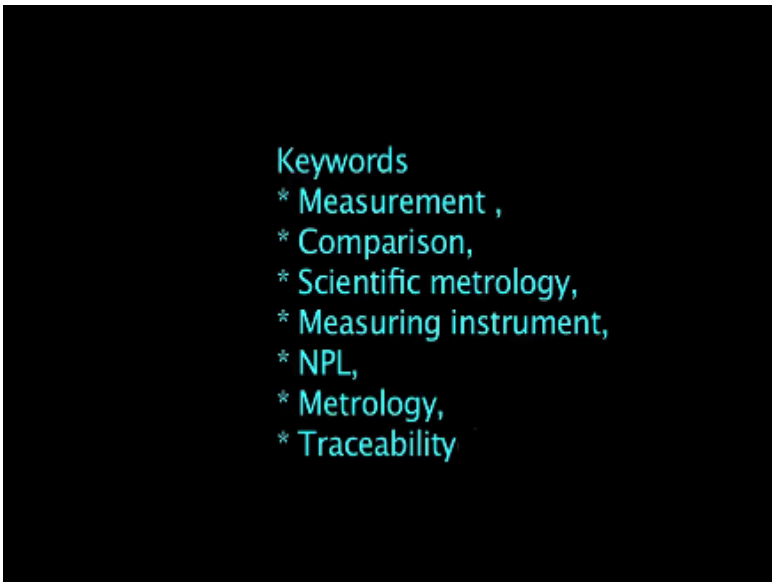
And then we will move on to measurement of surface finish and screw thread element measurements, gear element measurements, taper measurement, and radius measurement and in module number 9 we will be discussing about use of interferometry for measurement of flatness of resize surfaces will be discussing about construction and application of different interferometers available.

And in module number 10 we will discuss about different types of competitors and use in a dimensional metrology. In module number 11 we will be discussing about different alignment

test conducted on the lake and drilling the machines. Finally we will move to advanced metrology where in we will be discussing about universal measuring machines, coordinate with the machines in process caging, stage position metrology.

Nano technology instrumentation such as atomic force, macroscopy and finally we will discuss about optical system designing. I wish you happy learning throughout this course, thank you.

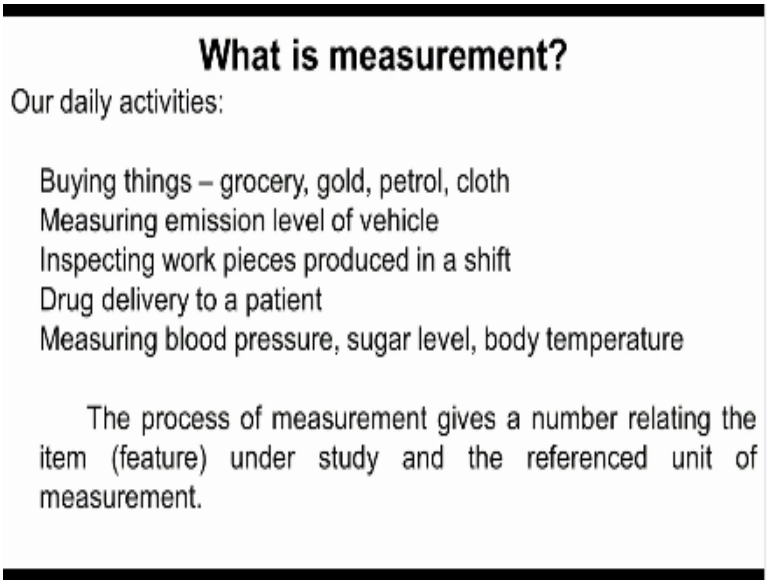
(Refer Slide Time: 05:25)



Now let us start the first lecture of the series, let us understand what is the meaning of the measurement, let us have a look at our daily activities like buying things like grocery, gold, petrol and cloth, measuring emission level of vehicles inspecting work pieces produced in a shift drug delivery to a patient measuring blood pressure, body weight, body temperature etc. In all these activities we are trying to measure a physical quantity like pressure, volume, length etc.

Now let us take a simple example of buying things like cloth and let us understand the measurement process in detail, when I go to cloth shop and ask for a certain length of material, immediately the shopkeeper will take the material and even take a measuring tape and he measures the cloth of the required length and cuts it and gives it.

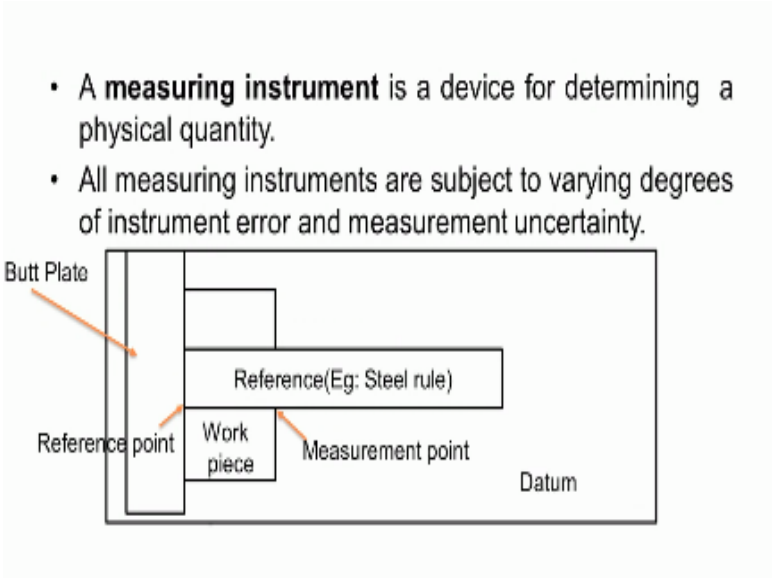
(Refer Slide Time: 06:49)



Now in this process we can understand that in the process of measurement a physical quantity is required for which we had to give the value and then we require a standard or a reference for measurement process and then there is a comparison process, that means the shopkeeper will open the cloth, he will spread the cloth in a table and then length of the cloth that is to be cut is the physical quantity.

