Engineering Metrology
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Lecture - 18
Comparators (Part 1 of 2)

So, the next topic of discussion is going to be Comparator. Moment you see the topic or title comparator, so then you will quickly realize that there is something to be compared. So, what is to be compared? Unknown value to a known value we compare and we try to get some data. So, this is what we are going to get the we are going to go through this in this particular lecture.

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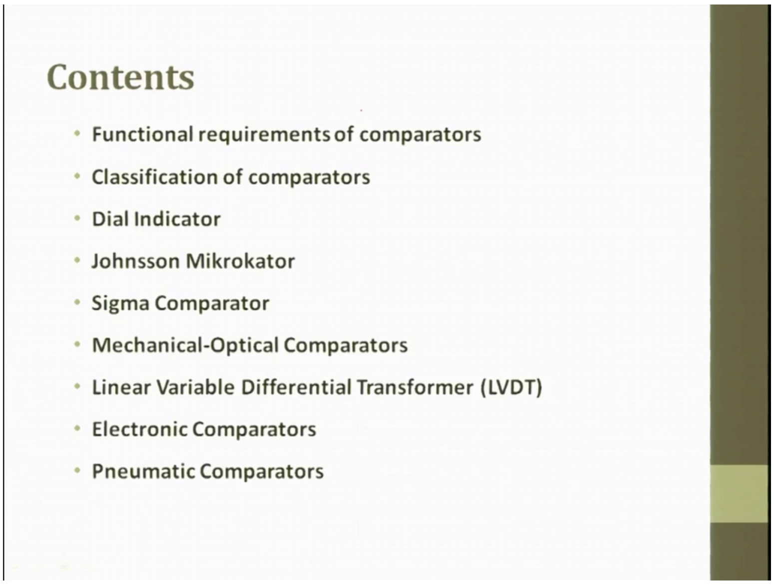

So, here the contents will be functional requirements of comparator, then classifications of comparator, dial gauge. So, we will look in to mechanical, then we will look into mechanical optical, then we will look into pneumatic then electronic and then we will complete this chapter.

So, we will see dial gauge, dial indicators which is exhaustively used in workshop as well as in tool room, then Johanssons Mikrokator, then sigma comparator, mechanical-optical comparators, linear variable differential transformers; LVDT, these are also comparators, electronic comparators and pneumatic comparators. At the end of the chapter or end of this lecture you will be able to understand and appreciate how are these instruments working.

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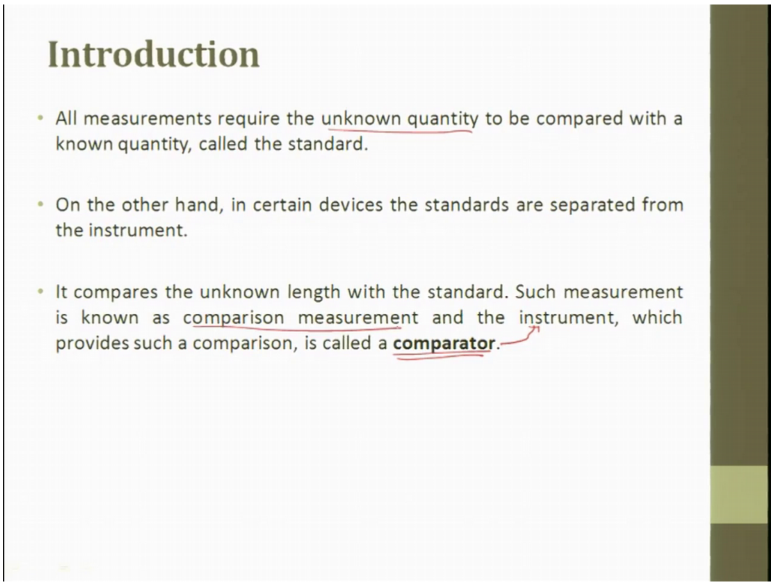

All measurements require an unknown quantity to be compared with the known quantity called the standard. On the other hand in certain devices the standards are separated from the instrument, it compares the unknown length with the standard such measurement is known as comparison measurement and the instrument which is used to provide that comparison is called as a comparator. The instrument is comparator and what we do is a comparison measurement.

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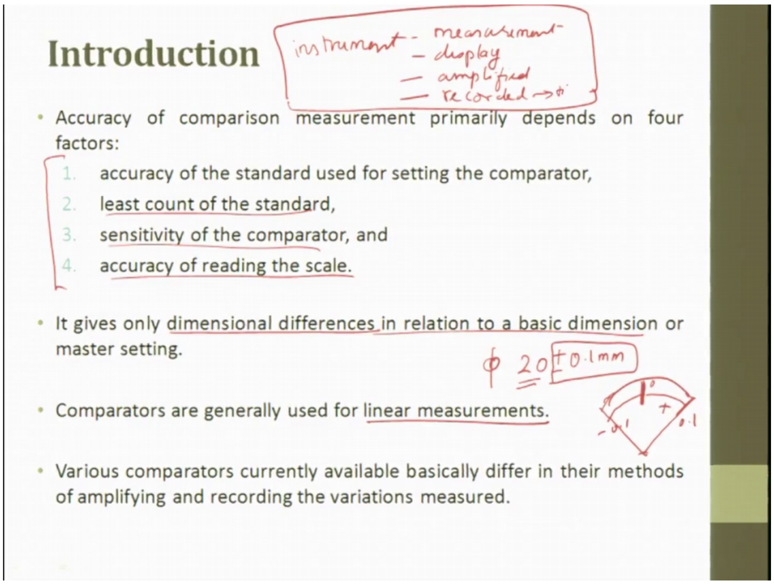

So, accuracy of a comparison measurement primarily depends on 4 factors these are very important 4 factors. First it depends on the accuracy of the standard used for setting the comparator, if the standard itself is not correct or if there is a small error then whatever you step on this comparator will be with that error base data plus that error and when you measure it will always going to be this error also is going to get magnified and then you see the data. And especially when you do linear it is, we able to control it, but when it is at an angle it is very difficult.

The least count of the standard is important comparison. The sensitivity of the comparator, sensitivity is how sensitive you are for example, you try to call up somebody you call up five times then there they turn and then they realise that, you have made a call, so that is sensitivity. And second thing is sensitivity also depends upon one how what is the small change can you measure to how quick can you measure these two are very important with this part of sensitivity. Then accuracy of the reading on the scale all these things are very important factors which are to be considered for a comparing comparator. It gives only dimensional difference in relation to the basic dimension or master set a comparator gives only a dimensional difference in relation to a basic dimension.

For example if you have 20 plus or minus 0.1 millimeter diameter to be measured. So, the question is so why do we want to always measure this 20 we will measure only this tolerance that deviation alone. So, you can have a dial gauge which has a 0 which this is the 0 limit which tries to have positive 0.1 and this can be negative 0.1 and you try to measure this is a dial gauge, this is the center value this is minus this is positive. So, all you have to do is measure this. So, it tries to it gives only the dimensional difference in relationship to the basic sets, ok.

Comparator are generally used for linear measurements. For example, this clip gauges when you stack it and then you make an n standard, you just have to check the n standard you put a dial gauge, dial it all through or take a surface plate dial it at ten places you get the deviations. So, it is more of linear measurements.

Various comparators currently available basically differs in their method of amplifying and recording the variation measures. So, when you talk about any device to the instrument I covered in the beginning itself instrument first is measurement, second thing is display of the data, the third thing is it has to be amplified and displayed, and then 4th thing is it has to be recorded. So, now when we look at any instruments we always try to see all the 4 data are capable in that instrument this because this is with respect to time, variation with time we can try to measure the data.

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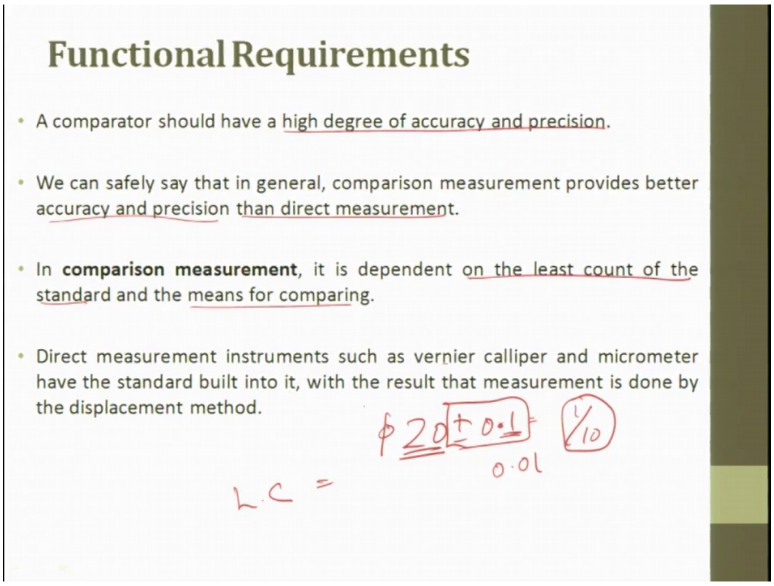

Functional requirement a comparator must have a high degree of accuracy and precision. We can safely say that in general comparison measurement provides better accuracy and precision than the direct measurement. Because here we are not worried about this 20 plus or minus 0.1, we are not worried about this 20 we are only worried about this small measurement. So, this small measurement can be easily done because this will be magnified and then you try to take, so it is better than the direct measurement. A comparison measurement it is dependent on the least count of the standard and the mean for comparisons.

