Engineering Metrology
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Lecture - 13
Angular Measurements (Part 1 of 2)

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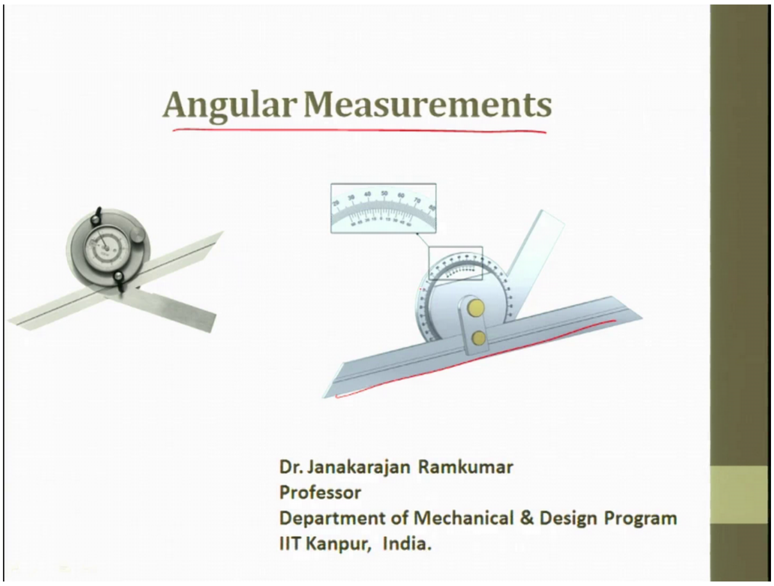

Welcome to the next topic of discussion which is on Angular Measurement. In engineering, if we know to draw a straight line and draw an arc right, so then we can split any complicated geometry into lines and arcs. So, if I know to draw this, then I can to a large extent general I saying that, I can draw any complex structures. In the same analogy, if you take it for measurements, if I know to measure a straight line, and if I am able to measure an arc in terms of angle and radius, then I can measure any complicated geometries given to me. So, of course, you have to build up your setup, such that you try to measure the angular one.

So, in angular measurement, here we are more focused towards the angle between two features or between two lines. The angle which is subtended, it can be used in gears, it can be used in threads, thread profile measurement, it can be also used for jigs ok and it can also be used for jibs ok. So, here are some of the places, where this angular measurement plays a very very important role.

If you look at the angular measurement, these are some of the devices, which we assemble we will go, we will see it in detail. You can see here there is a scale ok, the arc there is a flat plate or a flat base; this is a reference for the entire instrument. This reference should but against, another reference which is perfect, then only you can start measuring the angles. If the reference surface is not butting against a given standard reference, then these instruments will try to give error, because it is a relative measurement, which it takes. Suppose, if there is error between the two reference planes, then that angle will also get added to your to your result, whatever you see.

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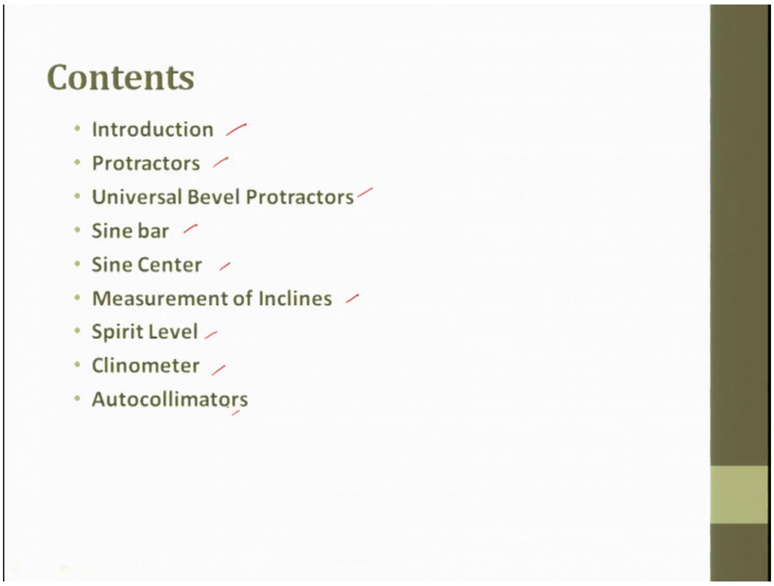

So, in this topic, we will try to see first introduction, then we will try to see protractors, which we used it right from the school age, this is still used. Then we will see a universal bevel protractor, then sine bar, sine center, measurement of inclines, spirit level, which is commonly used, clinometers, and finally, autocollimator, we will be using it. Autocollimator are used for measuring precise angles, which is there on a flat surface ok. Moment I know the angle, you can converted into the degrees can be converted into distance, you can converted into microns, and you can report the results.

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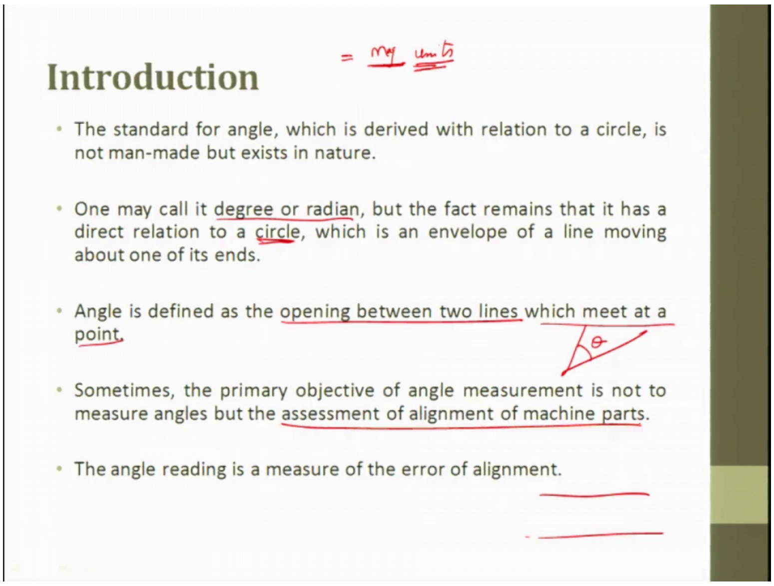

The standard of an angle, which is derived with relation to a circle, is not man-made, but exist in nature. One may call it degree or radians, this will be the units. See in metrology, what we do is we it is a science of measurement, here what we do is, we will try to have magnitude, and then we will try to have a units, these units are very very important ok, it can be in microns, it can be in radians. Now, once it is in radians, you can play back and get it into a linear scale in microns. And this is the magnitude, which is given, so ten microns, ten degrees.

When we start looking into the linear measurement, the we will always used to report it in terms of microns, millimeter, meter, all those things. When we try to go measure the angle, we always try to report it in terms of degrees and radians. If you are if we wanted to take this degree and then convert it into a linear scale, then we try to convert the units from degrees to microns or millimeter ok. One may call it as degree or radians, but the fact remains that it has a direct relationship to circle, which is an envelope of a line moving both about one of its edges.

Angle is defined as the opening between two lines which meets at a point. So, if two lines, if the definition is not properly done, so opening between two lines, which never meet, you will never get an angle. So, when we want to measure an angle, this is a very very important point which meets at a point. Sometimes, the primary objective of an angle measurement is not to measure angle, but to access the alignment of a machine part. Many a times when several of these parts are assembled together to form a sub assembly or complete product, the angle measurement is very very important. The angle reading is measured for the error of misalignment, for example, spindle run out ok. When spindle run out is there or work piece run out, so all these things can be easily found out.

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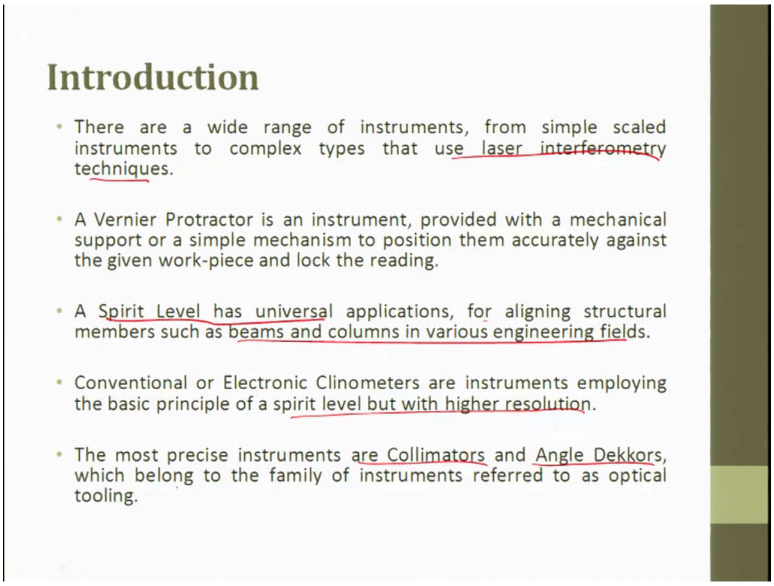

There is a wide range of instruments that instruments from simple scaled instrument to complex types that uses laser interferometer techniques for measuring the angle. A Vernier protractor is an instrument, we will see, provided with a mechanical support or simply mechanism to position them accurately against a given work-piece and lock the reading. So, in all these Vernier caliper, all these things we will always have a locking nut or locking screw, which we keep it at an angle, and then we lock it, and then we pull it out from the work-piece, and then see what is the measurement.

