Metrology
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Module-3
Lecture-5
Positional tolerance

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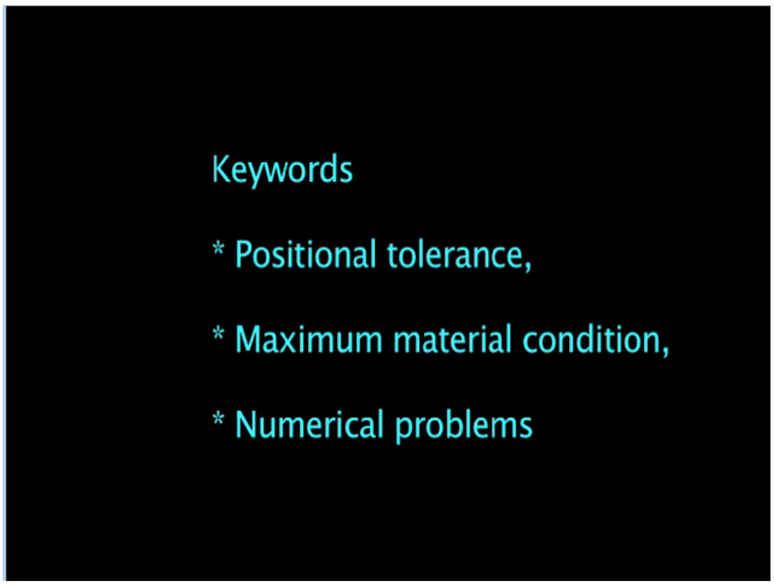

I, welcome you all for module 3 lecture 5. In this lecture we will be discussing about the various aspects of positional tolerances. And then we will see some numerical problems to understand the different kinds of fits and tolerances.

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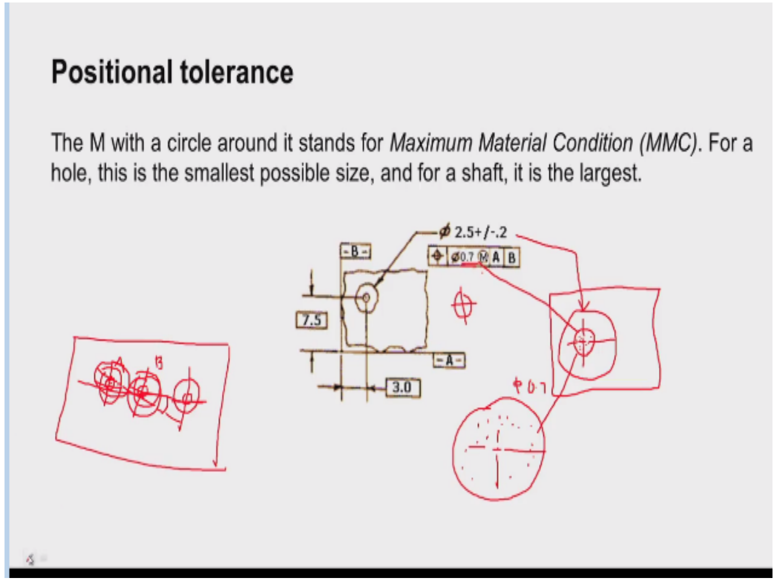

Now we will move to positional tolerance, now what happens is in the manufacturing of the work pieces. Sometimes we specify some drilled holes and we also specify the location of that hole. In this case this surface is taken as a datum end, this surface is taken as b. So, the centre of the hole that is to be drilled has some specification this distance from this particular corner is 3 millimetre and from here it is 7.5 millimetre.

And now in the drilling of hole exactly that particular location as specified here maybe difficult or it may not be possible because of various reasons like inaccuracy in the machine tool or because of the vibration or because of the thermal deformation. The tool, drill tool may not exactly coincide with the specified centre. So, it may deviate from the specified centre, so we have to specify what is the deviation that is allowed.

So, that is done by using the positional tolerance. Now we can see here this is the hole that is to be drilled and it is values are given here, the diameter of the hole is 2.5 millimetre and with some tolerance is also given. So, now what is the deviation that is allowed for centre, that is mentioned using this particular symbol. So, now this circle with the + symbol circle with + is the symbol used for to specify the positional tolerance.

And then in this case it is specified by the deviation that is allowed is 0.7 units, 0.7 millimetre. That means the centre of the hole this is the 0.7 millimetre okay. And the diameter within 0.7

millimetre diameter anyway this enter can lay satisfying this maximum it will condition. If we enlarge this potion, so this is the required centre desired centre is this one which is specified by 7.5 units and 3 units with reference to A and B.

Now the positional tolerance is given as 0.7 units that means the drill can go here or this enter can move anywhere within this particular circle. Now because of this what happens is say we have some patterns like this, we have to draw 3 holes. Because this centre will be varying , so this is the centre for A, hole A and this is the centre for hole B. Now we have the tolerance, positional tolerance for this hole A, positional tolerance for B.

Similarly positional tolerance for C, what happens is the centre can vary anywhere here. So, the hole is drilled at this particular taking this as centre within the positional tolerance. Then we get the hole like this and in the second case the centre is taken somewhere here and the hole is drilled like this. Then when we join this 2 centres we get the line like this then maybe some angle between the desired location and the actual location there is some angle this is within the allowed tolerance then it can be accepted.

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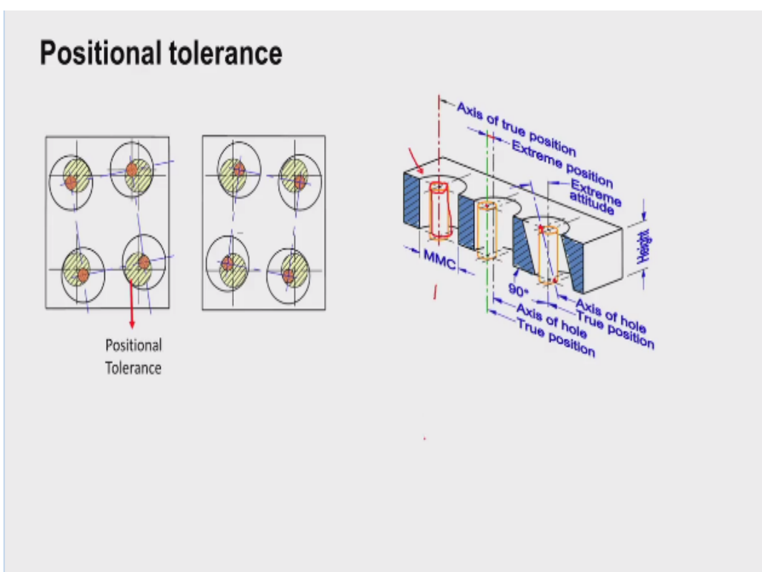

Now that is what shown here the patterns of holes. So, we have the hole that is to be drilled and this is the positional tolerance for the centre. Similarly we have 4 holes and depending upon how the centre of the hole varies we may get the patterns like this. And then sometimes what happens is height is also important. We can see here this is the positional tolerance for the centre of the hole in this particular plane.

Now when we consider the height now we get a cylinder like this, so within this volume the centre point can lay anywhere. That means now in the second hole can see here the centre of the hole is at the extreme end, that means instead of this is the ideal condition where the desired centre and the actual centre they are coinciding. And here there is a deviation from the desired position.

That means centre is of the hole is drilled is here and in this case there is angle. But again the centre is within the allowed deviation if it is within the allowed deviation then we can accept the work piece. This is the true position and this is the extreme attitude access of the actual hole that is drilled.