Least count means suppose let us assume you have to measure you are trying to make a shaft of 20 plus or minus 0.1 mm. So, now, you have. So, you are asking for a tolerance of 0.1. So, the least count for this instrument should be one-tenth of its measurement so that means, to say you should have a instrument for a dial gauge which has a least count of 0.01 at least then only you can try to measure this tolerance variation.

The thump rule says one tenth of the tolerance whatever is given you should have the least count for the equipment. If you do not have this then it is very hard for measure in this variation. The direct measurement instrument such as Vernier calliper and micrometer have a standard built into it with the result that measured is done by the displacement method.

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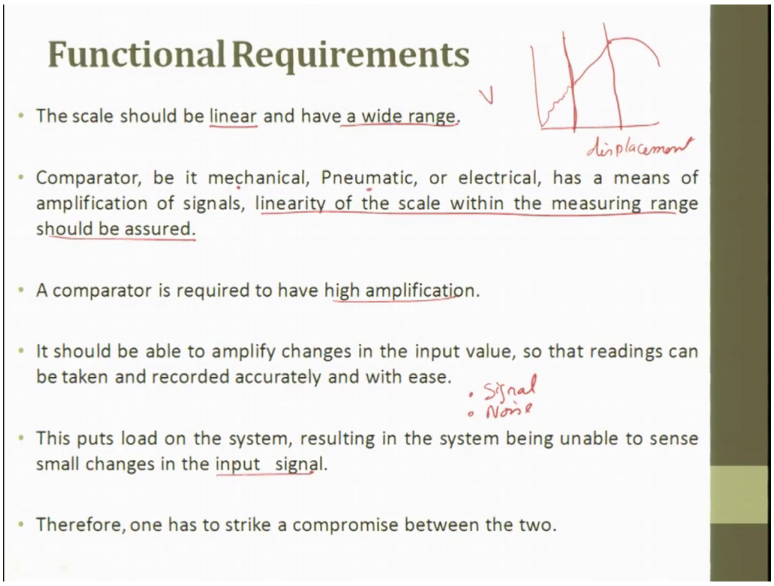

The scale should be linear and has to have a wide range the comparator be it mechanical be it pneumatic be it electrical so that means, to say the source for comparator can the instrument can work on the mechanical. Mechanical means it can be working with respect to spring, you use some levers so you can magnify it ten times demagnify it ten times both are possible. So, generally we magnify and then we have a coiled spring or a torsion spring what we have a leaf spring to do this.

Next you can use pressure, air pressure. So, difference in air pressure can be used for measuring comparator then electrical also can be used has a means of amplification of the signal, linearity scale within the measurement range should be assured. So, what we are trying to say is suppose let us try to say this is the voltage output and this is the displacement, the response can be something like this I am just amplifying it then the response can be linear and then the response can fall down like this, ok. So, now what we are saying is whenever you try to use an instrument look at the linearity range and try to use the comparator or the instrument in this range. Why because in this range it is easy for you to define an equation for what volt displacement you will have this voltage, ok. Here you can still write, but you will have error terms also here it will be much more easier that is what we are trying to say linearity of the scale within the measuring range should be assured, ok.

The comparator is required to have high amplification. It should be able to amplify changes in the input. So, that the reading can be taken and recorded accurately this puts load on the system resulting in the system being unable to sense small changes in the input signals therefore, one has to strike a comparison between the two. So, input output. So, if you have a very sensitive output then if there is a very small change in the input then it becomes as a mismatch.

This input load on the system resulting in the system being unable to sense a small change in the input signal. Too sensitive, so it will try to give you lot of signal and noise. So, when you try to use it in electrical it will get a signal and then you will also get one more term called as noise, and if it is too sensitive the noise becomes dominating the signal, and if the input small variation then it becomes very difficult for you to find out.

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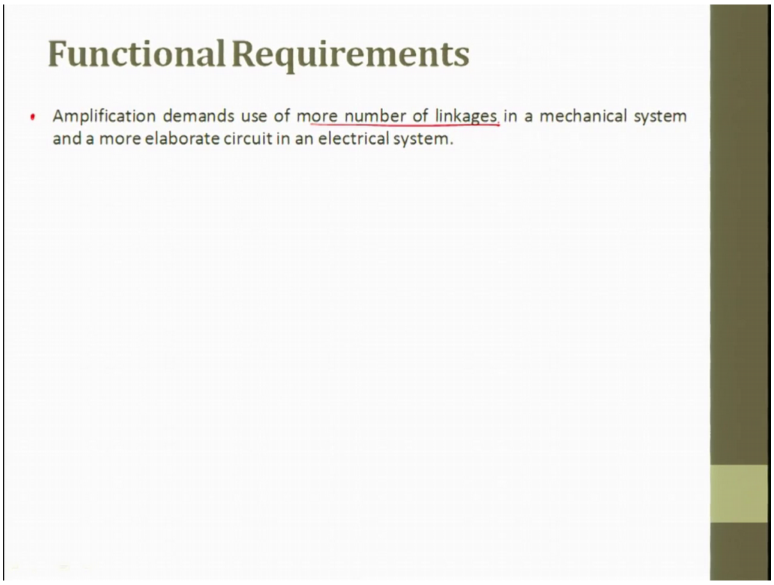

The functional requirement last point is going to be you should have the amplification demand used of more number of linkage in mechanical system and a more elaborate circuit in terms of electrical system is required when we try to do amplification, right. So, this number of links can also lead you to error we should be careful.

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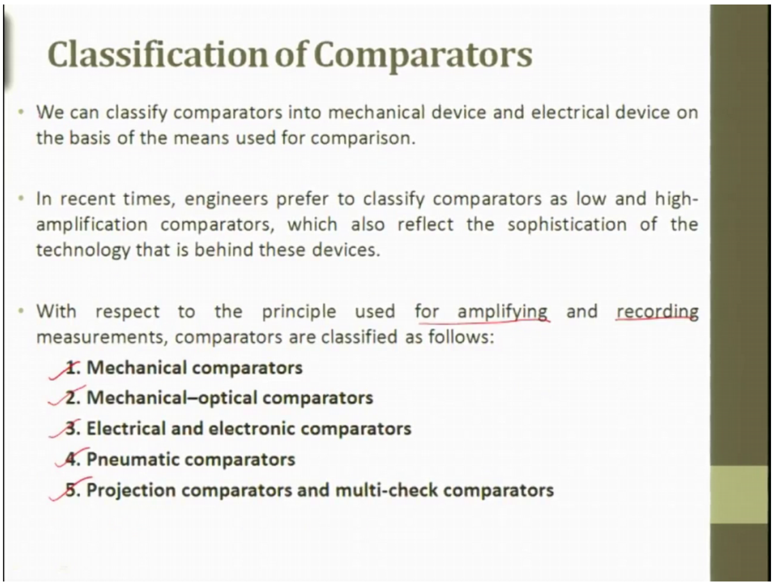

Classification of comparator, we can classify comparator into mechanical device and electrical device on the on the basis of the means used for comparison. In recent times engineer prefers to classify comparator as low and high amplification comparators which also reflects the sophistication of the technology that is behind these devices. So, they are classified like mechanical comparator, they are classified as mechanical comparator, mechanical optical comparator, electrical and electronics comparator, pneumatic comparator and finally, projection comparator and multi check comparator. So, these are the classifications which are done on the principle for amplifying and recording measurements.

Dial gauge which now we are talking about the mechanical comparator. So, mechanical comparator dial gauge.