And then a shopkeeper take the measuring tape and this is a reference for us to measure the length and then he compares the cloth length with the measuring tape, this is the process of comparison. That means in any measurement process we have 3 entities, first one is the physical quantity in our example length and then a reference for measurement that is measuring scale and then process of comparison that means comparing length of cloth with measuring tape. So that is the third entity.

(Refer Slide Time: 07:48)

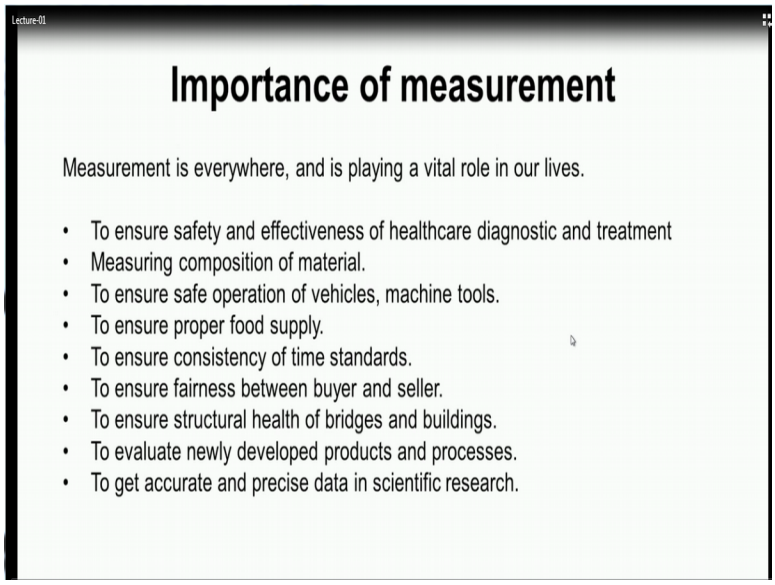


Now let us look at this simple picture and try to understand the measurement process in detail. So we have the datum on which the measurement process takes place and then we have work piece ok, the length of the work piece is to be measured and then we have a butt plate against which the work piece is pressed and then we need a reference for example a steel ruler measuring tape.

And again the steel rule is placed on the work piece and it is pressed against the work plate. Now he start measuring the length of the work piece from this point, from the edge of the work piece. So this is a reference point and then we look for the coinciding division on the steel rule which division on the steel rule is coinciding with the other edge. So this becomes the measurement point.

The difference between the reference point and the measurement point is the length of the work piece, that is the physical quantity that is to be measured. If the measurement process is very simple like measuring the length of a work piece or a diameter of work piece using the micrometre we can do that, we can just hold micrometre in our hand and we can take the work piece in other hand and then we can measure.

(Refer Slide Time: 09:43)



So in this case datum is not required, so in some cases datum will be required, in some cases datum will not be required. Now let us try to understand the importance of measurement process. So I gave some examples of our daily activities, where is measurement is carried out in all activities, that means measurement is everywhere and it is playing a vital role in our lives. No measurement is very essential to ensure safety and effectiveness of healthcare diagnosis and treatment.

We measure many parameters when we go to a hospital like blood pressure measurement that composition measurement etc. The measurement that is carried out should be accurate and should be precise. So that proper treatment can be given to the patient, then when we take the example of manufacturing industry we measure the composition of material, we look for maybe carbon presentation steel and other alloying element composition.

So if the measurement of these composition is proper then we can build good products, then to ensure safe operation of vehicles and machine tools we measure parameters like speed of the vehicle machine tools, what is a feed rate of various size of machine tool, what is the vibration level of machine tools or vehicle, whether the machine tools and vehicles are under safe condition, safe running condition.

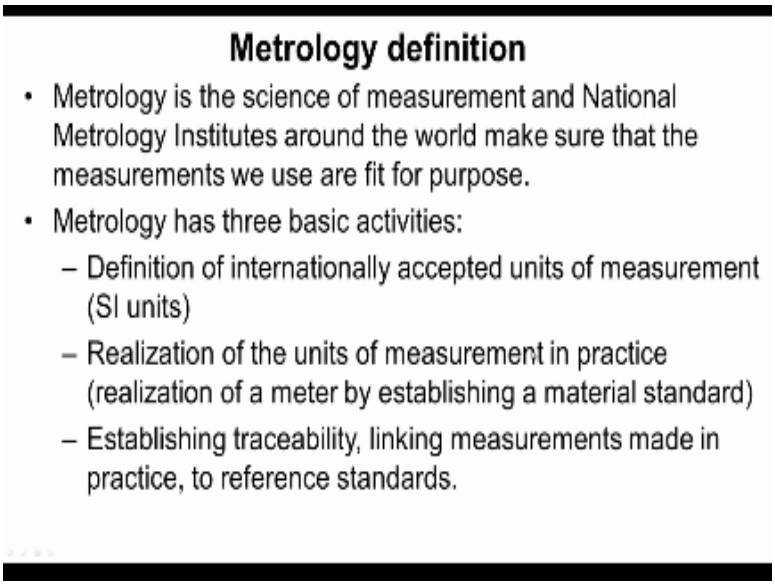
So to ensure that measurement is very very essential, also to ensure proper food supply whether any dangerous substances are included in their food supply to ensure that we need to measure the food that is supplied, then to ensure consistency of time standards. So that we can have comfortable communication between two different places or two different countries

to ensure fairness between buyer and seller measurement is very important, we gave the example of buying a cloth.