The spirit levels are also universally used. For example, you have a very large surface plate, and if you want to measure what is the deviation of a surface plate, generally what we do is either we try to dilate at several points, form a matrix, and try to find out the variation, or what we do is, we use spirit level, keep it at several locations, and see what is the inclination of angle from the centre towards both sides. From there, we try to find, we get the angle measurement; from the angle, we try to find out what is the linear error or the displacement ok.

Spirit level has universal application for aligning structural members such as beams and columns in various engineering fields. Majority of the mason use spirit level to measure, whether there flat surface. Conventional or electronic clinometers are instruments employed the basic principle of spirit level, but with very high resolutions. Finally, the collimator and Angle Dekkors, which belong to the family of instruments refers to as the optical tools are also used for angular measurement.

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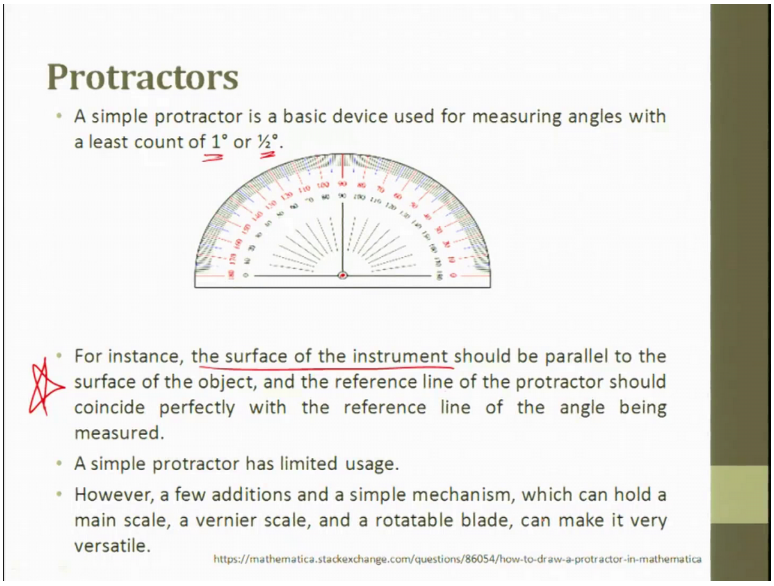

This is a simple protractor, where and which we fix at the centre; in school days, we use this. So, we fix at the centre, and we have angle varying from 0 to 180, you can have 0 to 180 or which can contain you up to 360 degrees. You have the least count can be 1 degree, if it is a large diameter protractor, you can even have close to half millimeter half a degree.

For instance, the surface of the instrument should be parallel to the surface of the object. So this is very important. The surface of the instrument, wherever displace should be parallel to the surface of the object, and the reference line of the protractor should coincide perfectly with the reference line of the angle. So, this is the very very valid point. The surface of the instrument should be parallel to the surface of the object, point number 1; and the reference line of the protractor should coincide perfectly with the reference line of the angle ok.

Simple protractor has lot of limitations, which we all know while using. However, a few addition or simple mechanism, which could hold the main scale or a Vernier scale, and a rotatable blade, can be used can make it very versatile. So, here what happens is you have only one, you generally if you see a protractor what we does, we make dot reference on a piece of paper, move the protractor dot there exactly match these two references and draw.

Suppose if I wanted to draw on top of this protractor, I wanted to draw a tangent, then placing a scale on top of this will be next to impossible, because it is radius, and tangent is a scale, so it will be very difficult for a for a line to stay in contact with the arc, so you will get only a point. So, drawing a tangent is very difficult for this. So, in order to get out of such limitations, what we do is we attach a main scale; we attach a Vernier scale, and a rotary blade, so that you can try to use it for versatile applications.

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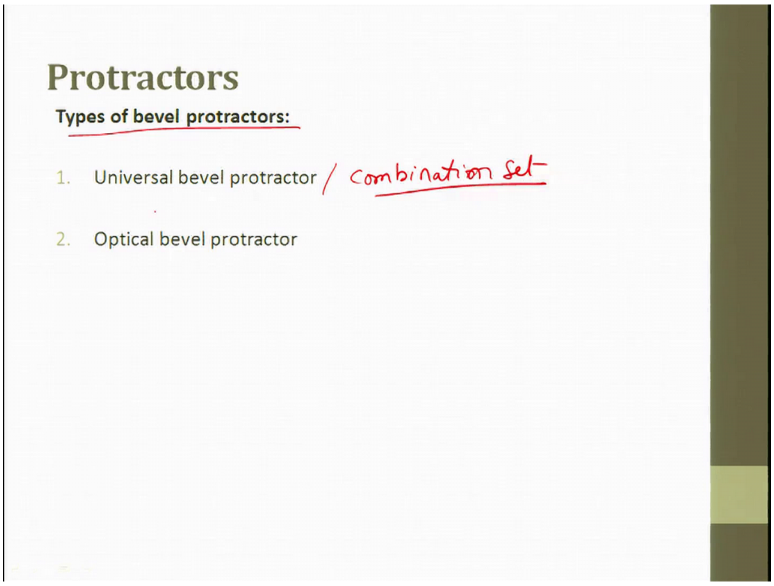

There are two types of protractors, which are advanced, which is generally used; one is called as universal bevel protractor, the other one is optical bevel protractor. So, universal bevel protractor is different from that of our combination set with combination set is different and this is different. So, these two are different, please do not get confused.

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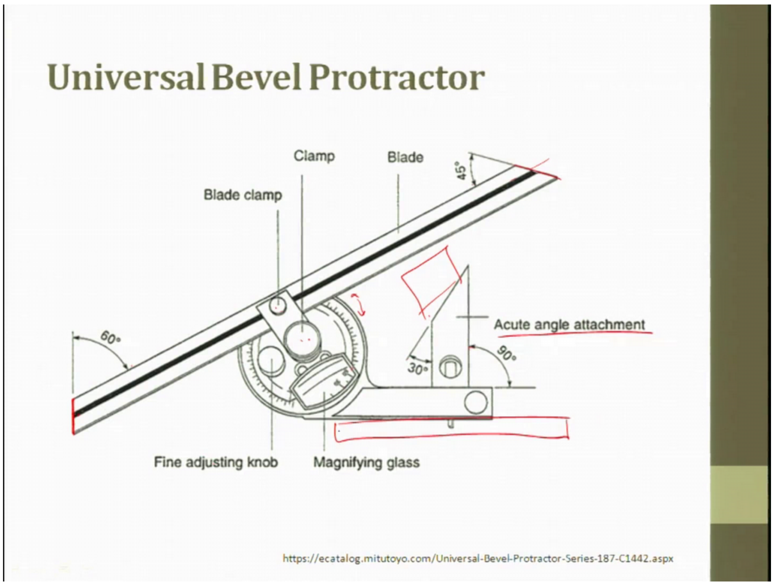

Universal bevel protractor, it is this is how it looks like a universal bevel protractor. So, you will have blade ok, so this blade will have a slot ok. So, here if you see there is a there is a slot, which is there is an end mill which is made. So, this is at an angular 60 degrees, and here it is cut at some other angle it is 45 degrees. So, this also can be used for placing the referencing. Then in this blade, you will see a fine adjustment knob, which are a protractor, which slides through which can slide. So, the protractor is clamp to the blade by a blade clamper. And this in turn is clamped by this, such that you make sure that this line is in parallel or it is in coincidence with the measuring object.

So, then you will have a protractor, which is at the bottom. Here is a magnifying lens, because in order to show the in order to have clarity in reading. So here you see a lens which is attached. And here you see a fine knob which is there, which is used for slightly dialing up and down, and you get the data. So, here is a reference plane, you can place the entire scale with respect to this reference plane. If you want, you can also place here the object, which is again an acute angle attachment. This is at 90 degrees, and this is at 30 degrees. So, you can see here, these are the angles, which are used to place the work-piece or dial the work piece and make it flat, and then place it, then rotate the protractor to measure the reading, we can use this as a reference surface.

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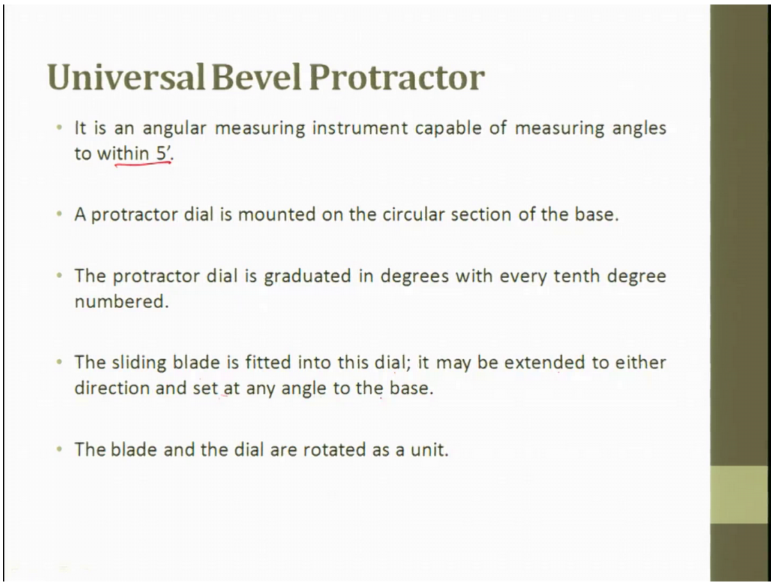

So, it is an angle measuring instrument capable of measuring angles within 5 minutes. The protractor dial is mounted on a circular cross section of the base. The protractor dial is graduated in degrees with every tenth degree numbered, so Vernier. The slide blade is fitted into the dial, it make it may be extended to either directions set at an angle to the base. The blade and the dial are rotated as the unit.