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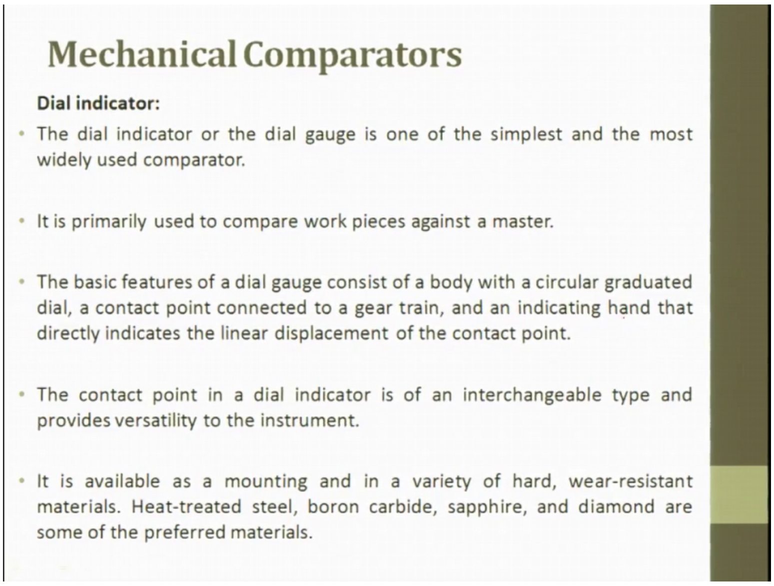

The dial gauge indicator or a dial gauge is one of the simplest and the most widely used comparator. It primarily used to compare workpiece as against a master.

The basic feature of a dial gauge consist of a body with a circular graduated dial or contact point connected to your gear train and indicating hand that directly indicates the linear displacement of the contact point. Let us see the figure.

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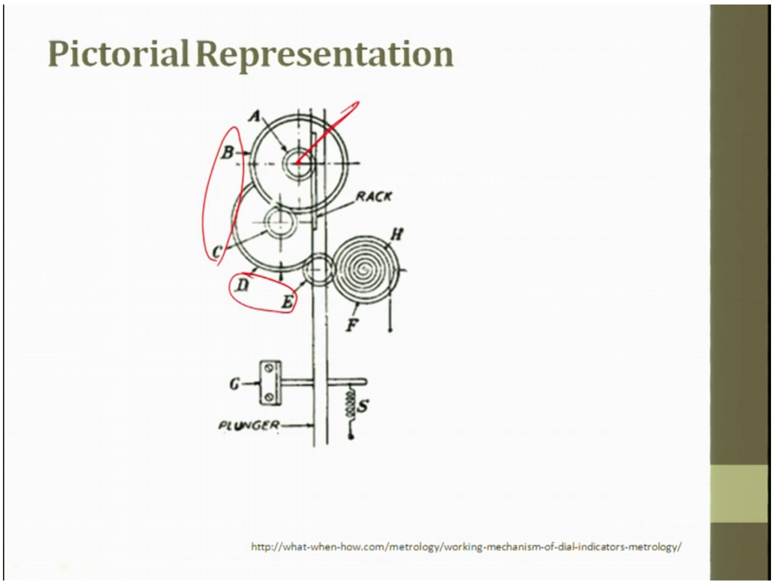

So, this is the figure right. So, you have a plunger which moves the plunger is now there is a spring which is loading to G, and here the displacement we will try to move this coil spring and you have a rack. So, from the rack you have a pointer or from here you can have a pointer which is displayed on a dial gauge.

The contact point in a dial indicator is of an interchangeable type and provides versatility to the instrument. So, the contact point which touches the workpiece in a dial gauge is of an interchangeable type. It is available as a mountain and in a variety of hard wear resistant material. The heat treated steel boron carbide sapphire diamond are also used are the tip contact tip, the plunger and the spindle are one piece.

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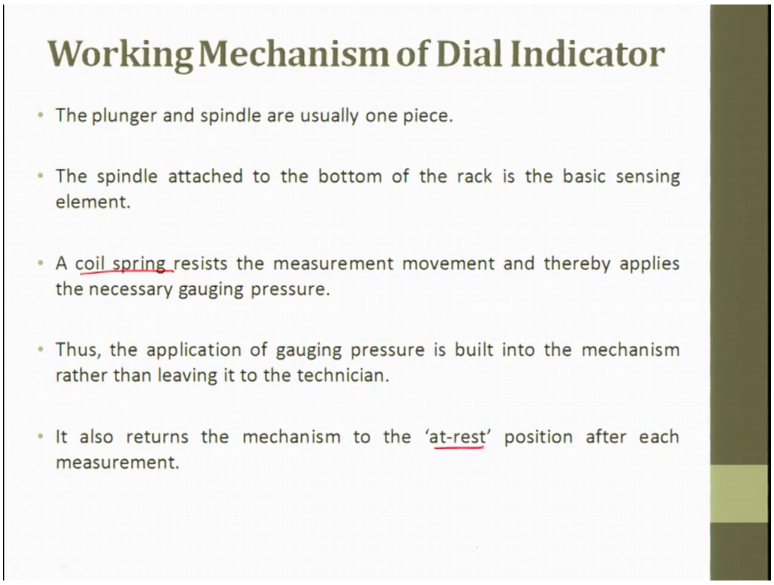

The spindle attached to the bottom of the rack is the basic sensing element. So, where is the spindle? The spindle attached to the bottom of the rack. So, here is the rack right here is the pinion, here is the rack. So, when you push, this rack moves then the pinion moves. So, in the pinion if you have a pointer then the pointer also moves.

A coiled spring resists the measurement moment and thereby applied the necessary gauging pressure. So, when it moves automatically if it goes if it goes up and if it stands there then it is of no meaning. So, there has to be a resistance given for this upward moment, so use a coil spring. Thus the amplification of the gauging pressure is built into the mechanism rather than leaving it to the technician. It can also return them the mechanism to the at rest position after each measurement that is because of the coiled spring whatever is available.

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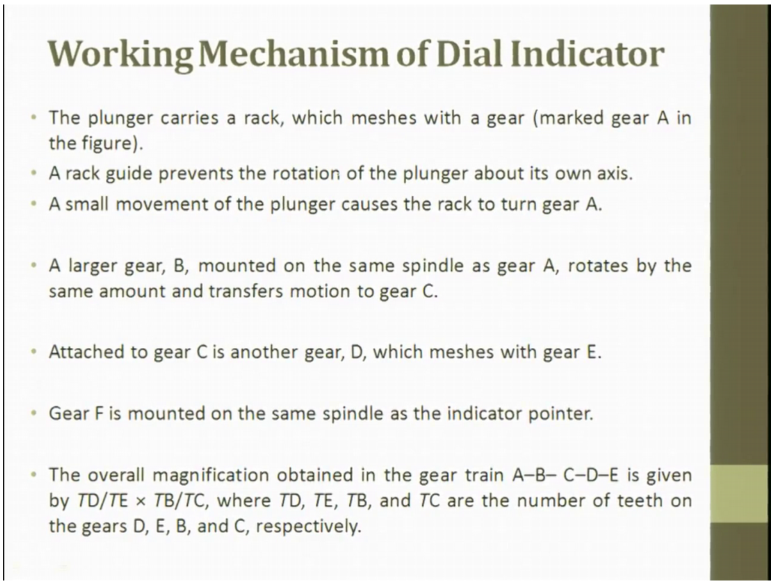

The plunger carries a rack which meshes with a gear, marked gear a in the figure. So, this is the figure which is marked A in the gear figure the rack guides prevents the rotation of the plunger about its own axis a small movement of the plunger causes the rack to turn a gear A. So, if you go back gear A have said when a large gear B mounted on the same spindle as gear a rotates by the same amount and transfers to the motion C. So, this gear this moves up and down. So, this is pivoted this, this gear is also pivoted on the same point. So, when A rotates B also rotates. Now, when B rotates C also rotates, when C rotates D also rotates and D in turn rotates E.

So, A large gear B mounted on the same spindle as gear A rotates by a small amount and transports the motion to C, attached to the gear C is another gear D which measures with the gear E. Gear F is mounted on the same spindle as the indicator point, gear F is mounted on the same spindle of the indicator point. So, the overall magnification obtained in the gear train A B C D and E is given by TD by TE into TB by TC, where TD, TE, TB and TC are the number of teeth on the gear D E B and C respectively.

So, it is all gear ratios. So, if you try to do the overall magnification it is all between D and E, if you go back to the figure D and E that is one, so DE is one set. Then the next set is going to be BC which is another set. So, these two sets are there. So, we try to get the amplification based on this. So, I have explained this figure. Here is a plunger rack this gear rotates, then this gear rotates, then this E rotates this in turn is attached to the coil spring.