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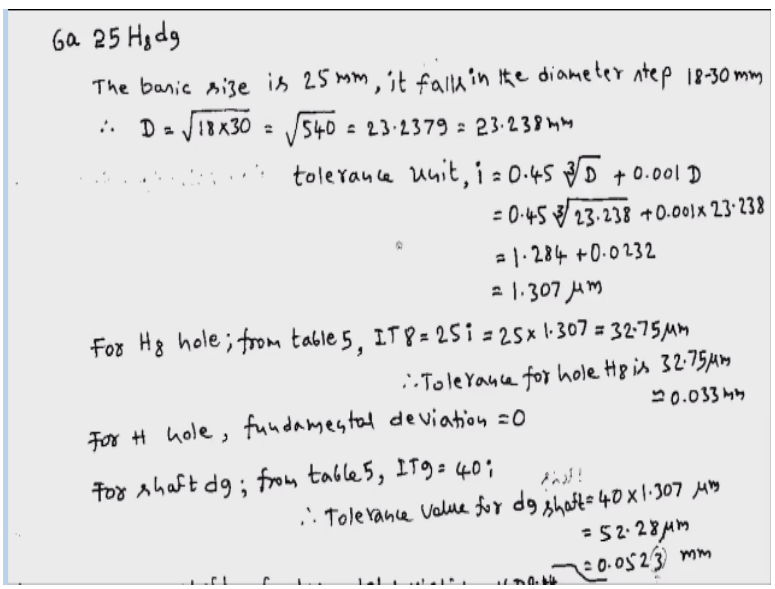

We will solve some numerical problems on fit and tolerances. Now this is the first problem, so wherein the basic size given is 25 millimetre and this diameter it falls in the diameter step of 18 to 30 millimetre. So, we can find the mean diameter is in this relationship, square root under square root D1 times D2. So, the mean diameter is 23.238 millimetre and then find the tolerance unit using this relationship.

So, we have to feed the value of D in millimetre then we get the tolerance unit that is 1.307 micrometres. Now for H8 hole from table 5 we find that IT8 tolerance grade is IT8 and for this IT8 tolerance value is 25 times i. So, we have this 25 times i is equal to 1.307, so tolerance value for the hole H8 hole is 32.75 micrometre or 0.033 millimetre. Now we know that for H hole that is hole basis basic shaft basic hole. We have the fundamental deviation is 0.

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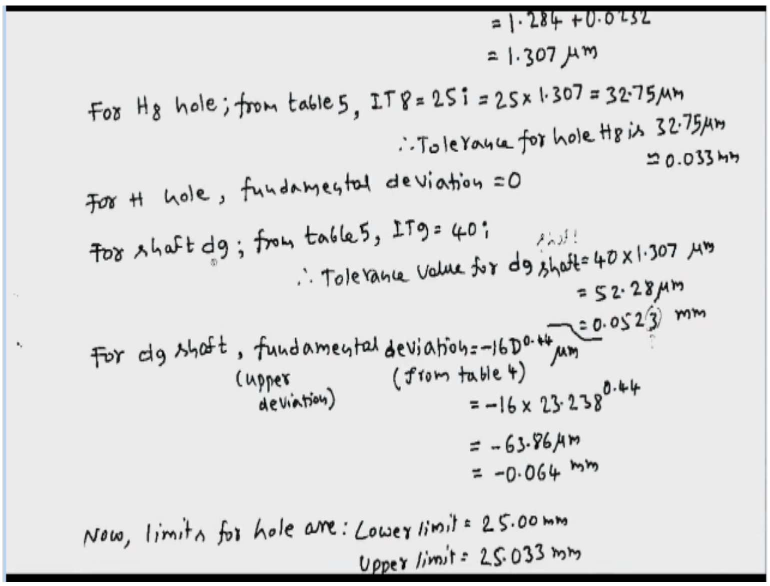

Now for shaft d9 from table 5 IT9 is equal to 40 i. So, tolerance value for d9 shaft is 40 times i, i is 1.307, so this will give us 0.0523 millimetre. So, for d9 shaft fundamental deviation that is upper deviation from table 4 is equal to -16 times d power 0.44 micrometres. So, we have to feed the value of D that is 23.238 then we get the fundamental deviation of -63.86 micrometre or -0.064 millimetre.

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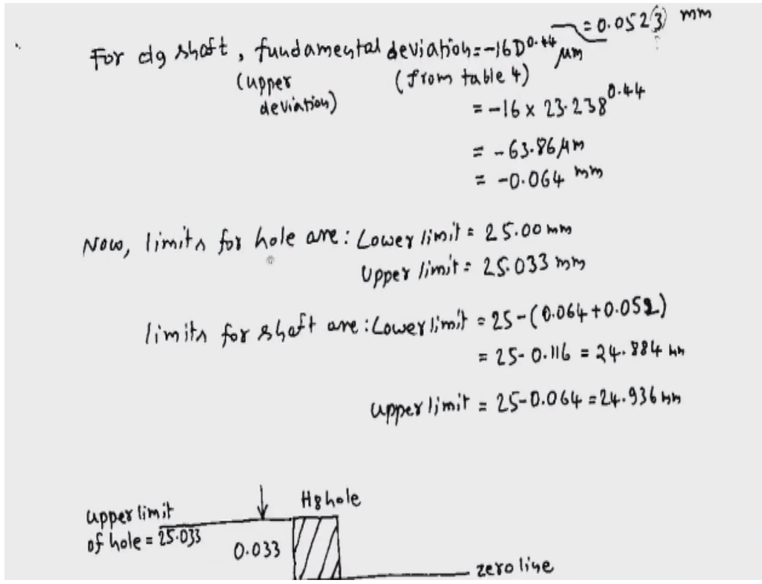

Now we can find the limits for hole and shaft. The limits for hole that is upper limit upper limit for lower limit for hole is 25 millimetre. Because it is coinciding with the basic size and upper limit is to the lower limit we have to add the tolerance value. Then we get the upper limit that is 25.033 millimetre. Similarly we can find limits for shaft lower limit is 25 millimetre that is the basic size. From this we have to detect the fundamental deviation as well as the tolerance value then we get the lower limit for the shaft 24.884 millimetre.

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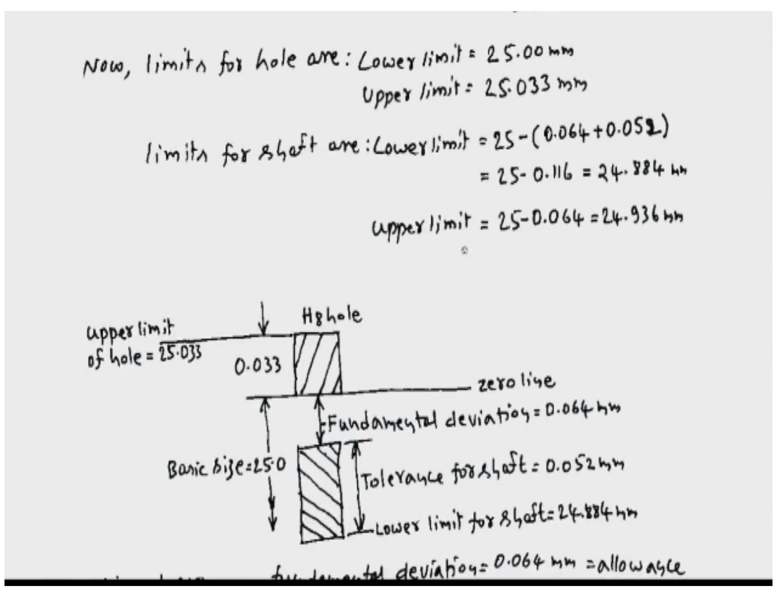

Similarly we can find the upper limit for the shaft, so for getting that this is the 0 line and this is the basic size 25 millimetre from this we have to detect fundamental deviation that is 0.04. Then we get the upper limit for the shaft that is 25-fundamental deviation of 0.064 will give us 24.936. So, this is the upper limit for the shaft.