The seller takes a measuring tape and measures, and gives the cloth, now t buyer also can take another scale and he can cross check whether the length that is supplied is correct or not. That means both the scales, scales used by buyer and seller should be compatible, that means they should be compatible to some national or international standards. So that there not be any dispute between buyer and seller.

Now to evaluate newly developed and processes we need to conduct measurement, we should behave after the completion of the assembly, we have to check what is the performance level with respect to the cutting the parameters or the vibration level or the health of the a machine tool we need to conduct many kinds of measurements to get accurate and precise data in scientific research we should have measurement process.

(Refer Slide Time: 12:42)



Now let us move to understand the definition of the Metrology. It is the science of measurement and there are national metrology institutes around the world to make sure that the measurement be used or fit for the purpose. Now methodology has 3 basic activities. The first one is defining the internationally accepted units of measurement. For example length, time etc.

Then realisation of the units of measurement in practice, example the defender length, now how to realise it. So that we can use it for the commercial purposes for the benefit of the

society and then establishing traceability linking measurements made in practice to reference standard. That means whatever instruments we make should be compatible to the national and international standards.

(Refer Slide Time: 13:41)

- Metrology has the following three basic subfields:
  - Scientific or fundamental metrology
  - Applied, technical or industrial metrology
  - Legal metrology

Now metrology has the following 3 basic subfield, scientific or fundamental metrology, applied technical or industrial metrology and the third one is legal metrology and let us understand se 3 subfields. The first one is scientific or fundamental metrology.

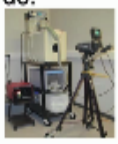
(Refer Slide Time: 14:03)

Types of metrology

- **Scientific or fundamental metrology**

  It deals with the establishment of quantity systems, unit systems, units of measurement, the development of new measurement methods, realization of measurement standards and the transfer of traceability from these standards to users in society.

  In India, National Physical Laboratory is the custodian of various primary standards.



Thermal imaging metrology for healthcare

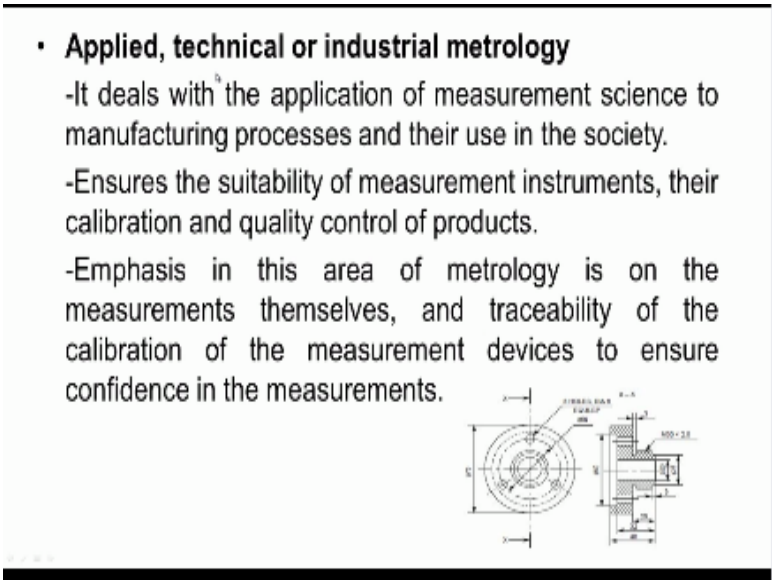
So this deals with the establishment of quantity systems, unit systems, units of measurement, the development of new measurement methods, realization of measurement standards and transfer of traceability from these standards to users in society. In India National Physical Laboratory is the custodian of various primary standards. Now you can see this photograph

which is concerned real imaging metrology for healthcare, that work is going on in real imaging which is used to detect cancer in earlier stages or the fever, scanning or the healing process of the body.

So such 3 activities and establishing corresponding measurement methods and measurement standards using activity which is carried out in the scientific metrology, what kind of measuring instrument should be used for such needy develop methods, what kind of environment should be provided, whether any specific conditions are there with regard to temperature immediate pressure or the vibration proof that in surfaces are needed.

And how to conduct the measurements of the guidelines for conducting the measurement process, how to report the measurement regards, these are the activities which come under scientific metrology.

(Refer Slide Time: 15:36)



Now we will move to apply technical ore industrial metrology it deals with the application of measurement science to manufacturing processes and their use in the society it ensures the suitability of the measurement instrument selected and date calibration and quality control other products. So in this area the emphasis is given on the measurement themselves and traceability of the calibration of the measuring devices to ensure confidence in the measurements.