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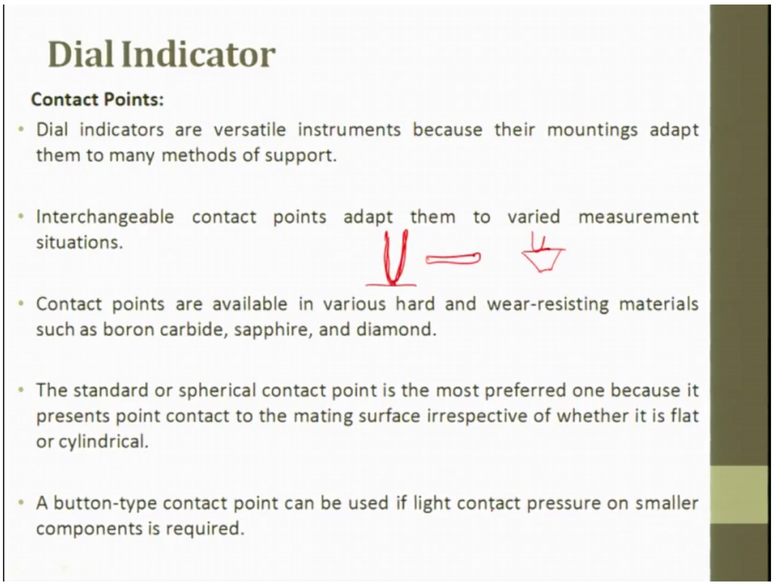

So, the contact point the dial indicator are versatile instrument because there mounting adapts them too many methods of support, the interchangeability of the contact point adopts them for vary in measurements. So, the tip can be changed. You can have a circular tip, you can have a flat tip, you can have a tip which is like invert like a plunger, you can have multiple tips.

The standard or a spherical contact is the most is most preferred one because present point contact on the mating surface irrespective of whether it is flat or not. What we are trying to say is we are trying to say when we have a circular contact then the point of contact is going to be a single point. So, the bottom type contact points can be used if light contact pressures of small components are used.

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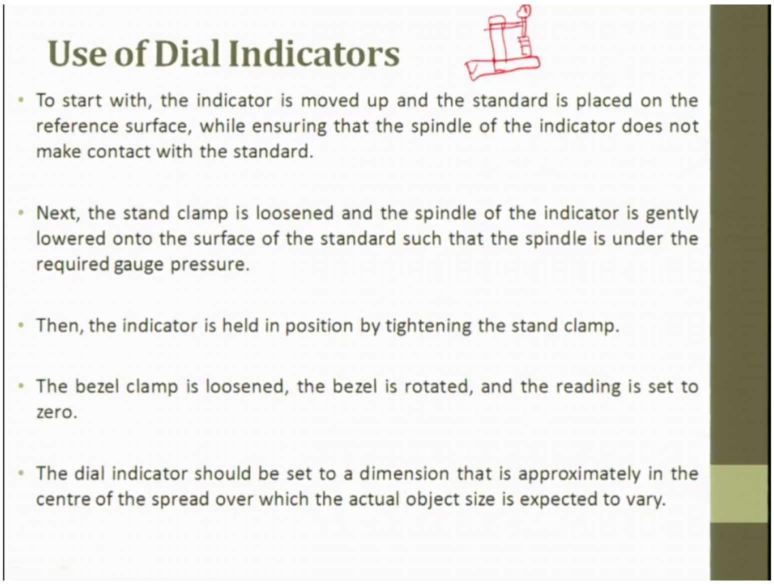

To start up these indicators is moved up and the standard is placed on the reference surface. While measuring the spindle of the indicator does not make an contact with the surface. So, first we keep we put it as a dial and then this dial is moved this dial is moved against say for example, there is a stand then we put all these standard measurement whatever it is then here on this stand we mount a dial gauge. To start up the indicator is moved up and the standard piece is placed on the reference surface while ensuring that the spindle of the indicator does not make any contact with the standard.

Next the standard clamp is loosened and the spindle of the indicator is gently lowered to the surface of the standard such that the spindle is under the given required gauge pressure. Then the indicator is held in position by tightening the stand clamp, the bezel clamp is loosened and the bezel is rotated and the reading is set to 0. So, now, here is the reading which is set to 0.

A dial indicator should be set to the dimensions that is approximately in the centre of the spread over which the actual object size is vary.

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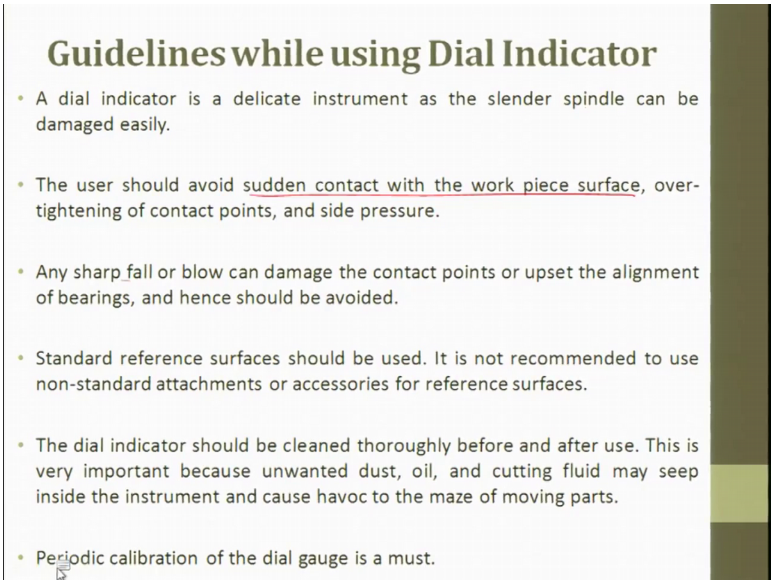

So, the dial indicator is a delicate instrument and as a slender spindle can damage easily. So, the user should avoid sudden contact with the workpiece surface overall tightening of the contact point. Any sharp fall or blow can damage the contact point standard reference surfaces should be used for measuring and dialling it to 0. The dial indicator should be kept should be cleaned thoroughly before use and periodic calibration of the dial gauge is must.

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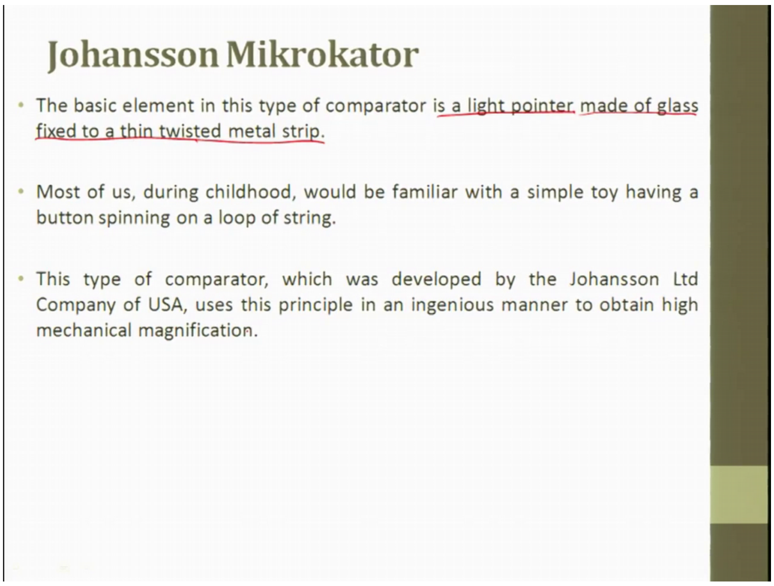

These are all for dial gauge type indicator.

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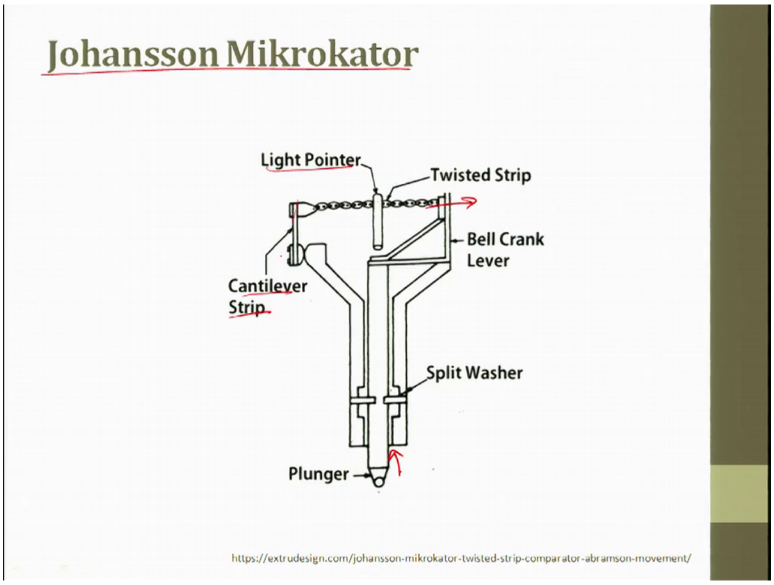

So, next one we will see the Johansson Mikrokator. The basic element of this type of comparator is a light pointer made of glass fixed to a thin twisted metal spring, is a light pointer made of glass fixed to a thin twisted metal spring. Most of us during childhood would be familiar with a simple toy having button spinning on a loop of a string. The same concept is used here by Johansson Mikrokator.