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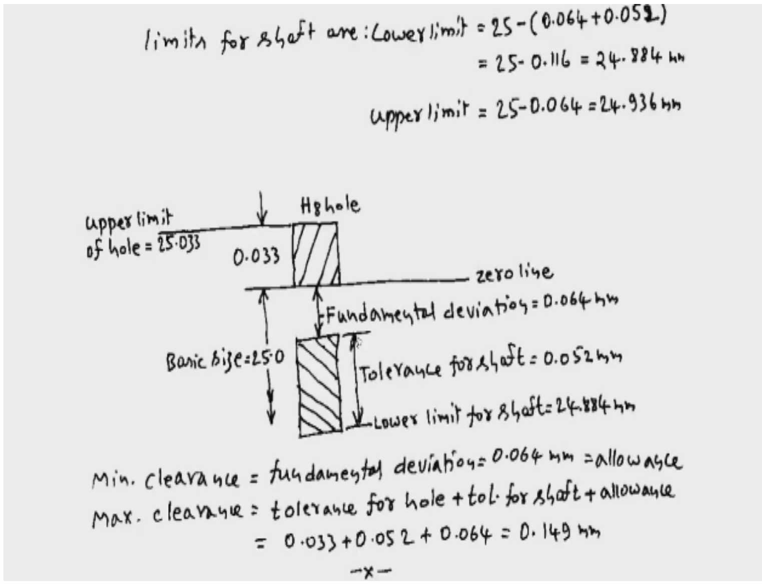

So, pictorially all the values are shown here this is H8 hole with the tolerance 0.033 millimetre and this 0 line this distance indicates the basic size and to the basic size if we had this tolerance value we get upper limit for hole that is 25.033 millimetre. Similarly we can find the upper limit for shaft as well as lower limit of shaft. Now we can calculate the minimum clearance and maximum clearance.

Now we can see we get the minimum clearance by subtracting the upper limit of the shaft from the lower limit of the hole that is nothing but fundamental deviation which is equal to 0.064 is also equal to allowance value. So, minimum clearance is 0.0464 millimetre and then to get the maximum clearance what we have do is we have to add tolerance value shaft fundamental deviation value and tolerance value for the hole.

Then we get the maximum clearance of 0.149 millimetre. Now we will move to the second problem 50 H7 p6.

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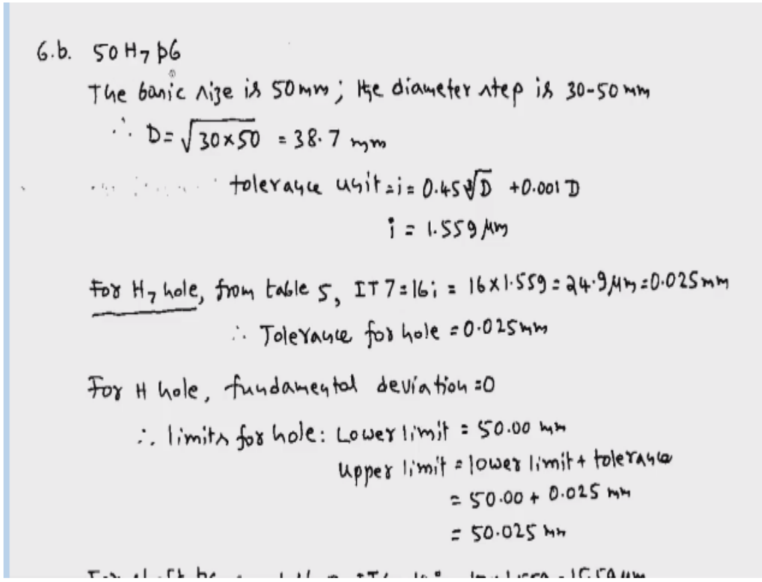

So, basic size is 50 millimetre and this falls in the diameter step of 30 to 50 millimetre. So, we can calculate the mean diameter which will be equal to 38.7 millimetre. And then tolerance unit we can calculate using this relationship we have to feed the value of D that is 38.7 millimetre in this equation. Then we get tolerance unit is equal to 1.559 micrometer.

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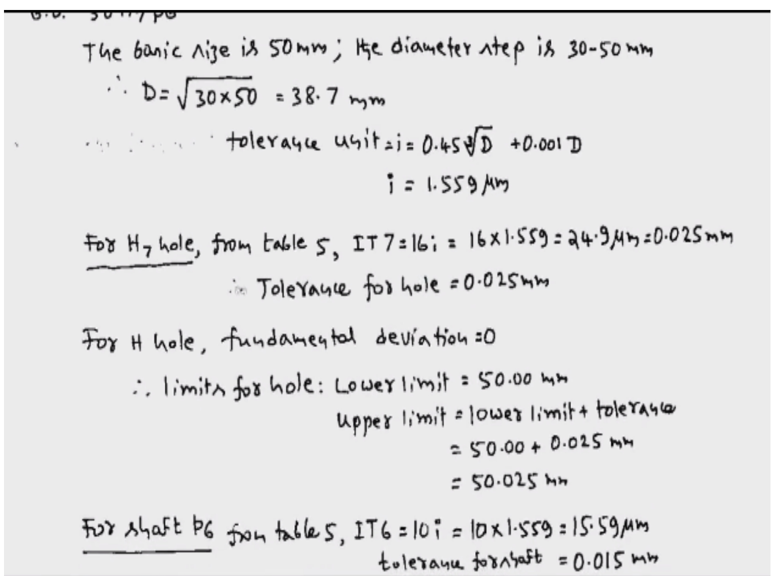

And then for H7 hole from table number 5 the tolerance grade is IT7 for this tolerance value is 16 times i. So, where I is tolerance unit with the value 1.559 micrometer then we get tolerance for hole that is equal to 0.025 millimetre.

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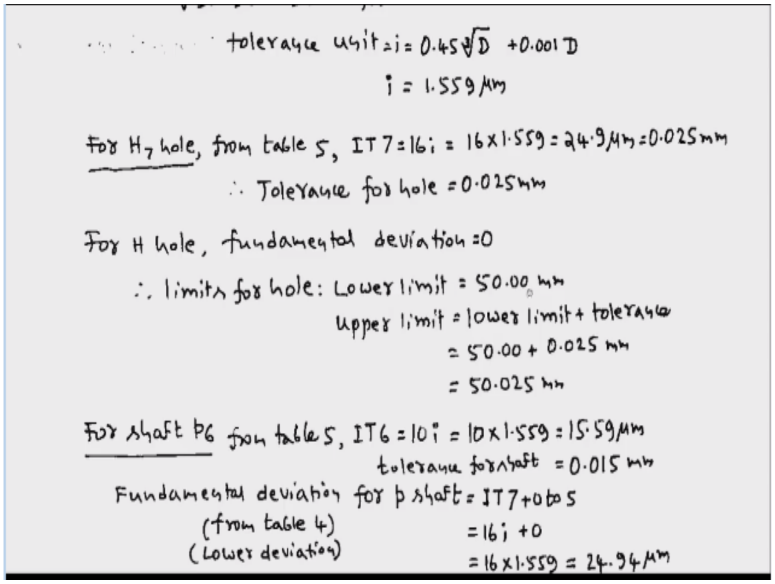

Now for H hole fundamental deviation is 0. So, now we can find the limits for hole lower limit is equal to 50 millimetre and upper limit for the hole is lower limit of the hole+tolerance. So, that will give us 50.25 millimetre.