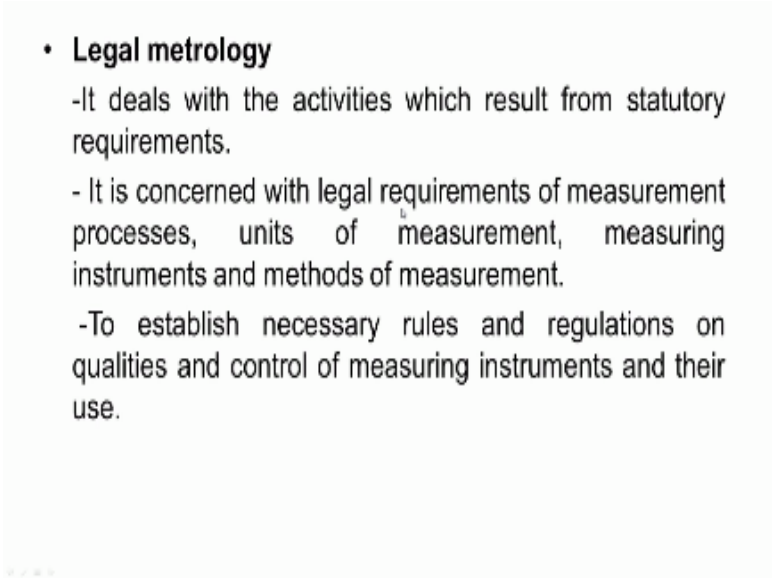
We can take the example of this drawing and will try to understand more about industrial metrology I can see in this figure we have the various parameters to be measured like

diameter of the component there are three holes of different diameter there is even bigger hole at the centre and then we have the depth that is to be measured, research is there for which we had a measure.

The depth and research services research they have to measure and various length we have to measure and there is a threaded portion here, we need to measure different elements like picture of the thread, plank angle, measure diameter, minor diameter etc. etc. Now to measure all these parameters we need to select appropriate instruments, sometimes may require their measurement of parallelism between two surfaces and perpendicularity between two surfaces.

And then what is the form of the drilled hole, whether there is any paper or whether it is bell shape or drum shape or whether any out of rhombus is there, such parameters we need to measure for which appropriate selection of instrument is necessary. So industrial metrology helps in all these activities, sometime it may have to measure inspection, we have to make inspection fixture, so that the inspection can be carried out easily. So all such things are carried out in industrial metrology.

(Refer Slide Time: 17:50)



Now we will go to legal metrology which deals with the activities which result from statutory requirements, it is concerned with legal requirements of measurement processes, units of measurement, measuring instruments and methods of measurement to establish necessary rules and regulations on qualities and control of measuring method instruments and their use.

(Refer Slide Time: 18:18)

-Statutory requirements might arise from, the needs for protection of health, public safety, the environment, enabling taxation, protection of consumers and fair trade.

-It helps in detecting frauds in measurement and to book offender for trials where necessary.

Now statutory requirements might arise from the needs of production of health, public safety, the environment enabling taxation, protection of consumers and establish fair trade. This helps in detecting frauds in measurement and to book offender for trials wherever necessary.

(Refer Slide Time: 18:43)

- **Forensic metrology** is a part of legal metrology.

  -It applies to forensic sciences. Forensic laboratories perfor numerous measurements and tests to support both crimin and civil legal actions.

  -Examples of forensic metrology activities include :

  -The measurement of blood or breath alcohol

  -The quantification of controlled substances (n and purity)

  -The length measurements of fire arm barrels.

  -Latent print examination, questioned documents examination, and DNA analysis.

  -3D laser scanning of crime scene.

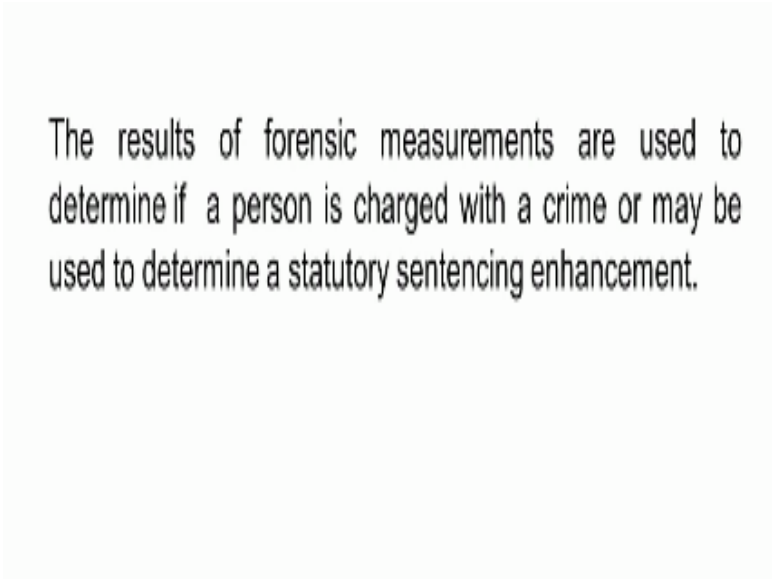
Now let us try to understand the forensic metrology which is a part of legal metrology. This applies to forensic sciences, forensic laboratories perform numerous measurements and tests to support both criminal and civil legal actions. The examples of forensic metrology activities are given below, the measurement of blood or breath alcohol content the quantification of controlled substances both for net weight and purity.

For example what is the purity of gold, so that can be checked in forensic mythology. Then length measurements of fire arm barrel. So you can see here this picture we have a fire arm

barrel, the length of the barrel we need to check, the diameter the barrel the surface finish, the various the form of the barrel we need to check and then latent prints examination for example fingerprint examination, question document examination like to check whether there is any forgery of signature and DNA analysis to establish biological relationship.