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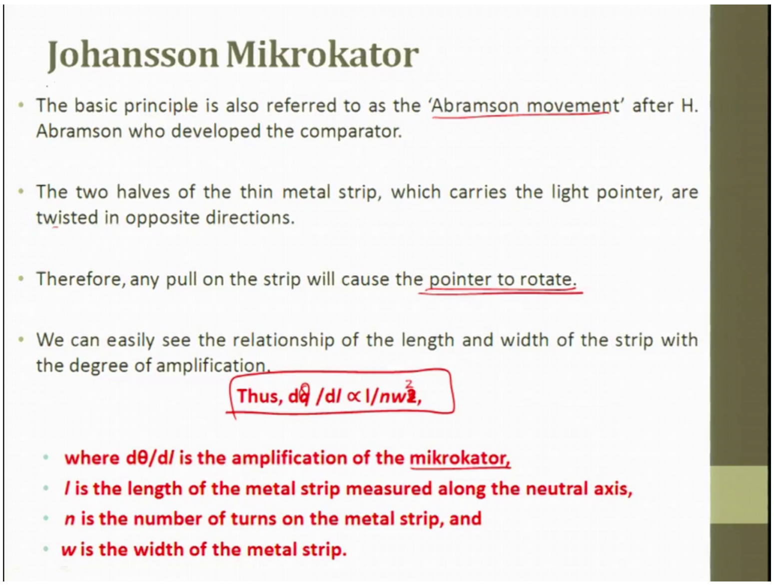

The basic principle is also referred as Abramson movement after H Abramson was developed the comparator. Two halves, this is the twisted spring this is the this is the pointer this is the twisted string which is there, and this is a bell crank lever this is the bell crank lever. So, this is attached to a plunger, is the light pointer, right. So, here is this is to guide the pointer we use it, and here is the cantilever strip. So, this is basically to hold. And here when this is moved this is when this is moved up this is pulled. So, then there is a deflection which is happening this is against a fixed, fixed cantilever strip, ok.

So, the two halves of a thin metal strip which carries the light pointer are twisted in opposite direction to half a thin metal strip which carries a which carries a light pointer is which carries are twisted in opposite direction. Therefore, any pull on the string will cause the pointer to rotate the pointer will rotate. We can easily see the relationship of the length and the width of the strip with a degree of amplification thus dq by dl is inversely proportional to l by n w square omega square.

So, here d theta by dl, so this is d theta d theta by dl is the amplification of the instrument, l is the length of the metal strip measured along the neutral axis, n is the number of turns of the metal strip and w is the width of the metal strip. With this we can try to we can try to see what is the amplification happens when this Johansson Mikrokator. So, we are talking about this right this rotates the pointer rotates that is what we say here. Therefore, any pull on the string will cost the pointer to rotate.

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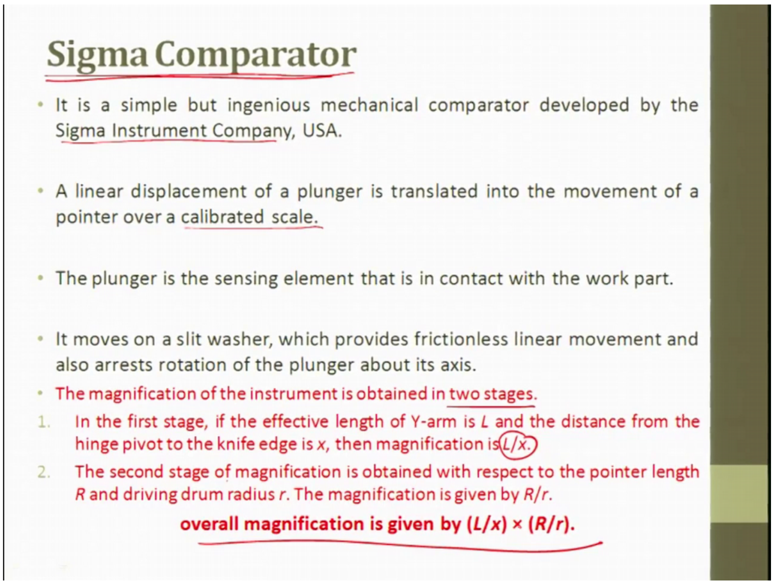

So, the next comparator is called as sigma comparator. Sigma was developed by Sigma Instrument Company in USA the linear displacement of the plunger is translated into the movement of a pointer over a calibrated scale.

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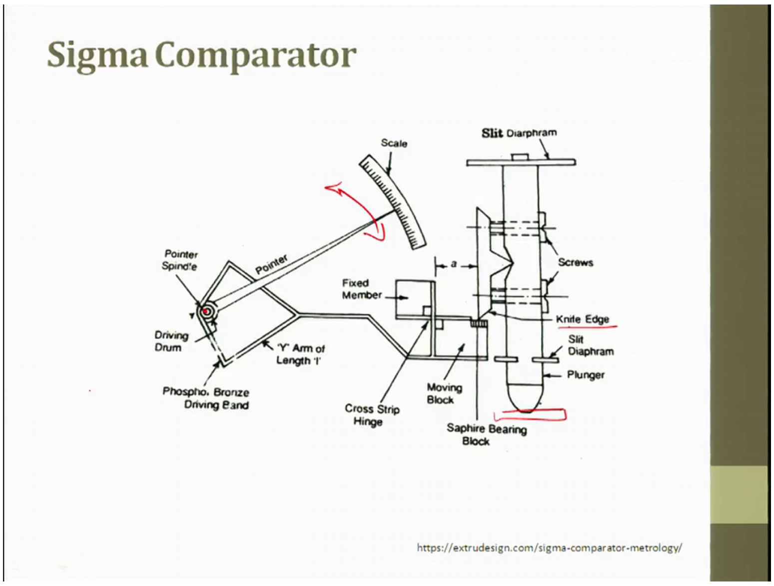

This is the sigma comparator. So, here is the plunger. So, here is the instrument you place. So, when this is pushed, when this is pushed this arm this is also moved, when this is moved. So, then you can see here that this translation happens and then finally, the pointer moves this way or this way the pointer is mounted, ok. So, this is attached to a band, this is attached to a band and this band in turn is attached to a fixed point and here as at movement the plunger moves, this a knife edge also moves. So, from the knife edge we get transfer this to the other points also.

The plunger is the sensitive element that is in contact with the workpiece. It moves on a slit washer the slit washer is everywhere, the slit washer is everywhere which is used to guide the plunger movement which provides frictionless linear movement and also arrests the rotation of the plunger.

The magnification of this instrument is obtained in two stages in the first stage if the effective length of Y-arm is L and the distance from the hinge pivot of the knife edge is x then the magnification is L by x. So, this is L and this is x. The second stage of magnification is obtained with respect to the pointer length R and a driving drum radius r, this is R and this is r. So, then the overall magnification is one time here and one time here. So, this is how we try to get the magnification of the of the measurement whatever is done to get the response. So, you can have a 10 times, you can have even 100 times response is possible.

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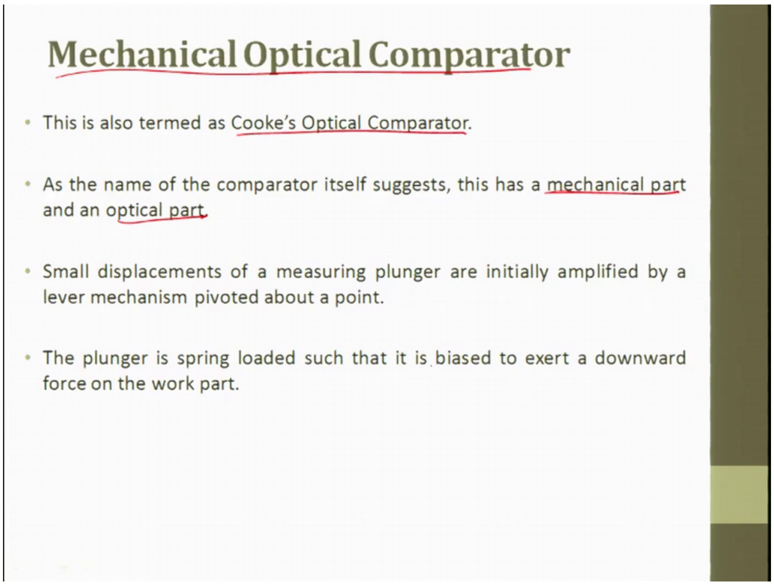

The next comparator is going to be mechanical optical comparator which was the term is also called as Cooke's Optical Comparator. The as the name of the comparator itself suggest it has a mechanical part as well as an optical part. Small displacement of a measurement measuring plunger are initially amplified by a mechanical system a lever mechanism pivoted about a point. The plunger is spring loaded such that it is biased to exert a downward force on the workpiece.