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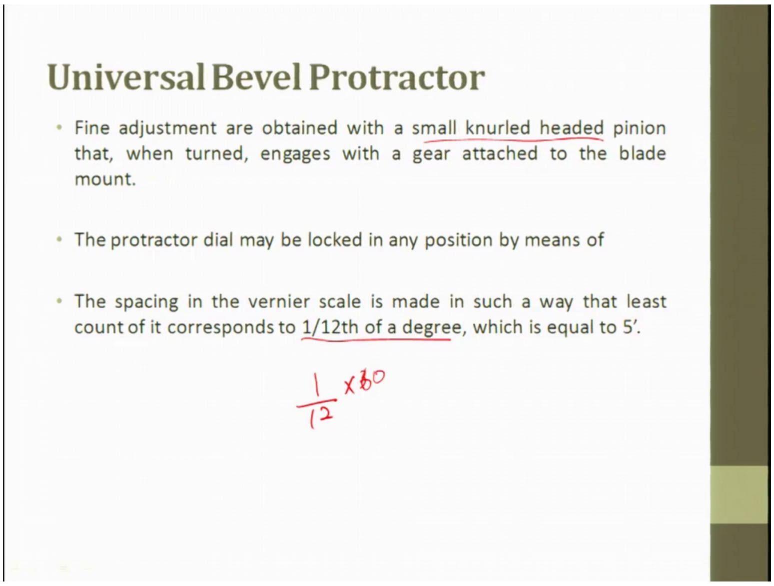

The fine adjustments are obtained with a small knurled headed pinion that is used, so that we can try to do fine adjustment and get the details. So, these are fine adjustment knobs, which are there; so that we try to see the matching of this Vernier and also the protractor angles. The protractor dial may be locked, the spacing in the Vernier is made, in such a way that at least the least count corresponds to 1 10th of degree 112th of degree, so 1 12th of degree ok. Suppose, you take 60 or 360, you can go get of 1 12 of it.

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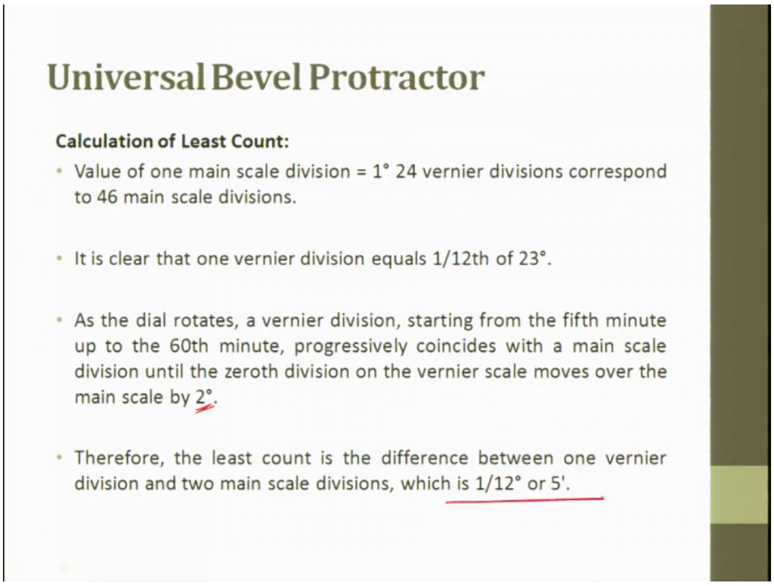

So, calculation of the least count: value of one main scale division. So, then it is clear that one Vernier division equals 1 12th of 23 degrees. As the dial rotates, a Vernier division starts from fifth minute up to 60th minute, progressively coinciding with the main scale division until the zeroth division of the Vernier moves over the main scale division by 2 degrees. Therefore, the least count is the difference between one Vernier division and two main scale division, which is 1 12th or 5 minutes.

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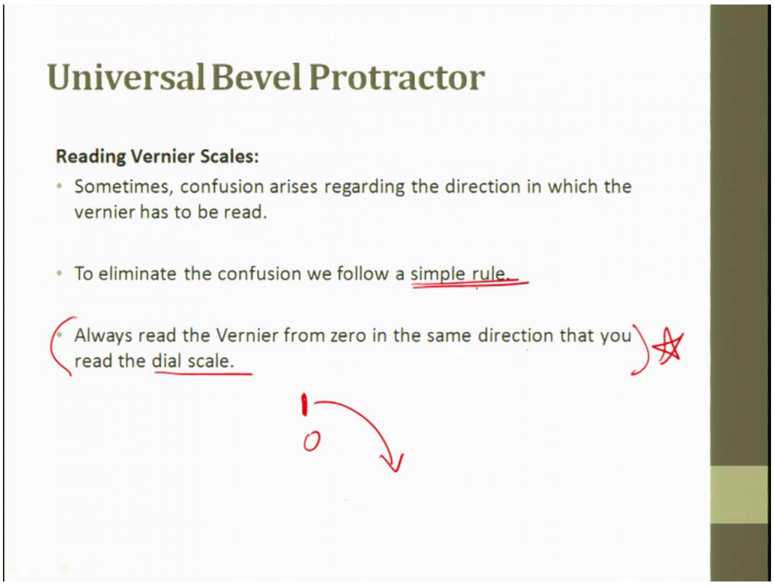

So, sometimes the confusion arises reading the direction in which the Vernier has to be read. In to eliminate the confusion, we follow a simple rule, the rule we should remember. Always read the Vernier from zero in the same direction that you read the dial scale. This is also a very very important point. A simple rule, this rule has to be followed. Always read the Vernier from zero in the same direction that you read the dial scale. So, this is zero, on the same direction you read. So, this if you follow, then there will be no confusion; whether it is positive or negative and then you try to get the details.

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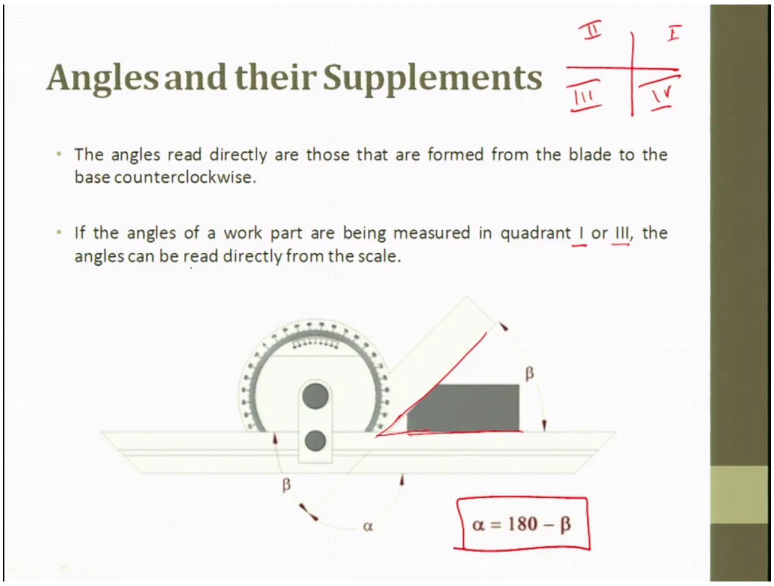

So, the angles and their supplements, you can see here. Here is a work piece, so here is the base, whatever we talked about, here is the protractor, and here is the knob, this is used to slide here. And if we want to find out this angle, so this is beta, this is alpha, so alpha plus beta will be alpha plus beta will be equal to 180 degrees. So, if you want to exclusively find alpha, it is going to be 180 minus beta. So, you get the angle beta, and you get this angle whatever it is with respect to the flat surface, this angle can be measured by dual protractor ok. The angle reads directly are those that are formed from the blade to the base counter clock wise, we do it. If the angle of the whole part are being measured in quadrant 1 or quadrant 3, the angle can be read directly; if it is the other way, data has to be converted.

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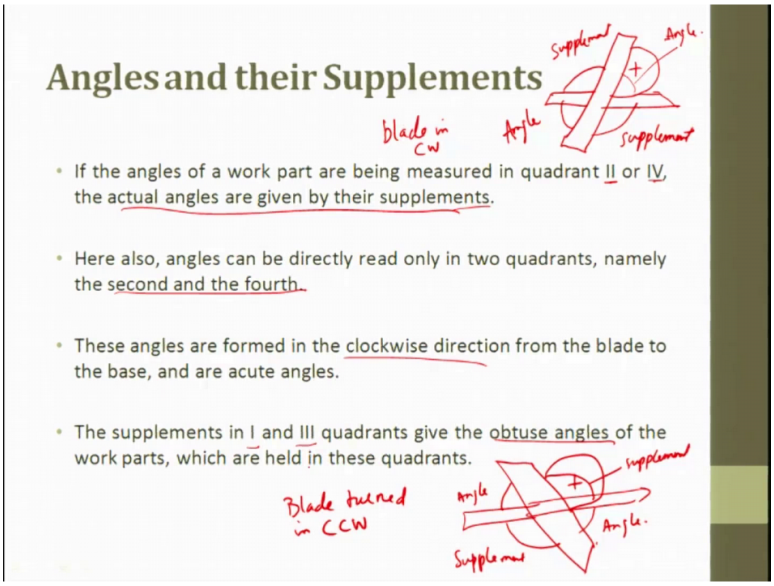

If the angles of the work pieces are being measured in quadrant 2 and quadrant 4, so, if you see the quadrants are 1, 2, 3 and 4 ok, these are the four quadrants. If the angle of a work part is being measured in 1 or 3, the angle can be readily it can be read directly from the scale. If the angle of the work part are being measured in quadrant 2 or 4 the actual angle are given by their supplements. Here also, the angle can be directly read only in two quadrants, namely second and fourth ok. These angles are formed in clockwise directions from the blade to the base, and the acute angle. The supplement 1 and 3 quadrants must be obtuse angle for the work part.