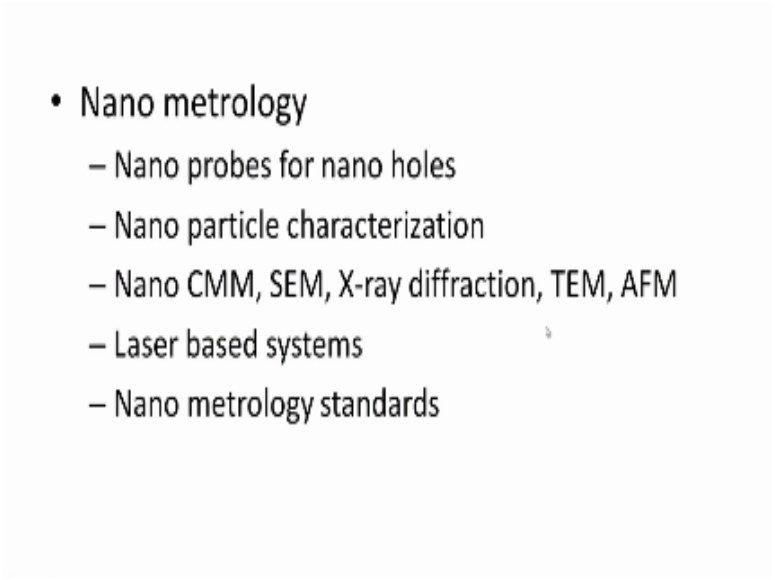
Then 3D laser scanning of crime scene can be taken, so that it can be visited again and again to study the crime scene.

(Refer Slide Time: 20:08)



Now the results of forensic measurements are used to determine if a person is charged with a crime or may be used to determine a statutory sentencing enhancement.

(Refer Slide Time: 20:24)



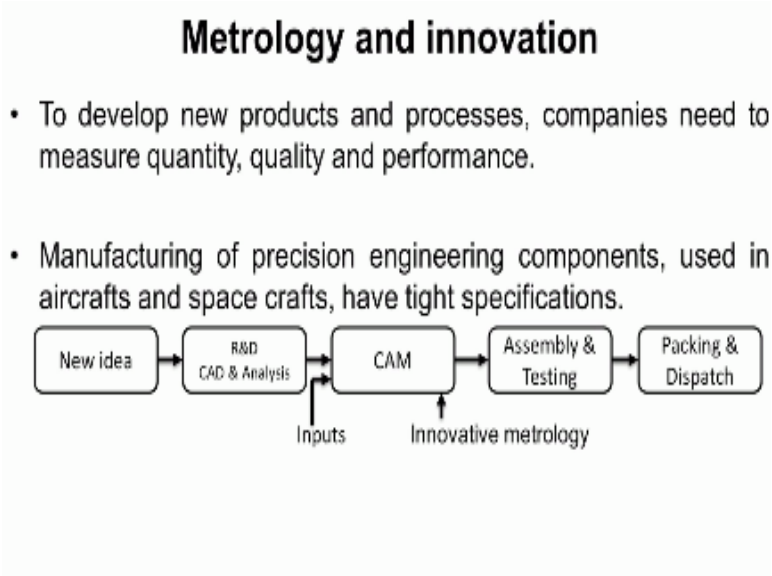
Now recently there is a another kind of metrology which is evolved because of the advancement in nano technology area, we need to measure nano holes in a nano structured particles for which we have to design and develop nano probes which can enter into nano holes to measure diameter, distance between the two holes etc. Nano particles characterization like what is the shape of the nano particle, what is the size of a particle.

What is the space between two particles such things we need to measure to characterize the newly developed composite materials nano composite materials. Then it in last few decades various measurement methods have been developed for the characterization of nano materials like nano CMM is developed which physically measures the mens products and nano products.

And then scanning electron microscopy, x-ray diffraction, tunneling electron microscopy, atomic force micros, all these are developed which will aide the characterization of nano particles, nano devices etc. and then recently laser base systems are developed which aide in inspection of nano devices and there is a need to establish nano metrology standards.

So that in all parts of the world same standards can be used. And the measurements that is carried out in a nano metrology could be comparable and usable throughout the world.

(Refer Slide Time: 22:18)



Now let us try to understand what is the role of Metrology in the innovation. Now the manufacturing industries always try to develop new kinds of methods, new kinds of products and then the manufacturing of precision engineering components which are used in aircraft

and space craft have very very tight specifications. So we need to design and develop new methods of meteorological methods.

The new kinds of metrological instrument which will be able to measure a tight specifications. Now if you study this diagram will come to know that whenever there is a new idea unrated out of warranty what will be carried out on that new idea that is generated and computer aided design analysis will be carried out on that particular idea to develop various models and to prepare a drawing.

Once the drawings are created there move for computer aided manufacturing where we manufacturer components as per the computer aided drawing that is provided using different kinds of inputs. Now if the components are new type of components having very complicated structures or profile we have to develop new methods of measurement, new instrument for measuring the complex profile.

So we should have innovative metrology, we should invent new kinds of instruments you remind new kinds of fixtures, fixtures in pictures. So that measurement becomes or inspections with component becomes fast and accurate. Now the metrology also applied in the assembly and testing of the new products that is developed. Finally the components and production are packed and dispatched.

(Refer Slide Time: 24:12)

Now let us try to understand what are the various objectives of metrology, metrological instruments are used in various sections of a manufacturing organisation. There used in tool

room, tools in machine shop, foundry shop, standards room, press shop, electroplating shop, paint shop, at all places in metrological instruments are used. In such a big organisation the metrology will have many objectives.

We will study some of the objectives to determine the type of measuring instrument needed by the plant and ensure that they are well maintained in the plant by periodical calibration depending upon the type of activities going on in the shop they have to suggest a quality control department will have to suggest what type of instrument is required, weather in process gauging is required of process gauging is required, what should be the range of the instrument, what should be the accuracy level of the instrument.

And then any special type of equipments are needed. For example I will write a sketch here say we have a component which has an internal groove like this and just writing the sketch, so there is about peace with internal groove like this, then the quality control department should suggest appropriate instrument. So this places like this one can use in inside micrometre caliper of this type.