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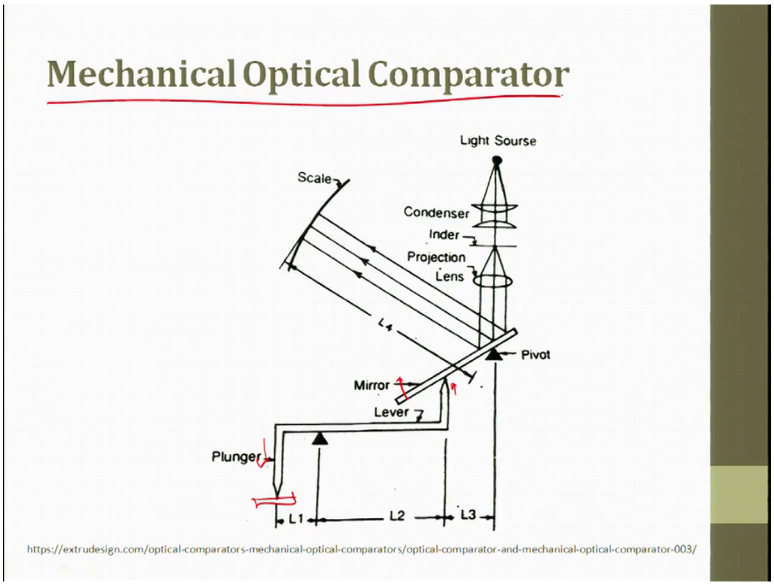

So, for example, here is the workpiece we keep, ok. So, here is a plunger which in turn tries to move this lever. So, this lever tries to move this mirror here, it is pivoted here. So, this is moved. So, then what happens that is a light source a condenser a up a projector which hits at the surface and then this gets reflected on a scale and then we try to measure the value, ok.

So, here you this is the workpiece which is kept a plunger, a plunger in turn is pivoted here this, the other end of the plunger is attached to the mirror. So, when the plunger moves down this moves up. So, once this moves up there is a change in the mirror angle. So, here it can move up this way that way. So, here is the pivot point. So, light source optical system, mechanical system put together called as optical comparator.

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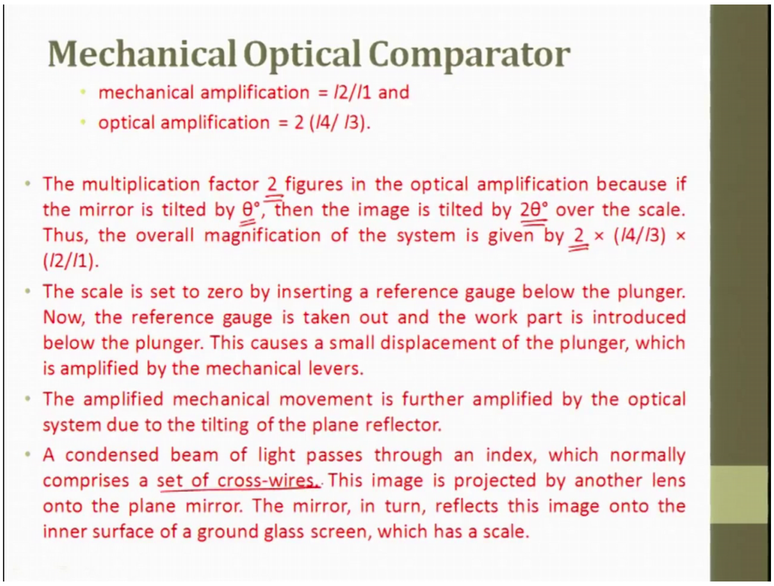

So, the magnification amplification, mechanical amplification is l 2 by l 1 and the optical one is l 4 by l 3 into two times. So, the multiplication factor two figures the optical amplification because if the mirror is tilted by an angle theta then the image is tilted by an angle 2 theta over the scale, thus the over magnification is going to be twice l 4 by l 3, then multiplied by l 2 by l 1. The scale is set to 0 by inserting the reference gauge below the plunger and the amplified mechanical movement is further amplified by optical system due to a tilt in the plane mirror.

The condensed beam of light passes through the index which normally comprises of a set of cross wires, so the image of the cross wires as measured and we try to take the amplification.

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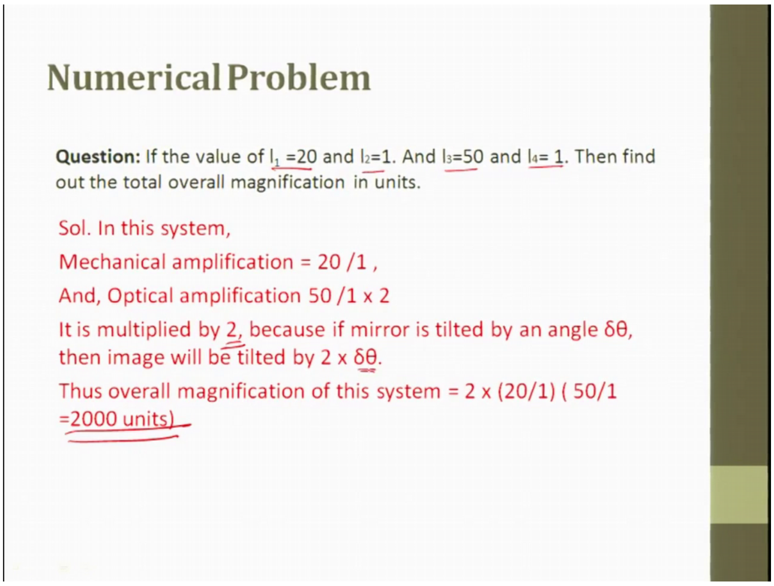

We can try a small problem if the value of l 1 is given l 2 is given l 3 is given and l 4 is given. So, to find out the overall magnification in units, so what we do is we try to do l 1 by l 2 then l 4 by l 3 then the multiplication is twice. So, if you see it will be 200, 2000 times magnification can be done and you try to get the output. So, why is a two times? It is two time into del theta the del theta is very small angle displacement we try to get this.

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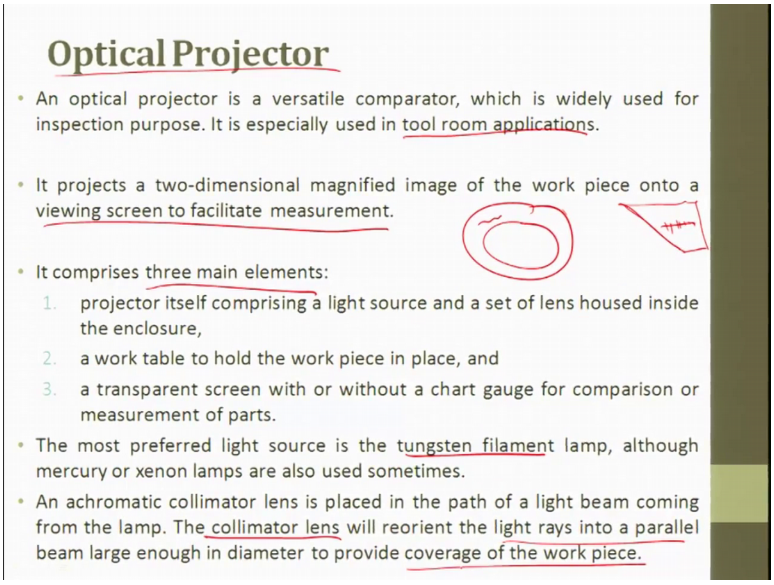

The next one is going to be optical projector. The optical projector is a versatile projector which is widely used for inspection purpose. It is essentially used in tool room application and the other thing is if you I gave you an example for oaring in the first lecture task for the students. If you remember I gave you an example of a oaring to measure the diameter of the oaring. So, optical projection is the most suitable technique to measure the oaring dimensions because the material is elastic in nature. The moment you push or touch against an instrument it is going to deflect or deviate.