So, when we move, I will try to draw the angle. Suppose, if you have a scale like this and then you have something like this as an angle ok, so what we are trying to say is this is supplement and with respect to this, this is also supplement ok. This is the angle, and here is also the angle, we directly measure ok. This is for a blade, which rotates in blade, which rotates in clockwise direction.

Suppose, if the blade rotates in anti-clockwise direction, then you will have a scale like this ok. So, this is supplement, and this is also a supplement. This is the angle which we measure, and this is also the angle which we measure right. So, this is for a blade, which is turned in counter clockwise direction; if the blade rotates in the counter clockwise direction, so this is how we get the supplement detail. So, in 1 and 3 quadrants, use the obtuse angle for the work piece which is held in these quadrants.

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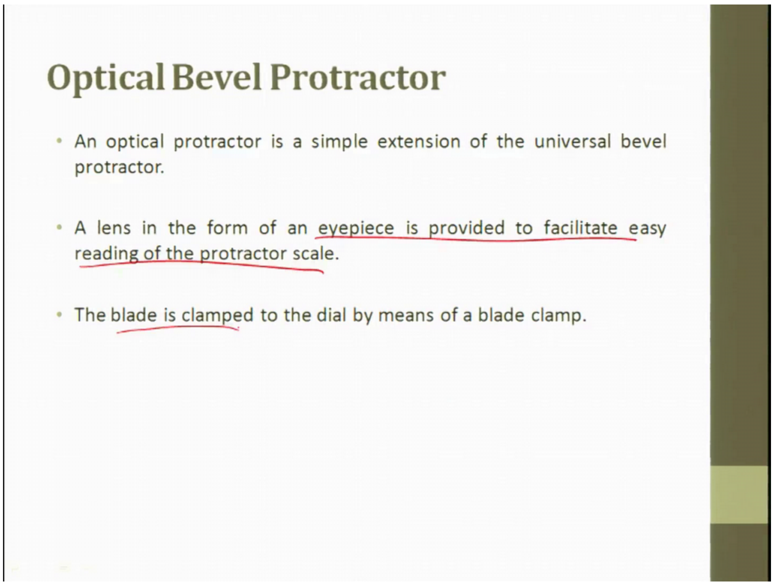

So, optical protractor is a simple extension of the universal bevel protractor. Here, we use a lens in the form of an eyepiece is provided to facilitate easy reading of the projector scale. The blade is clamped to a dial by means of a blade clamper.

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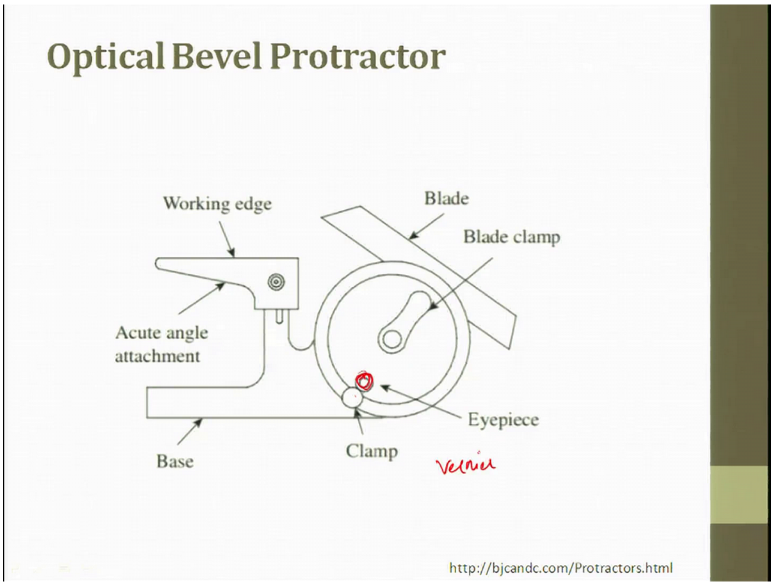

So, if you look at it, here is a working edge, you can keep, and acute angle, this is a base, this is a clamp. And here you have a small eyepiece to look at the reading. Here is a blade, which comes in contact with the work piece. And then, this is the blade clamping device, what we use. It is almost very similar to that of a bevel protractor, except for the optical thing, which is visible.

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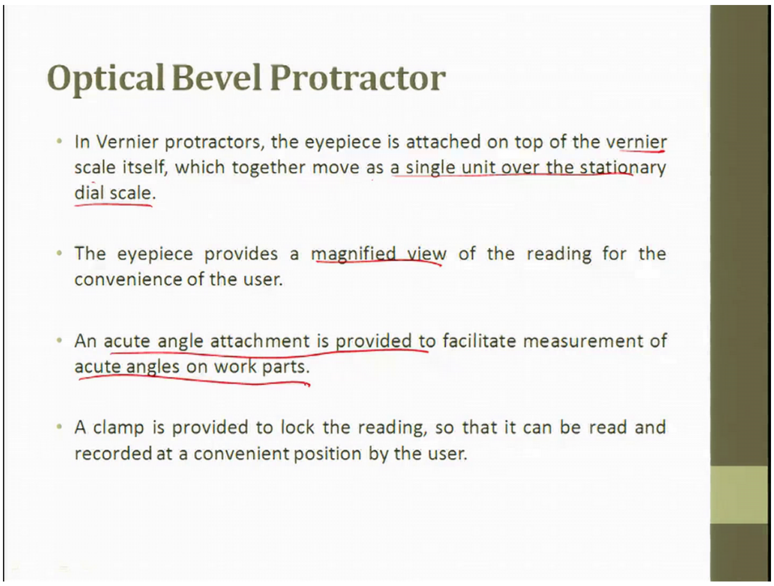

So, in Vernier protractor, the eyepiece is attached on the top view of the Vernier scale itself, which together moves as a single unit over the stationary dial scale. So, the eyepiece provides it in a magnified manner. The acute angle attached is provided to facilitate the acute angle on a work piece. If you want to measure, you can do it. Second thing, a clamp is provided to lock for the reading ok, there is a clamp, which tries to try, and then which prevents it from rotating. So, you look at the eye, and then try to take the reading. So, you will have a Vernier reading also here.

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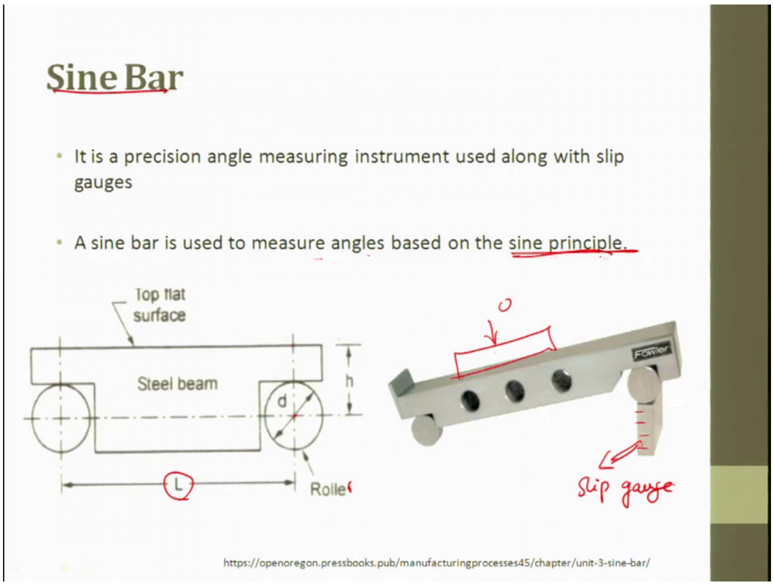

The next device is going to be sine bar. Sine bar is a precision angle measurement instrument used along with slip gauges. So, what we do is here is a slip gauge ok, here is a slip gauge, so you put the slip gauge you put the slip gauge at one end of the roller one end of the roller you put the slip gauge, so basically what you do is you keep and height. And here what you do is you this is a flat surface, now you place it at an incline, and then you put the work piece here, then dial it to find out what way the 0.

So, now what you have is, you can try to figure out what is the height; from the height, you can convert this and find out what is the angle ok. It is a precision angle measuring instrument used along with the slip gauges. If you do not use the slip gauge, this instrument is of not of big use. A sine bar is used to measure the angles based on a sine principle. So, you will have a top flat, this is a top flat surface. You have two rollers, these roller dimensions are given as d, and the centre of the roller to the head to the top of the flat surface is h, and between two rollers, the distance is L.