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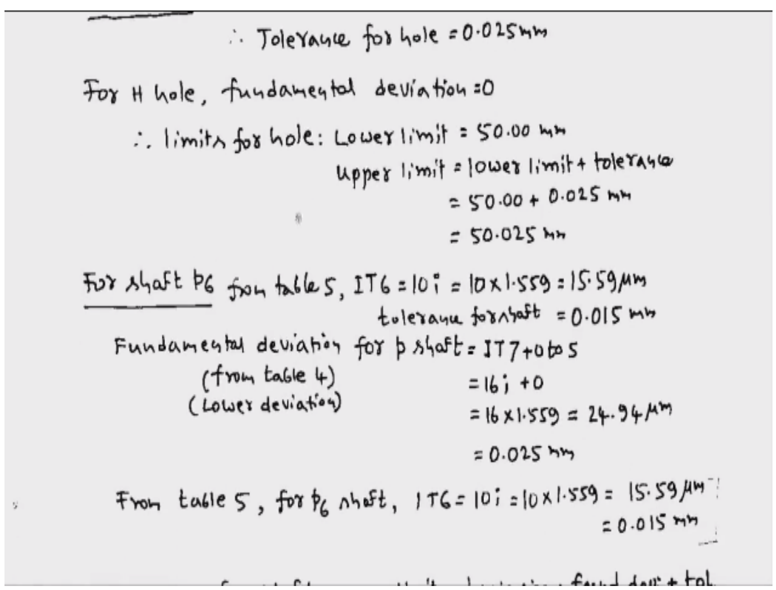

Now coming to the shaft we have shaft p6 from table number 5 for tolerance grade 6 that is IT6 we get tolerance value of 10 times i, where is i is equal to 1.559, so we get 15.59 micrometer as the tolerance. So, tolerance for the shaft is 0.015 millimetre. Now fundamental deviation for p shaft from table number 4 is equal to IT7+0 to 5. Now I am taking only this IT7+0, so 16 times i, i is equal to 1.559, this is equal to 24.94 micrometer which is nothing but 0.025mm.

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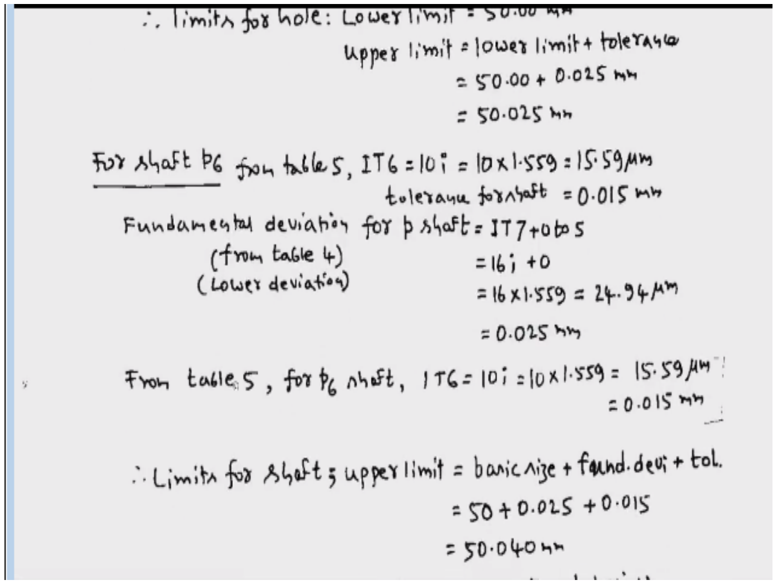

Now from table number 5 for p6 shaft that is the IT grade number is 6. So, IT6 is equal to 10 times i, so this will give us 0.015mm.

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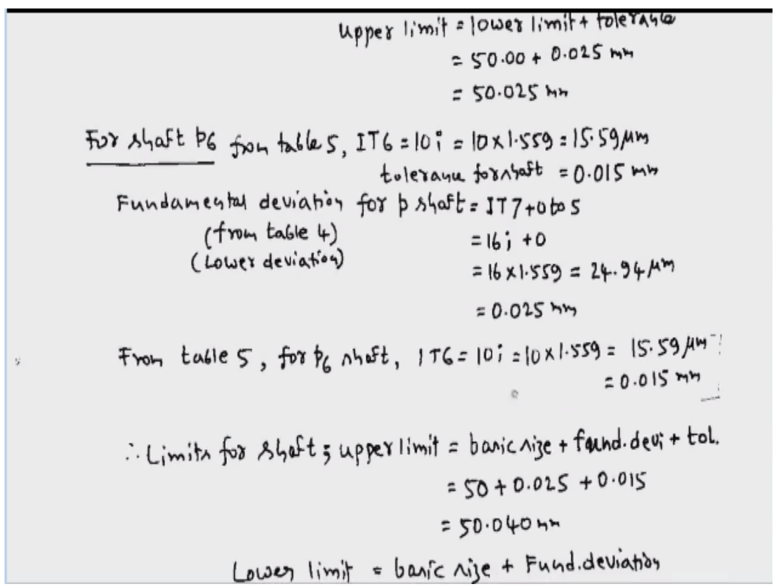

So, this is the tolerance value for the shaft.

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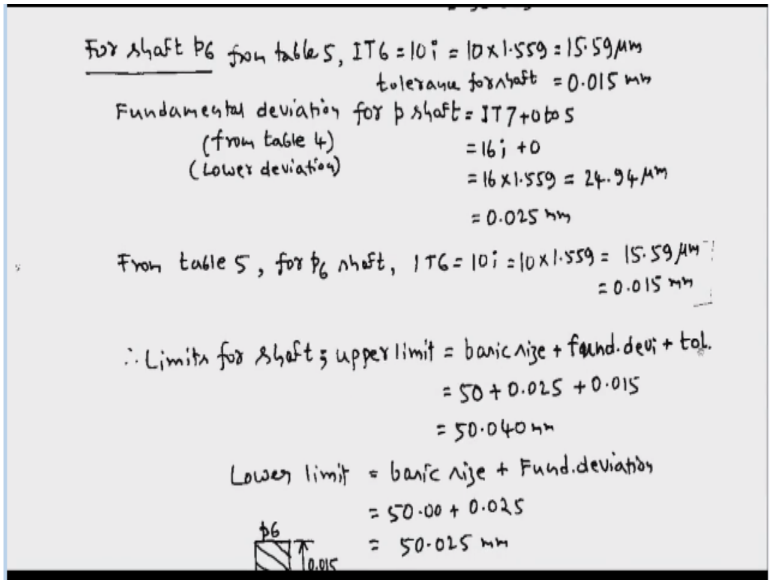

Now limits for the shaft, so upper limit we can find by adding basic size and the fundamental deviation and the tolerance value that is basic value, basic size is 50 millimetre and the fundamental deviation is 0.025 millimetre + tolerance value is 0.15 millimetre. So, when they add these numbers we get 50.040 millimetre as upper limit for the shaft.

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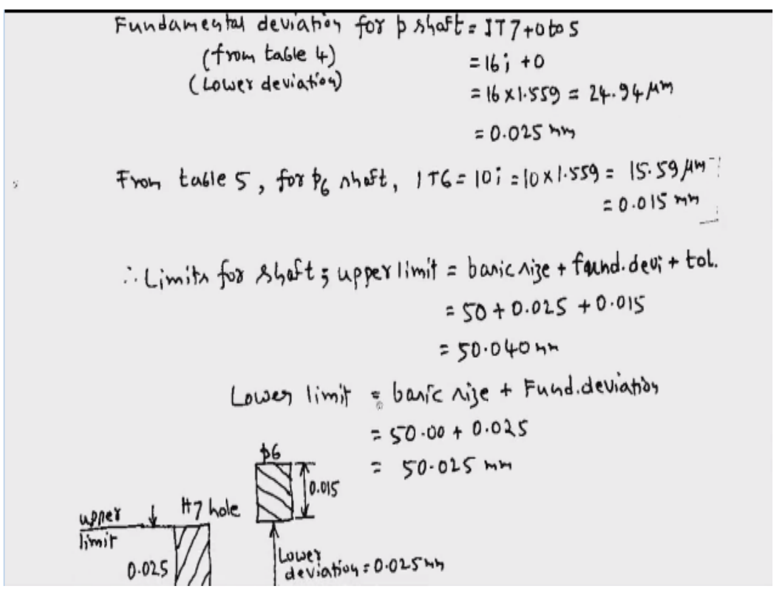

Similarly lower limit for the shaft is equal to basic size + fundamental deviation.