So, optical projection is the technique which is used for that in it projects a two dimensional magnified image of the workpiece onto a screen to facilitate the measurement. So, you can have an oaring there at this can be optically magnified may be 20 times 200 times and you try to see a very large image you can try to see, but even now the biggest challenge is on a on a oaring.

Suppose if there is a crack on a oaring if there is a crack, this cannot be detected by the optical projector because optical projector projects these dimensions only, but on the surface if there is a crack this technique cannot be used, ok. It comprises of 3 main elements projector, itself comprise a light source and set of lens inside then a working table to hold the workpiece then a transparent screen with or without a charge. So, what we say, this is a oaring and the transparent screen will be something like this. So, if you see a transparent screen so here you can have graduations.

So, the most preferred light source is tungsten filament lights all although mercury and xenon lights are also use sometime, achromatic collimator lens is placed in the path of a light beam coming through the lamp. The collimator lens will reorient at the light rays into a parallel beam, large enough in diameter to provide the coverage of the entire workpiece because if you try to project an object and you have to see the full dimensions full features of the object then we use a collimator lens. So, what it does is which gets all focused on top the light into a parallel beam large enough in the diameter to provide the coverage of the entire workpiece. So, this is how an optical projector works.

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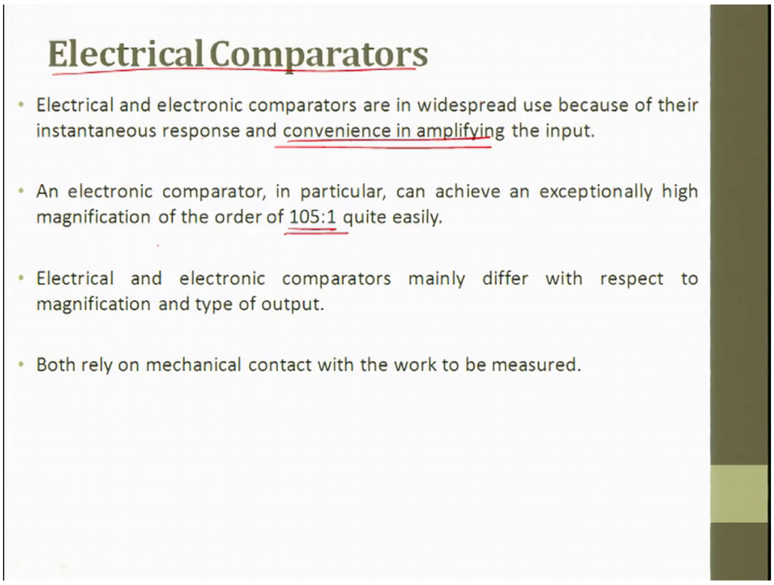

Next topic of discussion is going to be electrical comparator. The electrical and electronic comparators are in wide range used because of their instantaneous response and convenience in amplifying the input. See electronic amplification is very easy and it is very reliable as compared to mechanical because mechanical it is prone to have a wear and tear.

An electronic comparator in particular can achieve an exceptional high magnification of the order of 105 times is to 1 quite easily which is not possible in mechanical. So, mechanical if you want to do such amount of high magnification we do it on stages. So, that is why if you remember in the discussion itself. We when we discussed about the dial gauge we said using multiple levers lever mechanism we can start magnificent, but if there is a error in one of the mechanism it further amplifies and what the reading you get is not correct. So, that is the problem with dial gauge but in electronic you can easily go for very high magnification.

The electrical and electronic comparator mainly differs with respect to magnification and the type of output. Both rely on mechanical contact with the work to be measured, but finally, here it is only the display, but mechanical contact is always used.

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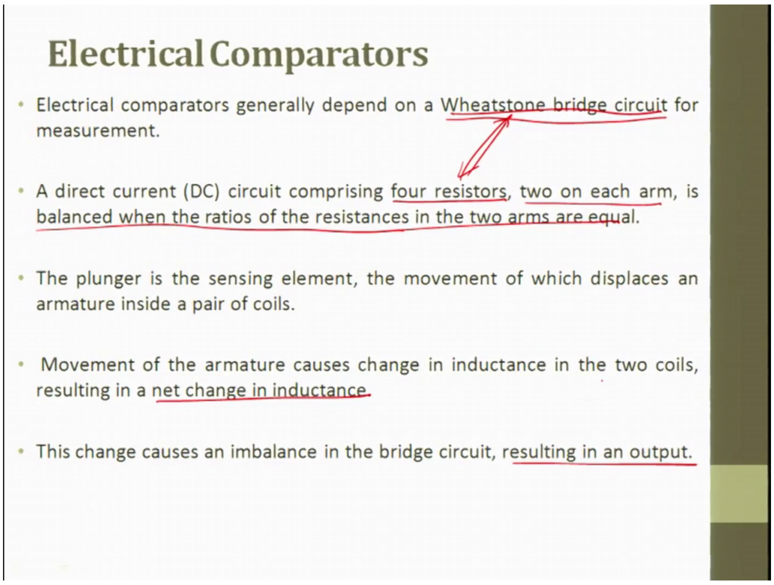

The electrical comparator generally depends on Wheatstone bridge principle, this we have studied in your basic engineering courses, Wheatstone bridge principle for measurement. A DC circuit comprising of 4 resistor each on both arms is balanced when the ratio of the resistance in the both arms are equal. So, this is nothing but Wheatstone bridge principle.

So, we use this Wheatstone bridge principle generally in electrical comparator a plunger. So, I told you earlier mechanical system is used and then we attach it to an electrical system. A plunger is the sensing element the moment of this displace the which displaces an armature inside a pair of coil. So, this is now converted into electrical, so mechanical to electrical.

The movement of the armature causes the change in the inductance in the two coils resulting in a net change in the inductance this change in the inductance brings an imbalance in the bridge circuit resulting in an output. So, the basic principle of electrical comparator works on Wheatstone bridge principle.

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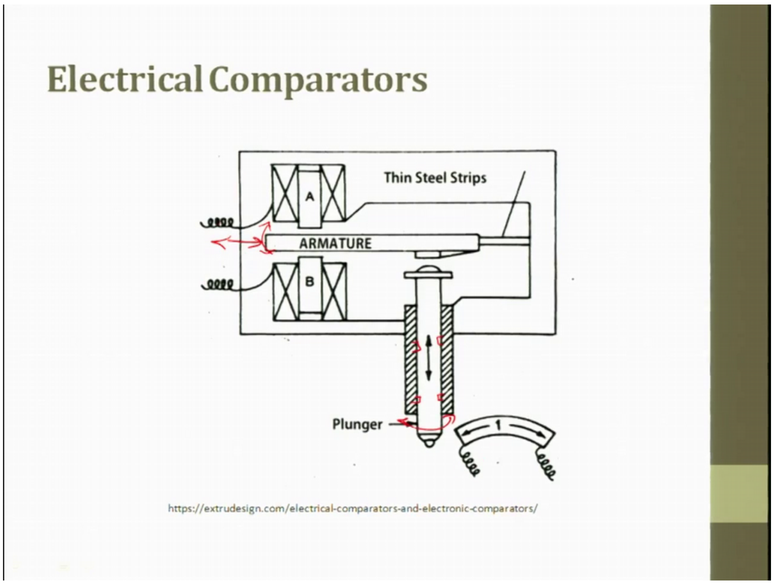

So, this is the electrical comparator you have a mechanical plunger. So, when you have a long arm or a long shaft you should always make sure it is supported at several places such that it is guided and the plunger does not deviates from its axis, ok. So, this is the, so this is what you see in the older ones we offer every plunger we had a we had a comparator. So, or we had you see here we have a slit diaphragm. This is only to make sure it goes along a straight line.

So, then here this moves then this is trying to push this fellow then this fellow armature might move, this might move like this or it can move like this depending upon the displacement here whatever you give. So, based on this there is a deflection which is coming this in turn is attached to the Wheatstone bridge then we try to measure the take the measurement.