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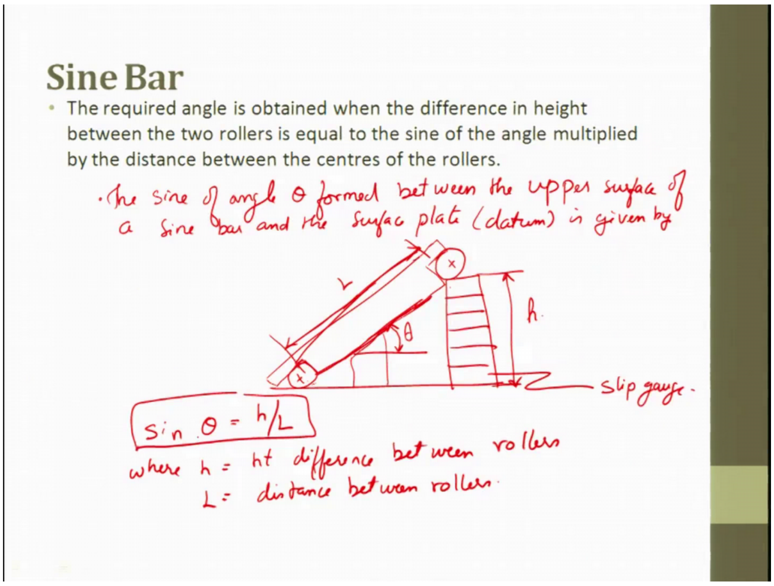

The required angle is obtained, when the difference in height between the two rollers is equal to the sine of the angle multiplied by the distance between the centers of the roller. So, the sine of angle theta formed between the upper surface of a sine bar and the surface plate which is the datum is given by; so, what are we trying to say, we are trying to say you have a flat, then you have a you have some object right and you have a roller. On the other way round, you have this. You have one more roller here ok.

So, this distance is L this distance is L ok. And this on this is resting; this is resting on a slip gauge. This is a slip gauge of a height h right of a height h fine. And if you want to find out this angle I call it as A, so then sin theta or A theta is equal to h by where h is nothing but the height difference height difference between rollers between rollers right, and L is the distance between rollers.

So, this is the important thing, which is said as the sine of angle theta ok. This is I said in the previous slide, which works on sine principle. So, this is the sin. So, sin theta equal to h by L right ok. Therefore, L sin theta is always equal to h. So, now what will happen is you know this is the flat plate, this is flat this is flat. So, with this, we can try to figure out the h, height is nothing but L into sin theta.

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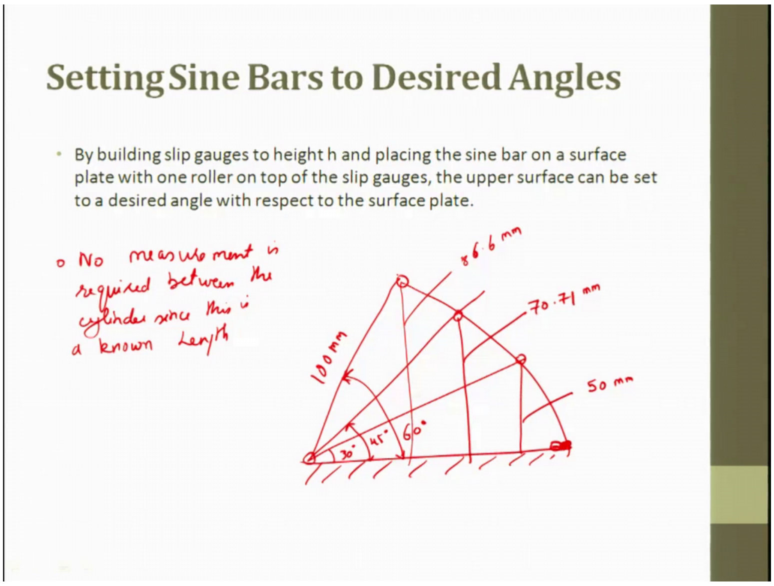

By building the sine gauge to height h and placing the sine bar on a surface plate with one roller on top of the slip gauge, the upper surface can be set to a desired angle with respect to the surface plate. So, here what we are trying to say is we are trying to say, so this is 1, 2, may be 3and may be 4 right and ok so you have one more roller here. So, assume that, this one is 100 millimeter ok, and it follows an arc ok. So, this is 60 degrees, this is 45 degrees sorry, this is 30 degrees this is 30 degrees, and this is 60 degrees.

So, the height if you see, this will be 50, the same thing will be 70.71. And if you try to take this drop this height, this will be 86.6 millimeters. So, you can see here, for varying heights. When a building by building a slip gauge of height h and placing the sine bar on the surface plate with one roller on the top of the slip gauge, the upper surface can be set to a desired angle. So, these are the angles with respect to the surface plate. So, no measurement is required between the cylinders, since this is a known length. No measurement is required, because it is a known length. So, this is what we are given. So, 100 millimeter, so the distance is 100 millimeter, you keep increasing. So, you see what is the difference you get for varying measurements.

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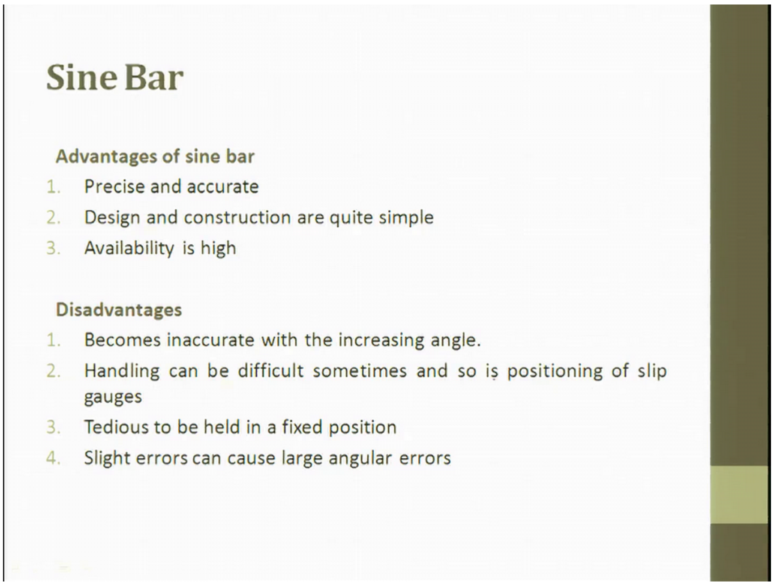

So, what is the advantage of sine bar? Sine bar is advantage is very precise and accurate. The design and construction are very quite simple. The availability is pretty high. Disadvantage, becomes inaccurate with an increased in angle. So, when it grows more than 60 or 80, it becomes very difficult. Handling can be difficult sometimes, so is positioning of a slip gauge. Then tedious to help to be held in fixing positions, slight error can cause a large angular error.

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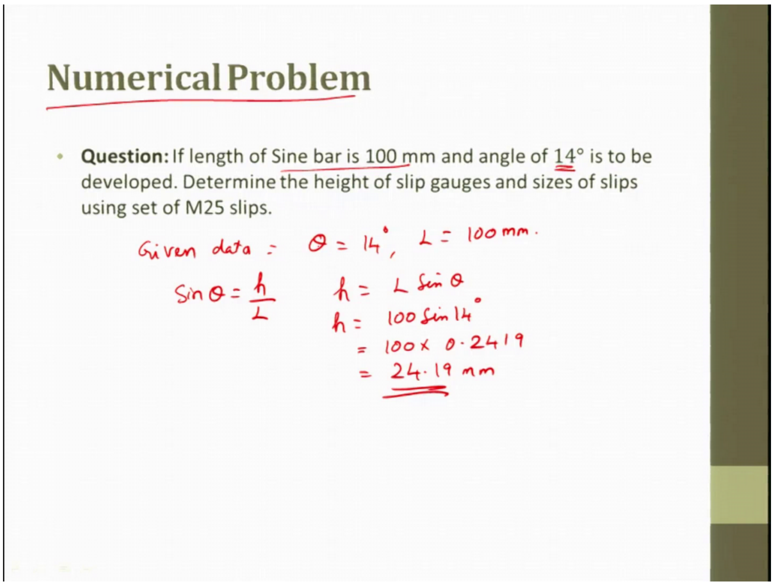

So, now let us try to solve this one numerical in this direction, such that we can try numerical to solve in the sine bar. If length of a sine bar is 100 millimeter and the angle is 14 degrees is to be developed. Determine the height of the slip gauge and the size of the slips using set of M25 slip. We have studied that. So, given data what is a given data given data is theta equal to 14 degrees, and then L is the length between the rollers is 100 millimeter. So, what are they asking, they are trying to find out what is h.

So, what is the formula, sin theta equal to h by L. L is given, so we know h equal to L into sine theta. So, h is the nothing but 100 sin 14 degrees, so this is nothing but 100 into 0.241 something like that, so it is 24.1 19, so 19 millimeter, this will be the h ok. So, it is a straight forward formula, sine using the principles of sine. So, sine sin theta, this sine bar length is fixed, so the only this L and this h keeps changing from problem to problem.

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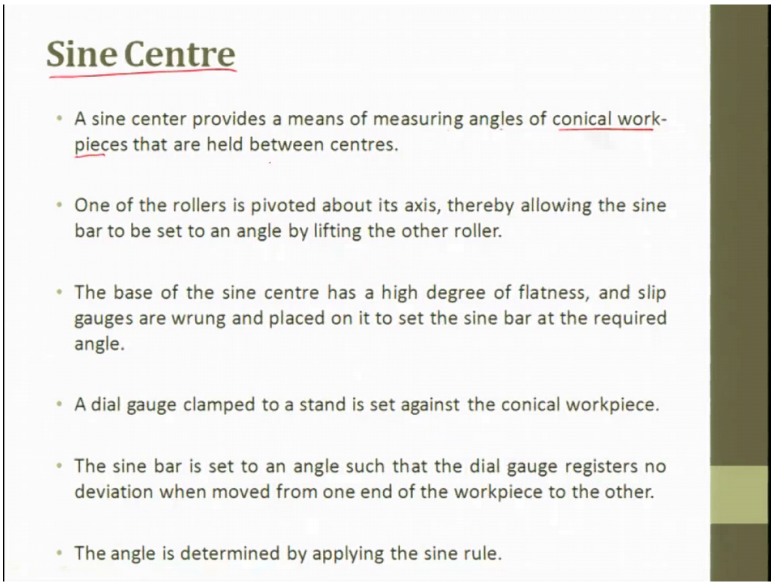

A sine center provides a means of measuring angle of conical work-pieces that are held between centers.