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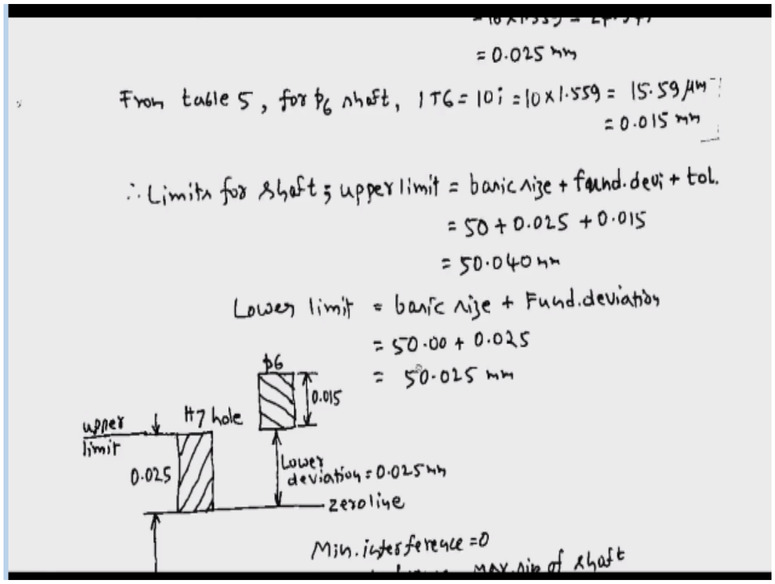

So, basic size is 50 millimetre and fundamental deviation is 0.025 millimetre when they add these 2 values we get 50.025 millimetre and this is the lower limit for the shaft.

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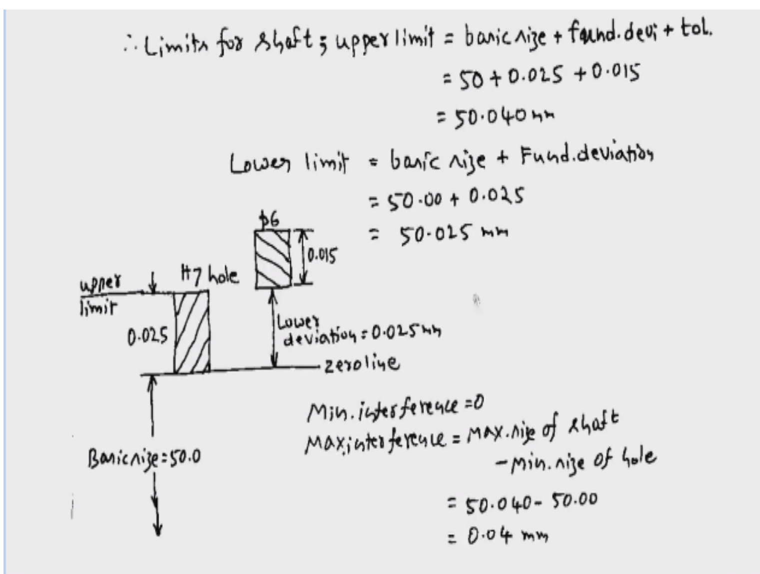

Now all the values are pictorially shown here. This is the 0 line with reference to which all other determines are shown here. This is the basic size 50 millimetre and we have this H7 hole where the deviation is 0. So, the lower limit of the hole is equal to 50 millimetre we have to add this tolerance value hole to this basic size to get the upper limit. Now similarly we have calculated the lower deviation for the shaft p6 shaft that is equal to 0.025 millimetre.

And the tolerance for the p6 shaft is 0.015 millimetre. Now we can observe that here the maximum size of the hole is equal to the minimum size of the shaft that means the interference is equal to 0, it will just slide there is no gap between hole surface and the shaft surface by application of little pressure the shaft will move into the hole. Now what is the maximum interference.

So, that we get by we have to detect minimum size of the hole from the maximum size of the shaft that is maximum size of the shaft is 50.040 – minimum size of the hole is 50. So, this difference gives 0.04 millimetre. So, this is the amount of maximum interference we get.

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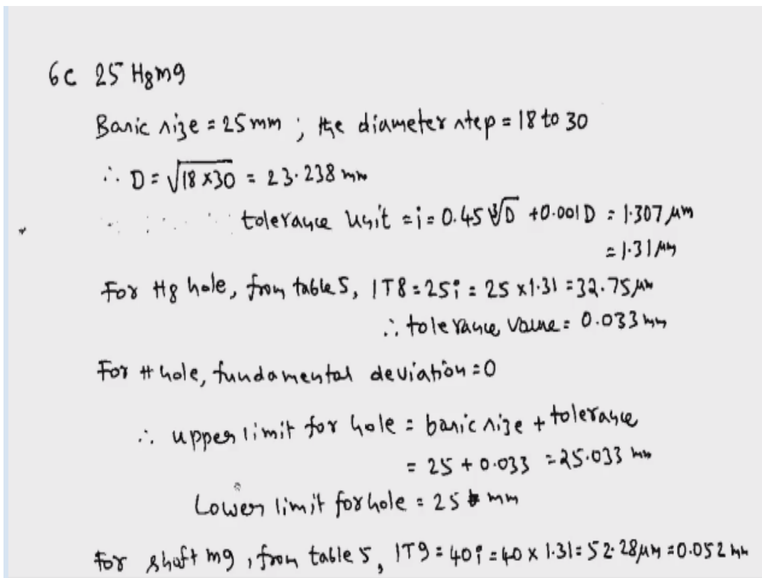

Now we will move to the next problem where the hole shaft combination is 25 H8 m 9. So, the basic size is 25 millimetre and this falls in the diameter step of 18 to 30 millimetre. So, the mean diameter is 23.238 millimetre and then we calculate the tolerance unit using this relationship and this will be equal to 1.31 micrometer and for H8 hole from table number 5 IT8 grade is equal to 25 i, then this is equal to 32.75 micrometer.

So, tolerance value for hole is 0.033 millimetre and for H hole we know that fundamental deviation is equal to 0. So, the lower limit for the hole is equal to the basic size that is 25mm. And upper limit for hole is equal to basic size + tolerance that is 25 millimetre+tolerance value is 0.033 millimetre then we get 25.033 millimetre this is the upper limit for the hole.

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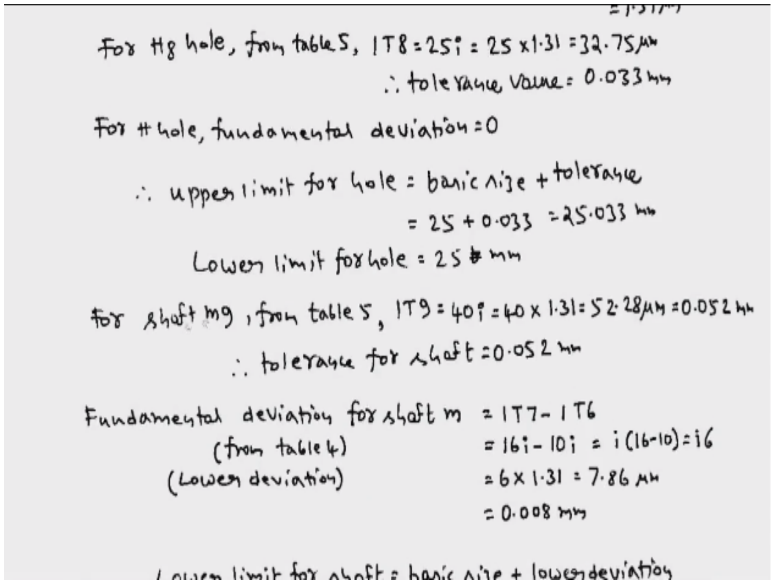

And coming to the shaft m9 from table number 5 for IT grade number 9 tolerance value is 40 i this is equal to 52.28 micrometer which is equal to 0.052 millimetre. So, tolerance for shaft is 0.052 millimetre.