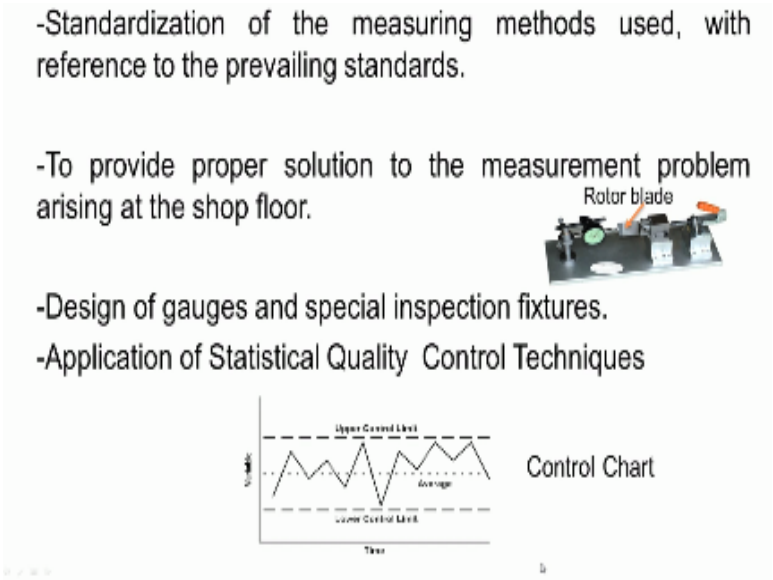
And also sometimes maybe having some wood pieces, having some board like this which are very deep, then the quality control department will have to suggest some pages are inspected measuring instruments, so that the depth of the group can be measured or the diameter of the group can be measured or sometime surface finish of that group can be measured. In that case we may have to use some long probes like this.

So the quality control department will suggest appropriate measuring instruments needed by the plant and also it ensures say every instrument will undergo some sort of wear, wear and tear due to continuous usage at regular intervals we need to inspect all those instrument to check for whether there is wear, if there is any wear they should be compared with the accurate instrumentation available in the standards room.

And the amount of error that is there in the instrument should be recorded on the instrument. So when we take the readings using such calibrated instruments we should count for the error that is mentioned on the instrument and then the quality control department will have to see what is the process capabilities of newly developed process, whether the new process

developer or really capable of doing what is expected or whether they are going out of the process for what kinds of changes are necessary.

(Refer Slide Time: 28:01)



So that the process capability increases. Now another objective of the metrology is standardization of measuring methods used with reference to the prevailing standards that means whenever new products are developed we need to measure we need to develop new methods of measurement and then what are the prevailing standards we should consult and then we should suggest the measuring instruments.

That means we should standardized the various kinds of methods as per the prevailing standard and then metrology department have to provide proper solution to the measuring problem arising in the shop floor, sometimes they operator will ask for suggestions how to check the particular parameter is unaware of using the instrument and some sort of training is to be provided to the new operators.

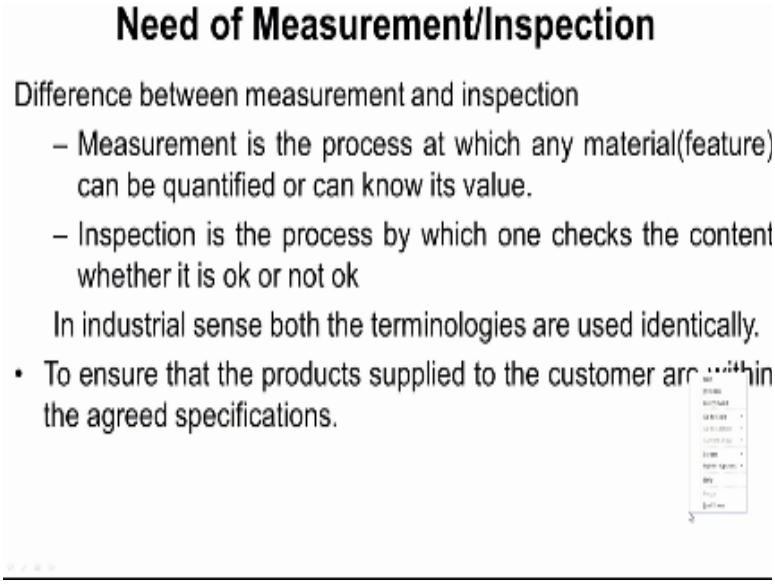
So the quality control department will teach them how to use instrument and how to come out of the problems that arise in the workshops and sometimes very complicated components like a rotor blade will have to be inspected. So in such cases we need to device special inspections pictures, one such example is shown here we have the rotor blade which is having very complex shape.

So we need to design and fabricate a holding device for holding the rotor blade and then they have indicated to measure the various parameters of the rotor blade and then application of

statistical quality control techniques to the various processes to study whether the processes are under control or not. We can see this diagram where in we have the upper control limit lower control limit and x axis time and y axis is variable.

And they have various measuring points and then the centre line indicates the average of variable size, now the measurement points are scattered well within the upper control limit and lower control limit. This indicates that the process is under control. Whenever a measuring point goes beyond the upper control limit or beyond the lower control limit then necessary action should be taken.