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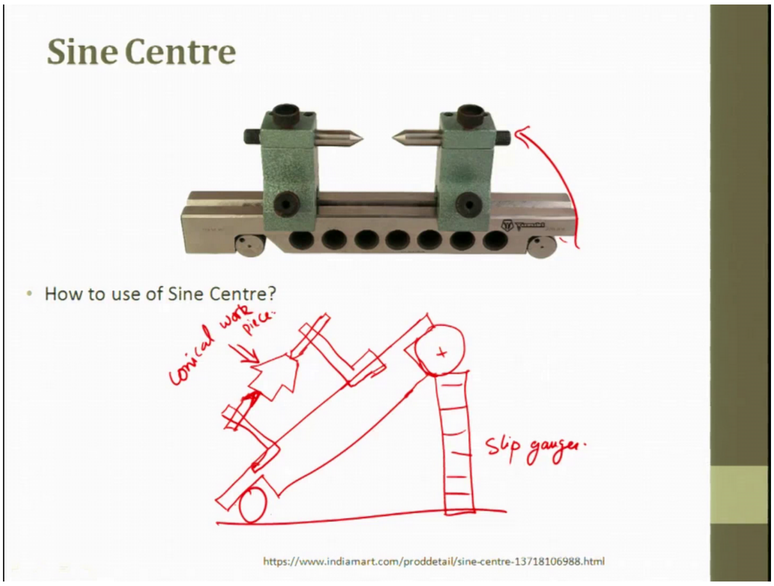

So, this is sine center. So, there are two centers, dead center, two live centre and dead centre or two dead centre. So, you can try to measure the conical work piece that is held between centers. One of the rollers is pivoted about its axis, thereby allowing the sine bar to be set at an angle by lifting the other roller. So, this roller, you can lift it, and then you can do. The base of this sine center has a high degree of flatness, the slip gauge are wrung and placed on its set the sine bar at a required angle. A dial gauge clamped to the stand is set against the conical work piece. The sine bar is set at an angle, such that the dial gauge registers no deviation, when moved from one end of the work piece to the other end. The angle is determined by again applying the simple rule.

So, what we are trying to say is we are trying to say, you will have a sine bar, so you will have a sine bar. And here you will have h, so these are nothing but slip gauge slip gauges. So, here you will have this one ok. Then what you do is you will try to put this is a conical one, this is a conical, so this is between centers, this is a conical work piece.

So, if you go back, you can see the base of the sine centre has a high degree of flatness. The dial gauge clamped to a stand is set against the conical work piece; you will set a dial here. The sine bar is set to an angle, such that the dial gauge registered no deviation, when moved from one end of the work piece to the other end. So, then what you will do is the angle is determined by applying the sine rule. So, now you will put a dial gauge move it here and there, and then try to figure out what is this height angle.

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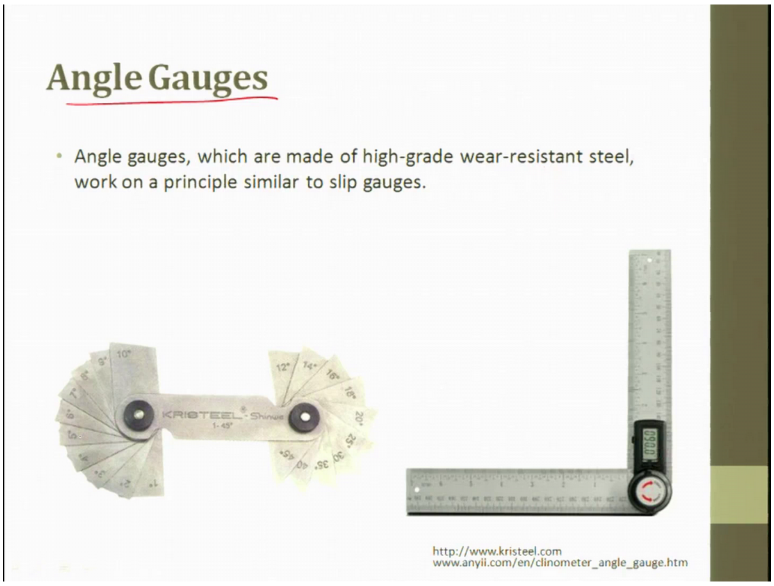

The next one is angle measurement, these are called as a feeler gauges. So, we can angle measurement, which are made of high-grade wears-resistant steel, work on the similar principle of slip gauges. So, you can try to measure the angle using the same concept like slip gauges, you keep adding and then, try to figure out what is the angle which is their subtended by the work piece. So, you can use this also, and then use this combination to measure the angle measurement.

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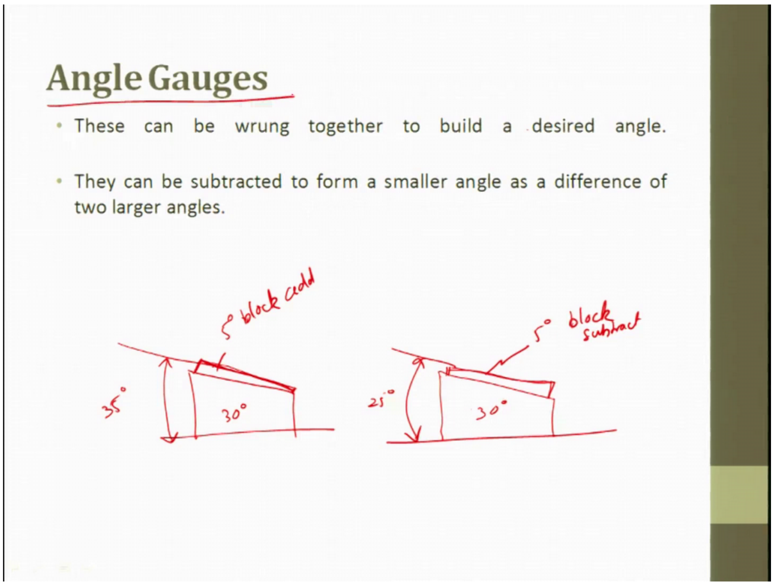

So, the angle gauge, this can be wrung together to build up a desired angle. They can be subtracted to form a smaller angle as a difference between two large angles. So, what they are trying to say is you can have a block ok, and then you can have so, this entire thing will be now 35 degrees. So, this is a 30 degree block, and this is 5 degree block 5 degree block or a slip gauge, whatever we are talking about. Suppose you would like to have this is 5 degree addition you can have.

The other way round is you can have 20. Just giving an example, this is this is again a 30 degree block, and then what you do is you try to have in ulta direction, so in reverse direction, and then you try it here what will be the angle is here it is only 25 degrees. So, this is also a 5 degree block. So, here you see, this is thicker, and here it is thinner, so this is addition. So, here it is thinner, and here it would thicker, it is subtraction. So, you can add blocks, you can subtract. The angle the block from the base angle, and then you can try to generate different angles for measurement. Again, here we use the concept of ringing to form the angle.

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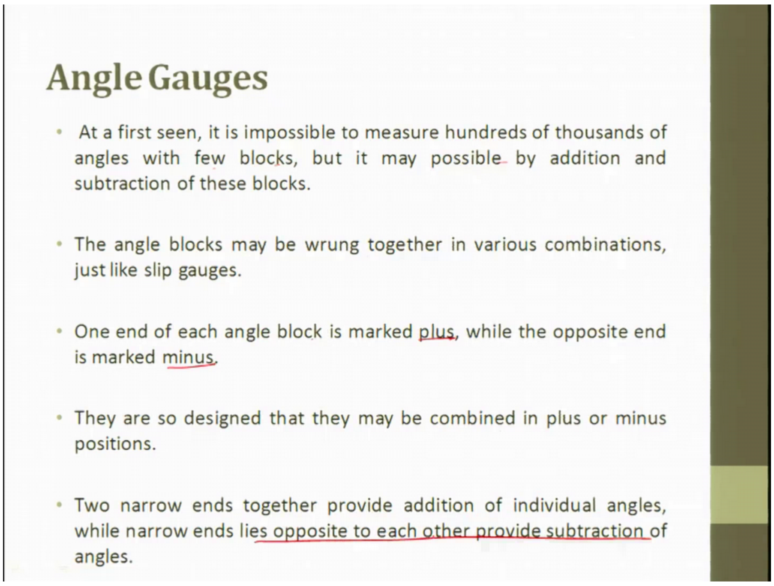

At first seen, it is impossible to measure hundreds of thousands of angles with few blocks, but it may be possible by addition and subtraction of these blocks. The angle blocks may be wrung together in various combinations, just like slip gauges. One end of each angle block is marked plus, while the opposite is marked minus. So, you will have a taper ok. They are so designed that they may be combined in plus or minus position. So, you can have plus and minus. So, you can have minus and plus. So, it subtracts and generates the angle. Two narrow ends together provide an addition of individual angles, which narrow end lies opposite to each other provides subtraction angle. So, this is what we saw here. So, it can be addition, it can be subtraction.