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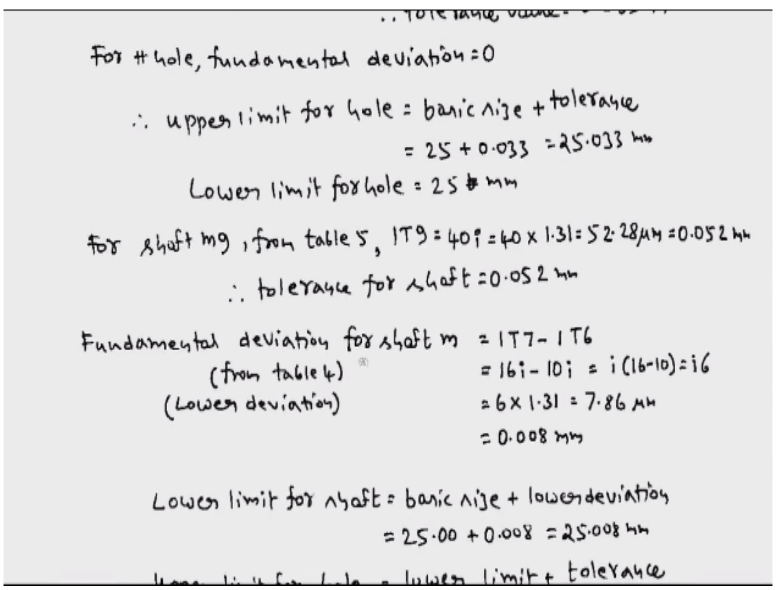

And then fundamental deviation for shaft m from table number 4 is equal to IT7–IT6 this is equal to 16 times i–10 times i. So, if we feed the value of i we get fundamental deviation of 0.008 millimetre.

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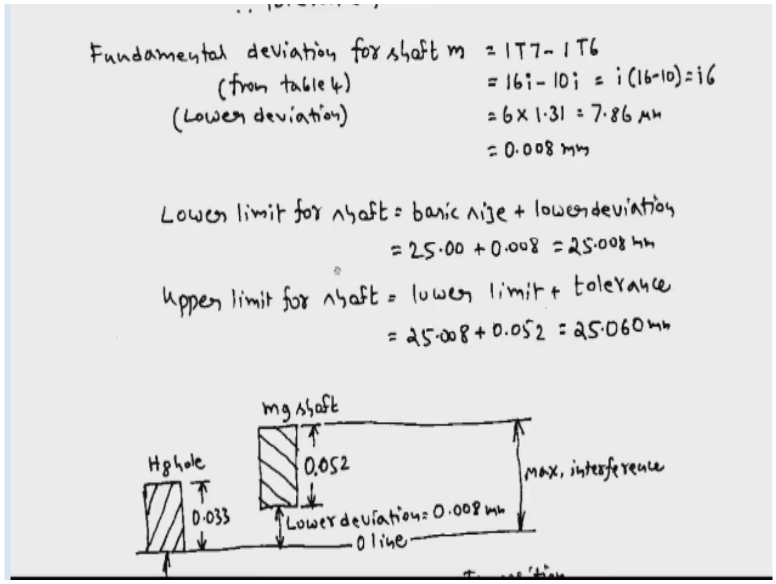

Now once we find this fundamental deviation and tolerance we can find the limits for the shaft that is lower limit for the shaft is equal to basic size+lower deviation. That is basic size is 25 millimetre+lower deviation is 0.008 millimetre and this will give us 25.008 millimetre.

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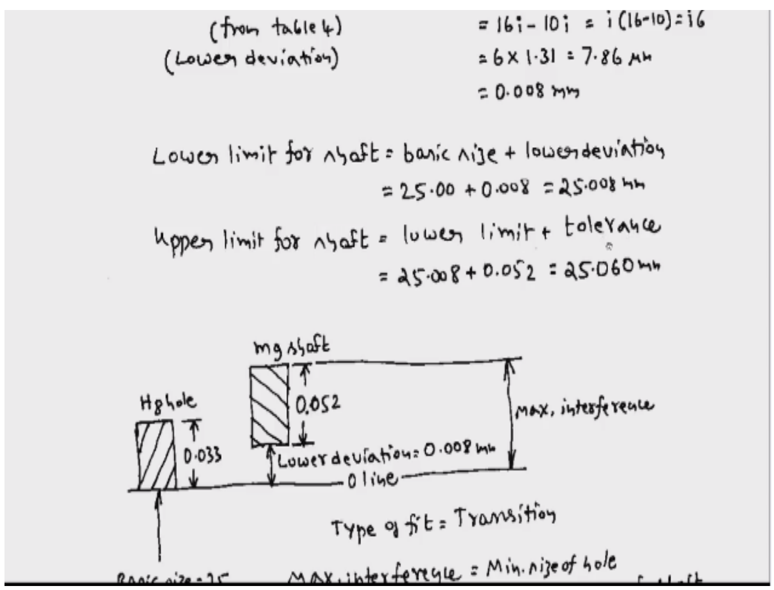

Similarly upper limit for shaft is equal to lower limit+tolerance value that is lower limit for the shaft is 25.008+tolerance value 0.052 then we get 25.060 as the upper limit for the shaft.

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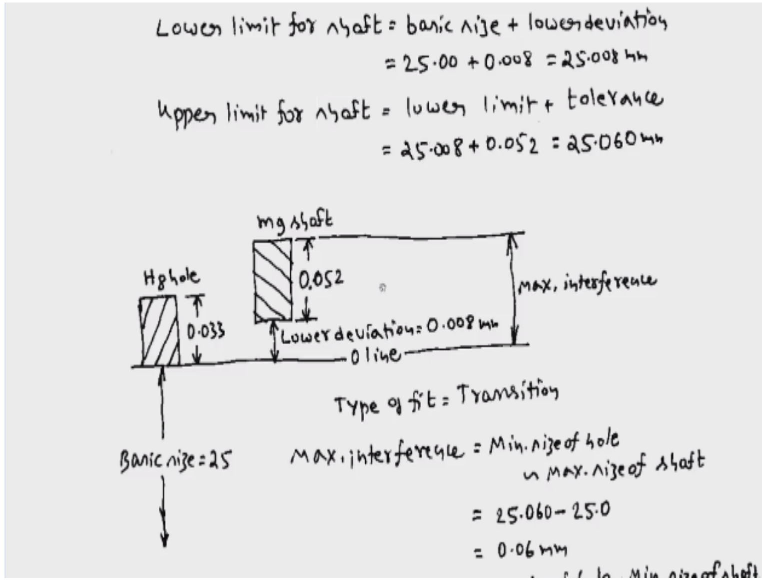

All these dimensions are indicated in this picture. So, this is the basic size 25 millimetre and 0 line and this is H8 hole with tolerance value of 0.033 millimetre. And this is the m9 shaft with tolerance value of 0.052 and the lower deviation is 0.008 millimetre and the difference between the maximum size of the shaft and minimum size of the hole will give us the maximum interference, so that is equal to 0.060 millimetre.