(Refer Slide Time: 30:56)

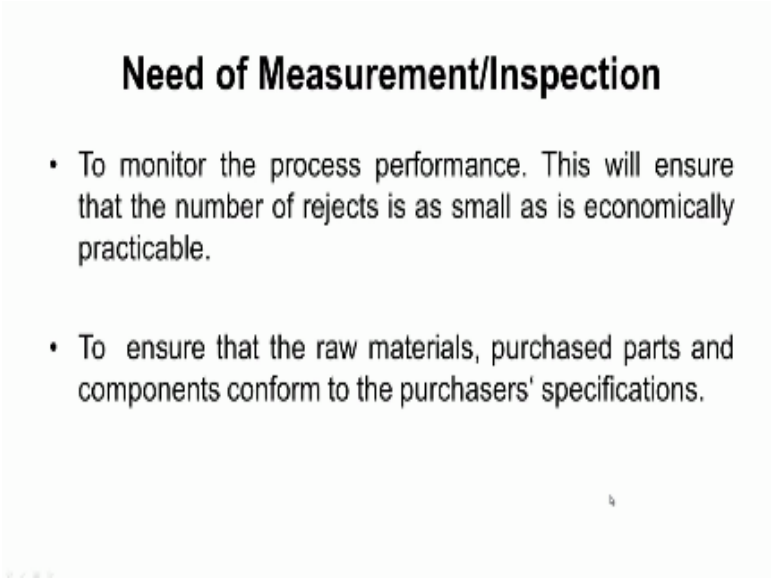


So that the process is brought back under control the action and reaction may be in the form of changing the machine setup or changing the computer program etc. Now let us try to understand what is the need of measurement for inspection try to understand what is the difference between measurement on inspection. So in the manufacturing area we need to produce various kinds of components various types of features like that depth, length, breadth surface finish etc. etc.

Now all these features we have to measure and we have to quantify them, so such a process is called measurement, sometimes we have to inspect about pieces to just accept or reject weather that PC is ok or not, only that information is required and no need of measuring the physical variable. So such an activity is known as inspection. In industrial science both the terminologies are used identically.

Now to ensure that the product supply to the customer or within the a grade specification. So whenever a customer give order he will give what are the various specifications of the product, what type of activity is required, what is the size, what is the weight, what are offences are needed, expected out of the products. All those things will explain. Now before the supply the product to the customer we should compare what are the specifications of the customer and what is that we are supplying.

(Refer Slide Time: 32:38)



If the match then only we should apply the product to the customer. Now inspection is also needed to monitor the process performance. This will ensure that the number of rejects is as small as is economic practicable. That means whenever they process goes beyond the control now we may have to do some changes in the process. So that it is brought back to control. Now to ensure that the raw materials purchased parts and components confirmed the purchase of specification manufacturing industries place order for various kinds of raw materials.

For example steel, aluminium etc. different length and differentiate they also place order for purchase parts like fasteners, electric motors etc. etc. and some components. Now before we accept the components or the raw materials purchased we should check whether they are as per our specifications then only we should accept them. So that defective parts will not move to the assembly area or the manufacturing area.

(Refer Slide Time: 33:48)

Need of Measurement/Inspection

- To meet the interchangeability concept (ie the diverse components produced in mass must be fit and mate if any component is chosen at random)
- To evaluate the possibility of rework of defective parts.
- To exclude sources of error, deficiencies in the processes.
- To establish limit gauging. 
- .

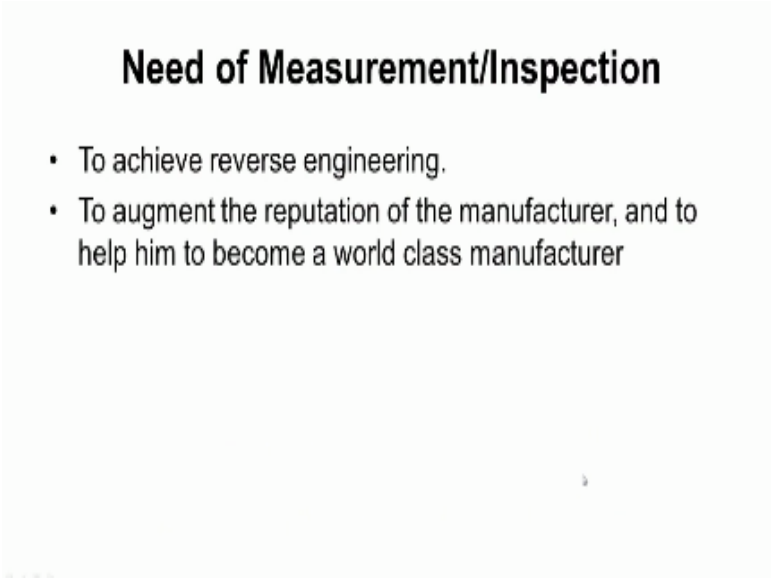
Now there is a concept called interchangeability, the meeting parts or made at different place and different countries due to their mass production concept and all these meeting parts when randomly selected and then need to match them, they should fit properly without any individual fitting operation. This is known as interchangeability. So to achieve interchangeability it is very essential that we produce the various components and parts as per the standard using standard instrumentation.

And to evaluate the possibility of rework of defective parts, now the inspector has rejected some parts, now we have to really check whether the some error can be performed, so that they can be accepted again. So far that we need to inspect defective parts and to exclude source of error, deficiencies in the process we need to conduct the measurement process, sometimes we go for limit gauging.

To establish limit gauging we need to inspect, sometimes in the manufacturing area what happens if any not have to actually measure the size of the variable, for example the diameter of the board or length of the board or the dubbed like that is needed is weather there within the acceptable limit or not. So actual measurement is not required, so such a system is called limit gazing.

To establish limit gauging also we need to conduct inspection. So this indicates that there is a need for inspection establish limit gauging.