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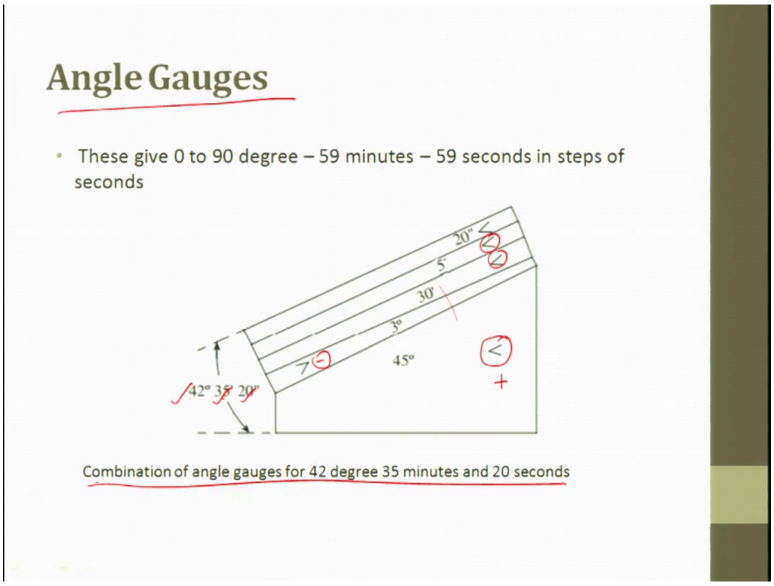

So, thus given 0 to 90 degrees, 59 minutes 59 seconds in steps of you can get in steps of seconds. So, here what we do is we try to take 45 degrees right. So, let us take this is positive, and then the arrow is towards this, so this is negative; so, 45 minus 3 which lead to 42. And then, here we try to take 30 degrees 30 minutes, and then we also take 5 minutes both are in the same direction, so we get 35, and then we also take 20 minutes. So, this is there. So, it is 42 degrees, 35 minutes, and 20 seconds, which can be developed by the combination of different angles. Looking into the direction, we either add or subtract, so that is why it is called as the combination of angle gauges.

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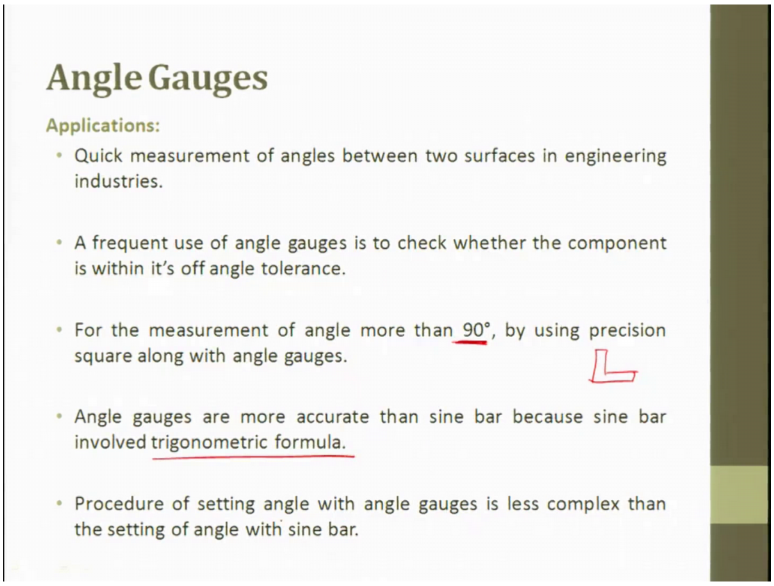

So, application, it is a quick measurement of angle between two surfaces in the engineering industry. A frequent use of angle gauge is to check, whether the component is within its off angle tolerance. For the measurement of an angle more than 90 degrees by using precision squares something like L square we use, so that is what along with angles. So, this is what we showed here a combination ok. So, you can use this, along with the combination of this to generate the various angles ok. Angles are more accurate than sine bar. These angles are more accurate than sine bar, because sine bar involves trigonometric formula, so here it is not show. And procedure for setting angles with the angle gauge is less complex compared to sine bar.

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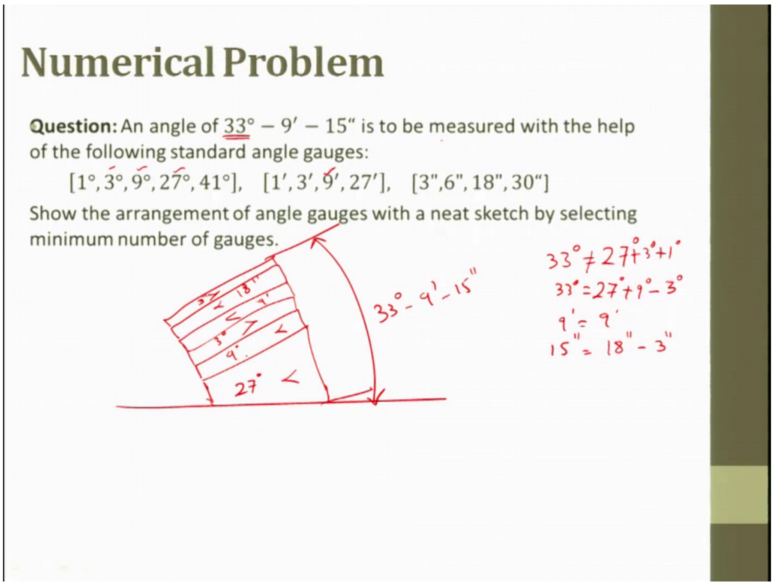

So, let us take this as a question. An angle of 39 degrees 9 minutes 15 seconds is to be measured with the help of the following standard angle gauges. So, it is 1, 3, 9, 27, and 41, we are supposed to generate 33. So, what are the possibilities, 33 can be generated by 27 plus 3 plus 1. So, it is not coming plus 3 plus 1, it is not coming to 33. So, the next combination is 33, we can try to take is as 27 plus 9, so 27 plus 9 is 36. 36 minus 3 degrees is one possibility, 27 plus 9 minus 6 is one possibility we can do. So, let us do that. So, what we have done is we take a flat plate, so first we try to make 27 degrees. So, this is 27 degrees. And let us make this. And then next is 9 you make 9. Again, in this direction, so we set minus 3, so we put 3 here, so 3 this is minus. So, what we have done is we have got this as 33.

Now, the next thing is 9 minutes you want, so 9 minutes directly you have 9 minutes. So, I add a I add a 9 minutes here, so I add a 9 minutes in this direction, so directly 9 minutes is got, so no problem. And then, I need to have 15 seconds, what I can do is I can generate it as 18 minus 3, I can get it done. So, I will add 18 in the same direction, and then I will subtract 3 in this direction. So, now what I have got is the angle, which is 33 degrees, 9 minutes, and 15 seconds. So, this is addition, and you can see this is subtraction, you try to get and this is how the answer is got ok.

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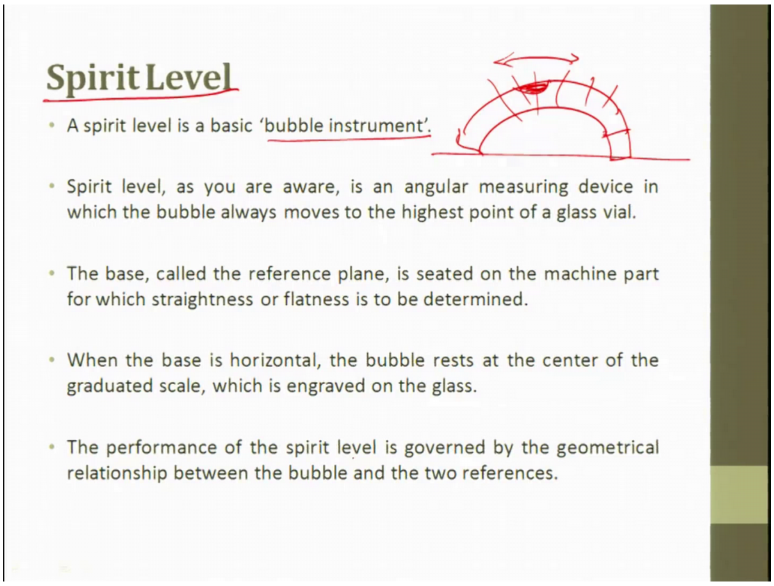

Then we move to spirit level. A spirit level is a basic bubble instrument. The spirit level, as you are aware, is an angle measuring device in which the bubble always moves. So, it is something like this, you have a bubble ok, so you have graduations. So, this is a bubble, which moves bubble which moves. And here is the graduation glass tube. So, a spirit, as you are aware, is an angular measuring device in which the bubble always moves to the highest point of the glass vial.

The base called the reference plane. So, this is the reference plane, is sitting on a machine part for which the straightness of the flatness can be determined, so maybe it can come up to here right, so it can be. When the base is horizontal, the bubble rests at the center of the graduated scale. The performance of the spirit level is governed by geometric relationship between the bubble and the two references.