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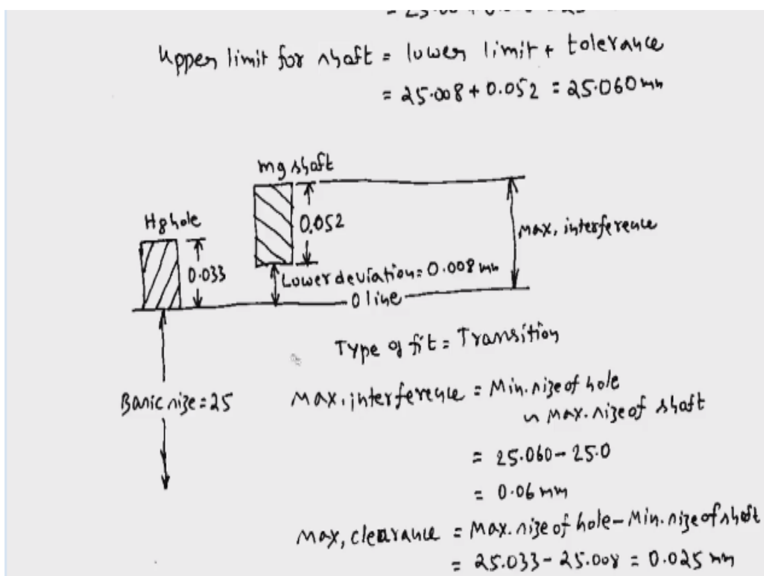

And the maximum clearance we get by subtracting the lower size of the shaft from maximum size of the hole. So, then we get maximum clearance of 0.025 millimetre. Now from this picture we can understand that there is overlapping of tolerance zone of hole with the shaft. So, depending upon the actual size of the shaft and actual size of the hole we may get interference fit or we may get clearance fit, so this is a case of transition fit.

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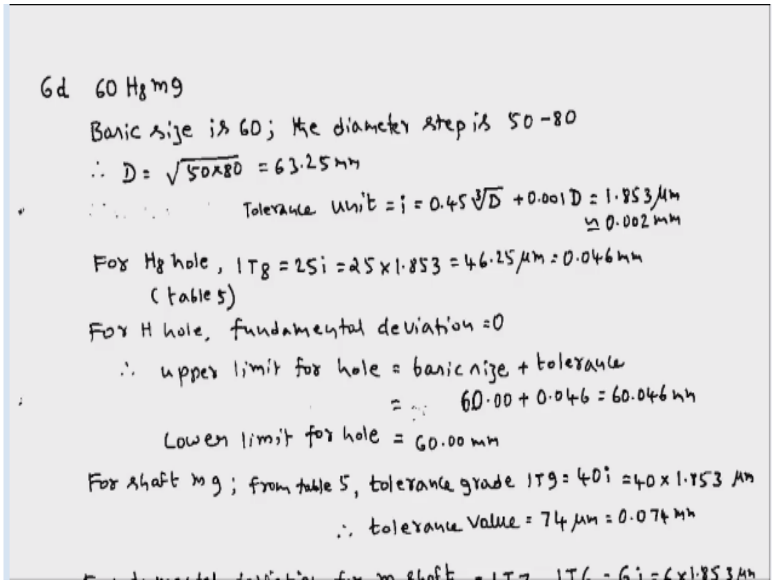

Now we will move to the next problem wherein the basic size is 60 millimetre and this falls in the step of 50 to 80. And then the mean diameter is 63.25 mm, and we can find the tolerance unit using this relationship and when you feed this 63.25 in the equation we get tolerance unit of 0.002 millimetre. Now for H8 hole from table number 5, we IT grade number is 8, so IT8 is equal to 25 i. So, we have to feed the value of tolerance unit that is 1.853 micrometers.

Then we get the tolerance value for the hole that is 0.046 mm and we know that for H hole the fundamental deviation is 0. So, upper limit for hole we can get by adding tolerance value to the basic size. So, the basic size is 60 millimetre and the tolerance value for the hole is 0.046 millimetre, then the upper limit for the hole is 60.046 millimetre. Similarly for the lower limit for the hole is equal to the basic size that is 60 millimetre.

Now moving to the shaft m9, the tolerance grade suggested for the m9 shaft the tolerance grade that is suggested is IT9. So, from table number 5 tolerance grade IT9 is equal to 40 times i. So, tolerance value for m9 shaft becomes 0.074 millimetre.

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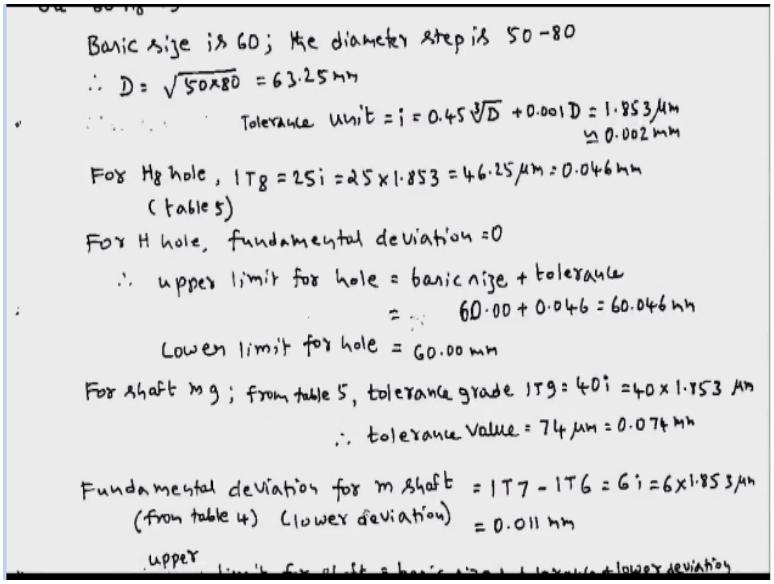

Now fundamental deviation for m shaft for that is nothing but lower deviation from table number 4. We can calculate by using this relationship IT7–IT6 this is equal to 6 times i, this is equal to 0.0 11 millimetre.

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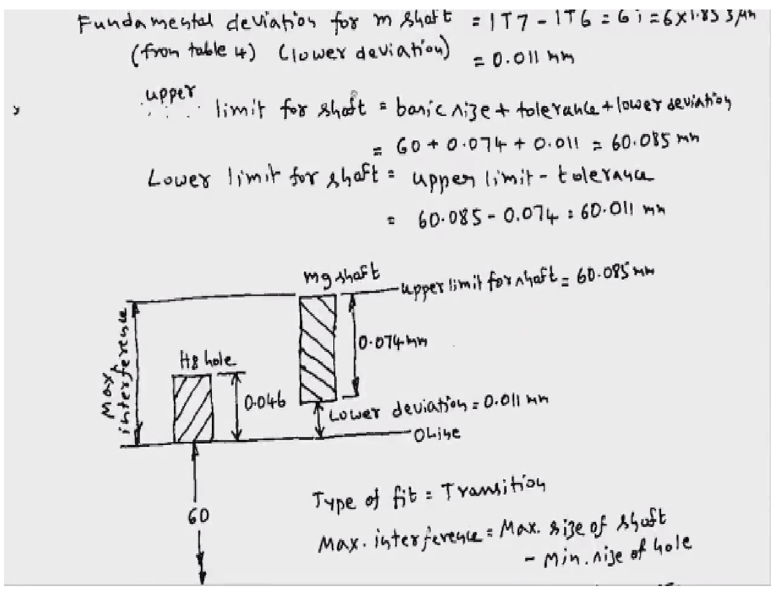

Now after finding the fundamental deviation and the tolerance value for the shaft now we can find the limits for the shaft. The upper limit for the shaft is equal to basic size of the shaft + lower deviation that is allowed and then we have to add the tolerance. So, then we get the upper limit for the shaft that means the basic size is 60 millimetre and then the lower deviation is 0.011 millimetre and then tolerance value is 0.074.

If we add all these 3 values we get upper limit to be 60.085 millimetre. Similarly we can find the lower limit for the shaft that is upper limit of the shaft – tolerance. So, will give us the lower limit, so that is equal to 60.011 millimetre. So, all the values are shown in this pictorial representation.