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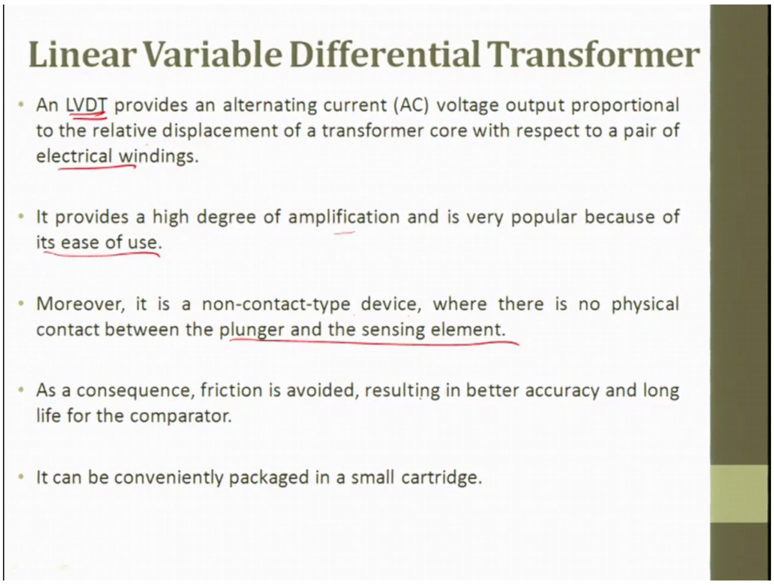

The LVDT is an provides an ac current. So, here we talked about dc the next one is LVDT which is nothing but Linear Variable Differential Transformer. It provides an alternative current voltage output proportional to the relative displacement of a transformer core with respect to a pair of electrical winding, so core with respect to electrical winding. So, see it is left to you.

So, if you have a change in the construction the armature can slide up and down in this direction or it can deviate LVDT is for displacement. It provides high degree of amplification and it is very popular and it is easy to use. Moreover it is a noncontact type device where there is no physical contact between the plunger and the sensing element, plunger and the sensing element. As a consequences friction is avoided result in better accuracy and long life of comparator. So, it is it is used. It can be conveniently packaged into small cartridges.

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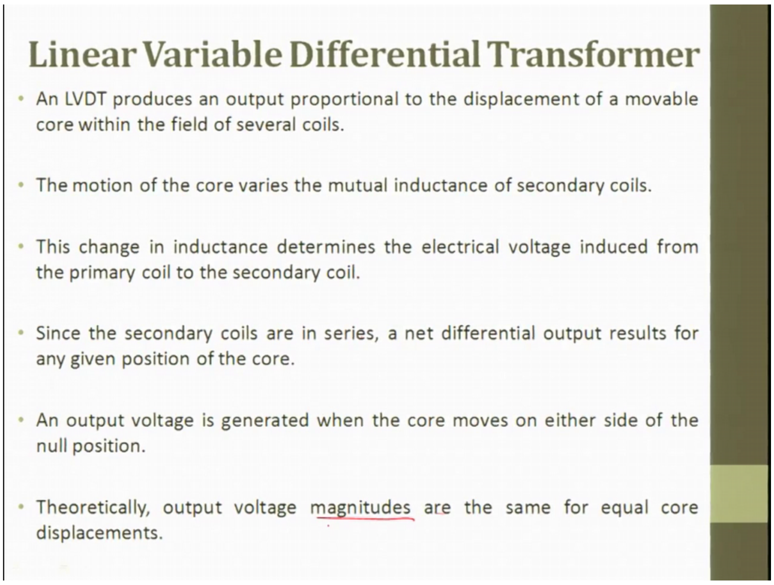

An LVDT produces an output proportional to the displacement of the movement of core within the field of within the field of several coils. The motion of the core varies the mutual inductance, as I told you in Wheatstone bridge. The change in inductance determines the voltage induced from the primary coil to the secondary coil. Since the secondary coil are in series and net differential output results and gives the position of the core. The output voltage is generated when the core moves on either sides of the null. Theoretically the output voltage magnitudes are of are very small are the same for equal core displacement. So, this is how an LVDT works.

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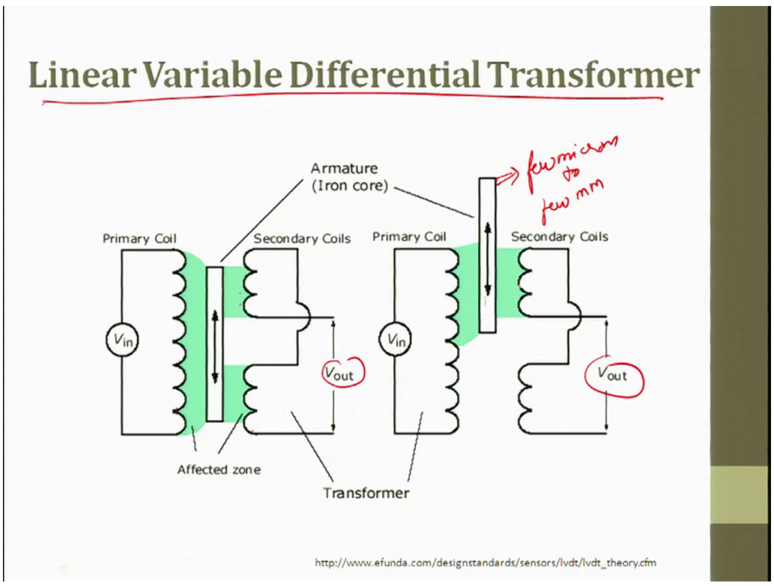

So, you can see here this is a primary coil, these are secondary coil, this is the in voltage the voltage you apply, this is the out voltage. So, this is a these are transformer right. So, this is an armature when it moves up or when it moves down you can see that there is a displacement change and this is the voltage output there is a change. So, you see here voltage output. And again here it is between these two transformers it always try to display a null and when it is move upward down then you see a change in voltage.

So, this is how a linear variable differential transformer works and here the displacements can be from few microns it can go up to few millimetre. This itself is to huge, few millimetre it can measure, but we are more interested in the lower sensitivity.

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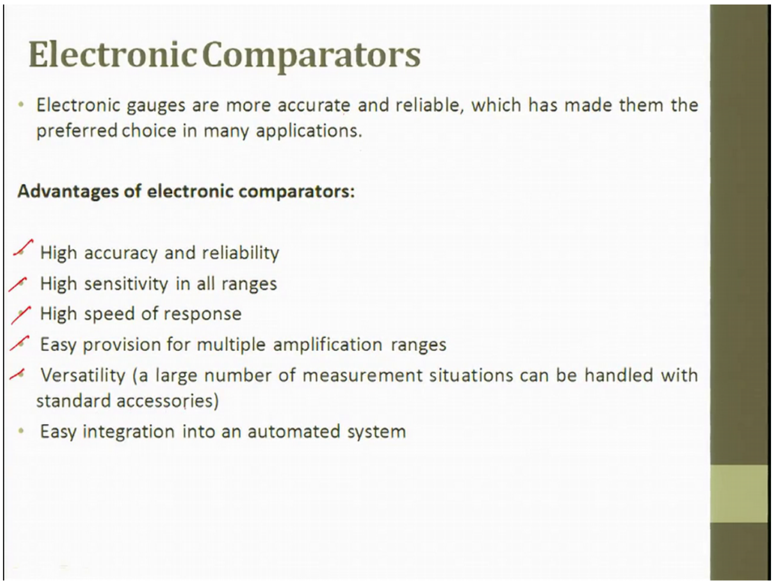

So, the electronic comparator electronic gauges are more accurate and reliable which has made them preferred choice in many applications. So, they are highly accurate reliable, highly sensitive, sensitive in terms of speed, it easily provides multiple amplification, it is versatile a large number of measurement situations can be handled with a standard accessories and it can be easily integrated to any automated system.

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So, this is how an electric electronic comparator looks like. So, you can set values, you can also see the displacement here. So, you can see here it displays to the third decimal point.

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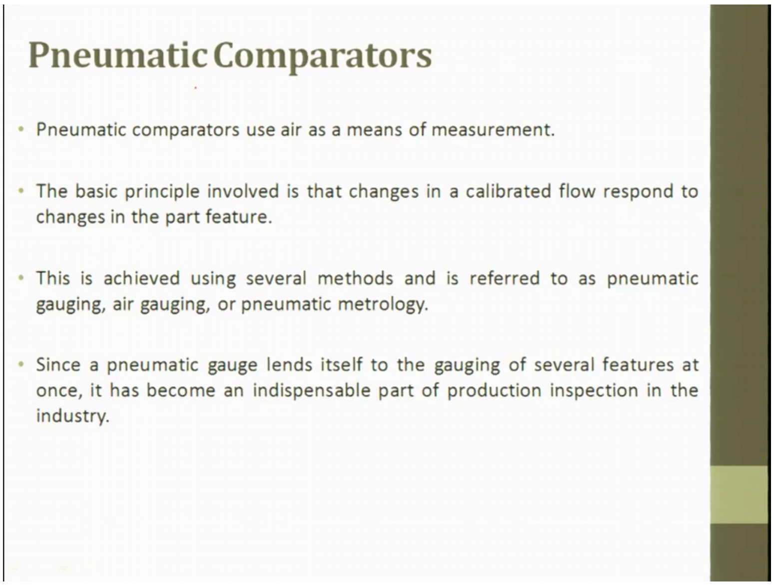

Next topic of discussion is going to be Pneumatic Comparator.

Thank you very much.