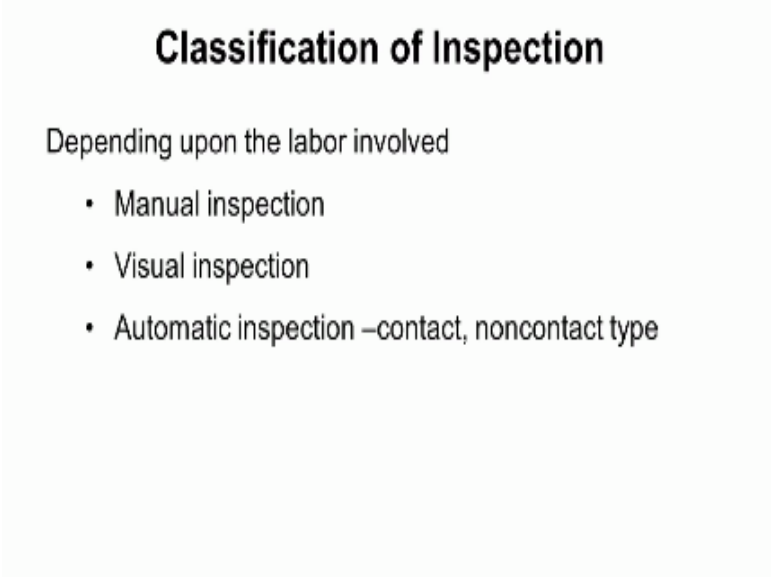
(Refer Slide Time: 35:36)



Now to achieve reverse engineering also measurement is very very essential, sometimes we have the part, but corresponding the drawing are not available. In that case we have to inspect the component that is available for its composition, for its physical sizes like length, depth, breadth, the size of a hole or they surface finished that is preparing etc, all these things they have to measure by conduct in the inspection.

And then back to prepare the drawing and then we can go for producing such components. Now to augment the reputation of the manufacturer and to help him to become worthless manufacturer measurement is very very essential. We need to conduct measurement maybe 100% inspection if the components are critical or inspection and we have to eliminate remove all the defective parts and only good products should be supplied to the customer.

(Refer Slide Time: 36:49)



So that the customer will be happy and we get repeated orders from the customer. Now let us try to understand the classification of inspection how the inspection procedure for classified. So one type of classification is depending upon the labor that is involved, that is manual inspection, visual inspection, automatic inspection. In Manual inspection what happens if the operator will take the work piece that is to be inspected.

He will take the appropriate measuring instrument and he will check the parameter for example length or diameter hole or surface finish. So this is called the manual inspection. So this process sometimes becomes very slow and it is subjected to the effects of fitting of the operator and the visual inspection no instruments are used, the work pieces are inspected by the operator for any defects like the determines of burns or presence of any cracks etc. etc.

No instrumentation is used, in the most the operator may use a magnifying lens without type of inspection is automatic inspection. So this can be contact type inspection or non contact type inspection. So in this process the intention of the operator is not there, after the production of the component it is clean, and then it is placed on the measuring machine. For example a co-ordinate measuring machine where is the probe will touch the various parts of the component and the various physical quantities are measured.

In non contact type light-based measurement systems are used and the various parameters like surface finish diameter, component etc. are measured without any contact with the work piece. So this non contact type automatic inspection can be used during the processing or in-processing gauging is also possible.

(Refer Slide Time: 39:14)

Now the second type of classification is based upon the area of inspection where the inspection is carried out, so we have different types like receiving inspection, first piece inspection, process inspection, batch inspection, final inspection and tool and gauge inspection. Now there is a proceeding inspection is the manufacturing industry places order for various raw materials or parts.

So when we receive them we have to inspect them for all the physical parameters composition etc. etc. So this is known as receiving inspection. If there are any detective part supplied by the supplier that a reserved them so that defective components will not move into manufacturing and assembly area. Then CAD to part analysis or first piece inspection. Now based upon the CAD that is provided, we produce the first piece and now we have to use a different kinds of instruments to measure the various kinds of physical parameters.

To check whether all the parameters as per the CAD drawing. If there are any error we need to make some changes in the CAD and again react to reduce the peace and again we had to adapt the fast space inspection till get the first page which is acceptable and then we can start the mass production of that component. Now the process inspection is during the process itself we can conduct the inspection.

For example I get example of non contact inspection of inspection process wherein the parts are inspected during the machining process, we can take the example of a grinding process, so whenever the grinding process is going on without stopping the grinding machine we can

use a laser light, laser light will fall on the work piece and with the work piece achieves, attends the correct size.

The light that is reflected, amount of light that is reflected is sensed and then a proper instruction given to the machine tool for stoppages machine tool and then we have the batch inspection a batch of components are collected and they are based upon the formalities and then the decision is taken to observe the best or not and it final inspection once all the process of processes are completed we need to.

And then when all the components are assembled to make the product final inspection we need to carry out to check whether painting is over or not whether all sub assemblies are properly assembled whether the movement of all parts moving parts is the correct or not or whether there is any leakage or vibration levels are exceeding the limits things are inspected before dispatch the product to the customer.

And then tool and gauge inspection, all instruments are subjected to wear, so at regular intervals we need to calibrate the instruments with the help of instruments available in the standard room and then we need to record what is the amount of error. So when you use such instruments we have to account for the error that is mentioned on the gauges. Now let us conclude the first lecture.

Now let me summarise the lecture, in this lecture will try to understand what is the measurement process and then what are the various objectives of metrology, what is the need for measurement process, what are the different kinds of inspection processes. In next lecture we will continue with the other basic concepts thank you.