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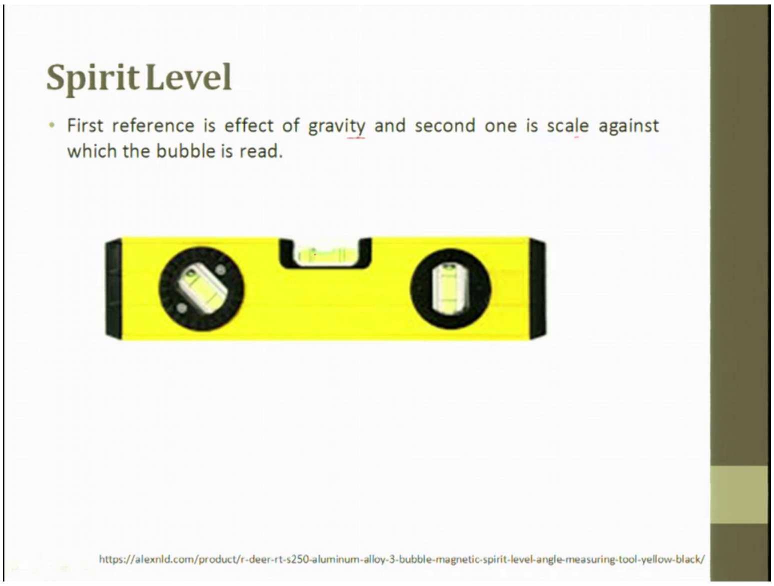

So, these are various spirit levels, which are available today in the market. So, the first spirit level the first reference is effect of gravity, and the second one is scale against the bubble in reading. So, first we try to put it as against the flat surface, measure the angle and then try to take the reading.

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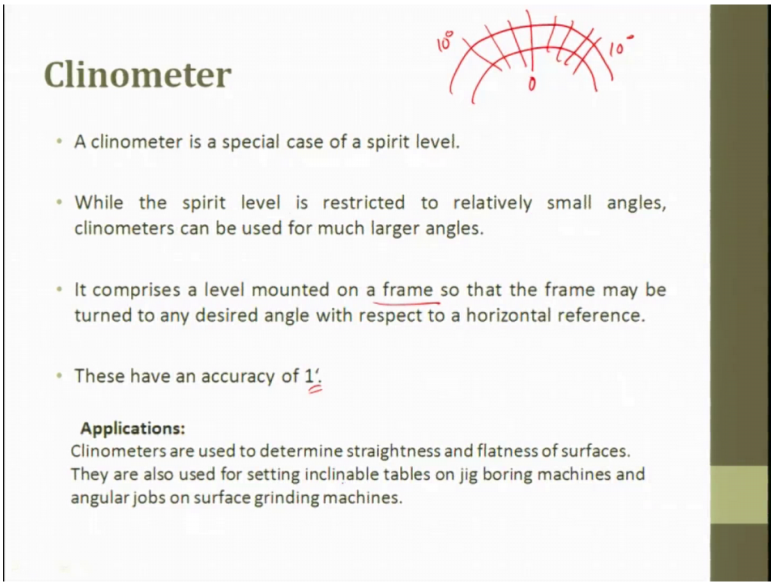

A Clinometer is a special case of spirit level, because generally in a spirit level what happens, you would always try to have a smaller angle. So, this will be something like this, and you will have a this will be the 0 point. And may be here, you will have maximum 10 degrees, and this side, you will have 10 degrees. These are the maximum graduations you have. If you want to measure a very large area, then you cannot use a spirit level.

So, it so this Clinometer comprises, it comprises a level mounted on a frame, so that the frame may be turned on any desired angle with respect to a horizontal reference. So, here the accuracy can go up to 1 minute. So, are used to determine the straightness, flatness of surfaces. They are also used to set inclinable tables of jig boring machine, and angular jobs on surface grinding for machining.

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So, we use this clinometer. So, you can see that. So, here we can try to change the angle lock it like your bevel protractor. Here is an angle, and here is the sub division. So, you can try to get the base angle, and then a minute, reading you can get it from here. So, this is more precise for a larger angle, we use these clinometers.

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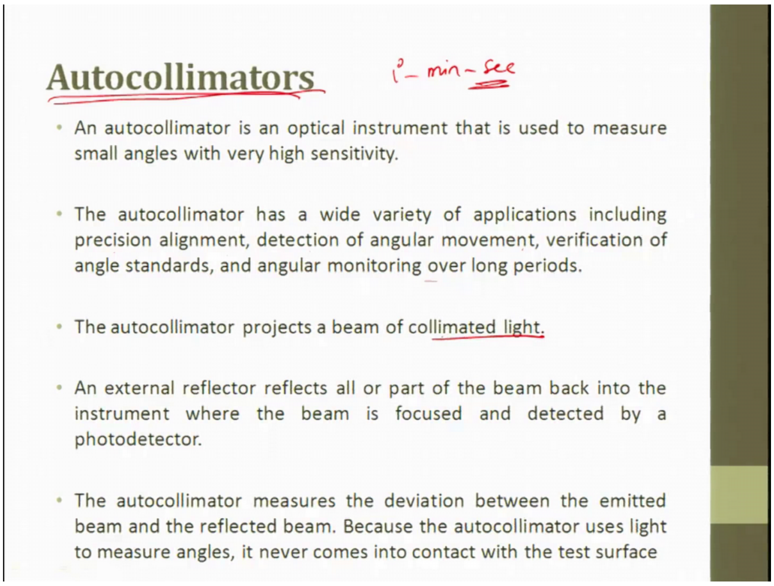

The next topic of discussion is going to be autocollimator. So, autocollimator is an optical instrument that is used to measure small angles to very high precision. Till now, what we were measuring is we were measuring it degree, then we went to minute and then we were talking about second. So, if you want to be more sensitive in second level and the minute level, then we always use autocollimator. Autocollimator has a wide variety of application including a precision alignment, deduction of angular movement, verification of angle standards, and angular monitoring over long period can be done by an autocollimator. So, when I say auto collimator, so moment I say colli, so then that has to be a light. So, in autocollimator, we use a beam of collimated light. Reflection is used.

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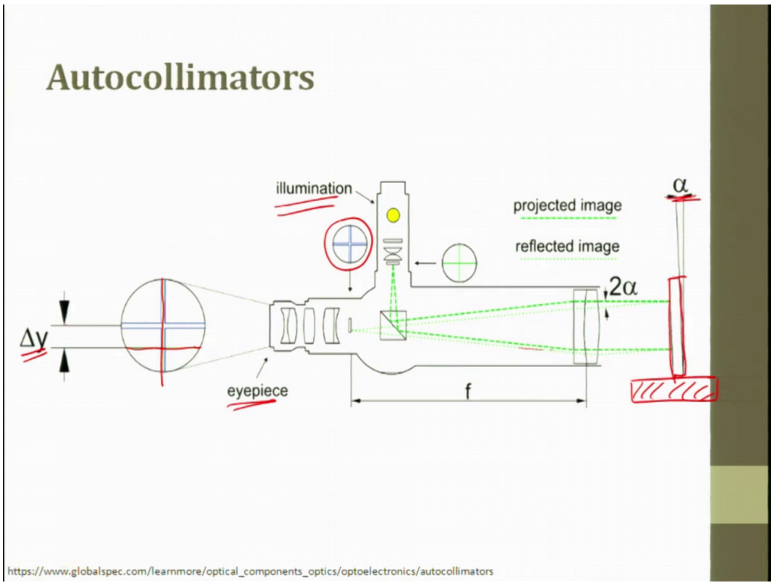

So, this is an autocollimator. So, what we do is we try to illuminate lights, this is the beam splitter. So, it goes hits at the object or at reference, and then this gets projected back, this is reconstructed, and then we watch it through the eyepiece. So, this is illumination. In the eyepiece, what you have is the before the eyepiece, we have a cross wire, and then this is projector, and this is reflector. So, the light comes from here, goes to the beam splitter, it splits the light and half of it goes this way, and it tries to hit at the surface. And then it comes back, they get reconstructed, and you can see it at the eyepiece, and then you can subsequently see it in the in the eyepiece side. So, here you will have a cross wire, which is seen.

So, if you look at it very clearly, you see the y is getting displaced from the center to a corner. And y is this displacement; this displacement is because the reference plate or the mirror, which is kept on the work piece, this is the work piece. So, this is at an angle, so reflection happens. So, there is a displacement. So, this is the delta y, which is used to measure the angle in terms of displacement, we can try to get it. So, very small angles can be measured using a autocollimator. The external reflecting the reflector reflects all are part of the beam back into the instrument, where the beam is focused and detected by a photo detector. The autocollimator measure the deviation between the emitted beam and the reflected beam. Because of the autocollimator use of lights to measure an angle, we can test it for a very long distance, and try to get the output.

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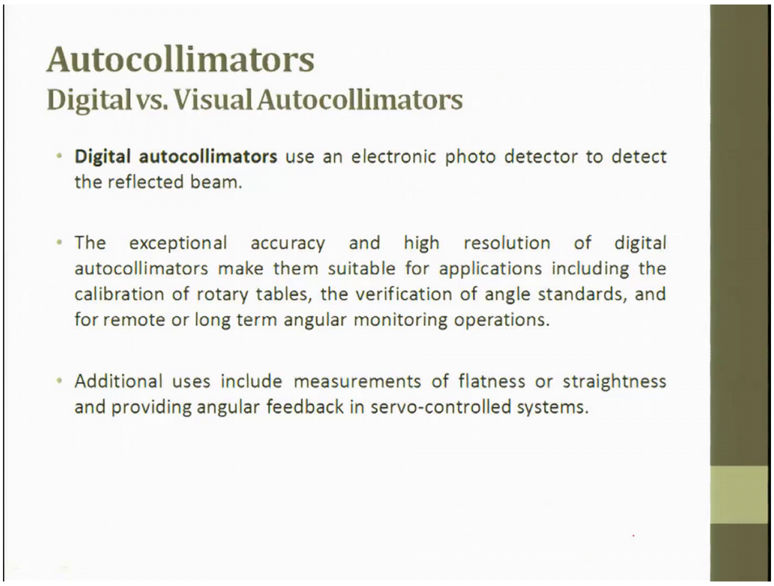

Thank you very much.