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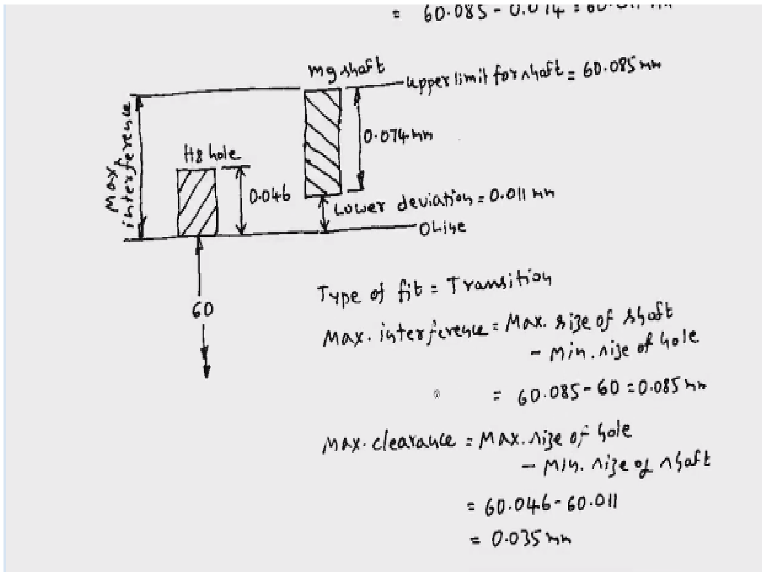

So, now we can see there is overlapping of this zones, the tolerance zone for shaft is overlapping with the tolerance zone for hole. So, we have a transition fit, so we can find what is the maximum interference and what is the maximum clearance. So, maximum interference we get by adding the lower deviation and the this tolerance for the shaft that is equal to 0.085 millimetre. Similarly the clearance we can find by subtracting the lower limit of the shaft from maximum size of the hole.

So, that maximum clearance will be 0.035 millimetre that means depending upon the actual size of the hole and actual size of the shaft we may get interference fit or we may get clearance fit.

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6e 25 H8s6

Basic size is 25; diameter step is 18-30; $D = \sqrt{18 \times 30} = 23.238$ mm

Tolerance unit $= i = 0.45\sqrt[3]{D} + 0.001D = 1.31\ \mu m$

For H8 hole, $IT8 = 25i = 25 \times 1.31 = 32.75\ \mu m$
(table 5) tolerance for hole $= 0.033$ mm

For H hole, fundamental deviation $= 0$

$\therefore$ upper limit for hole = basic size + tolerance
$= 25 + 0.033 = 25.033$ mm

lower limit for hole = basic size $= 25.0$ mm

For shaft s6; from table 5, $IT6 = 10i = 10 \times 1.31 = 13.1\ \mu m$
$\therefore$ tolerance for shaft $= 0.013$ mm

Now we will move to the next problem wherein the basic size is 25 millimetre and we are using H hole with IT grade of 8 and then we are using s shaft with tolerance grade of 6. So, the 25 basic size it is in the step of 18 to 30, so the mean diameter is 23.238 millimetre and then we can find the tolerance unit by feeding the value of D is we get 1.31 micrometer as the tolerance unit.

And then for H8 hole from table number 5 we are using IT grade 8. So, IT 8 is equal to 25 i, so tolerance value for the hole is 0.033 millimetre and for H hole fundamental deviation is 0, so the upper limit for the hole is equal to basic size + tolerance value that is equal to 25 + 0.033 millimetre which nothing but 25.033 millimetre is the upper limit of the hole. And since the fundamental deviation is 0 for H hole the lower limit for the hole is equal to basic size of the hole that is 25 millimetre.

Now moving to the shaft s6 we from the table number 5 we have IT6 is equal to 10 times i, so this will be equal to 13.1 micrometer. So, tolerance for shaft is equal to 0.013 millimetre.

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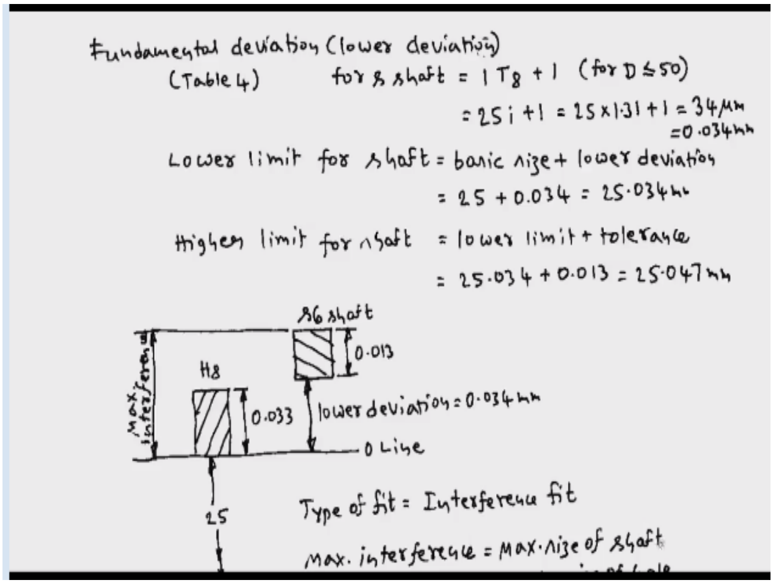

Now fundamental deviation for the shaft from table number 4 it is nothing but lower deviation this is equal to IT8 + 1. So, this relationship can be used if the mean diameter is less than 50 millimetre. So, IT8 is equal to 25 times i+1, so this is equal to 0.034 millimetre, so this is the tolerance that is allowed on the shaft, fundamental deviation for the shaft. Now once after finding the tolerance value and the lower deviation for the shaft we can find the lower limit for the shaft and upper limit for the shaft.

Lower limit of the shaft is equal to basic size+lower deviation, so this will give the lower limit for the shaft that is lower limit of the that is basic size is 25 millimetre+lower deviation is 0.034. So, we get the lower limit of shaft is equal to 25.034 millimetre. And similarly we can find the higher limit for the shaft, so that we can find by adding tolerance value to the lower limit of the shaft okay that is lower limit is 25.034 millimetre+tolerance value 0.013 millimetre. So, higher limit of the shaft is equal to 25.04 millimetre.

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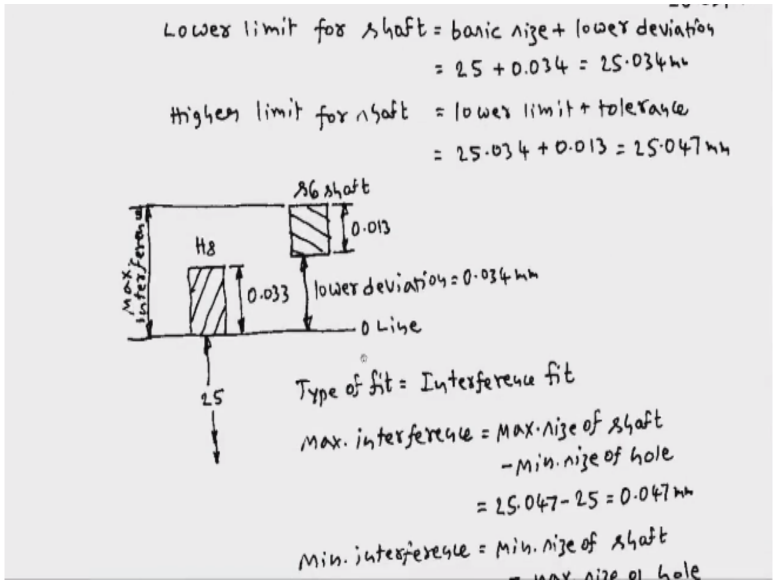

Now we can understand that the lower deviation for the shaft is greater than the tolerance value of the hole that means the lower limit of the shaft is greater than the upper size of the hole. So, we are getting an interference fit here, so in the maximum interference we can get by adding lower deviation to the tolerance value that is 0.047 millimetre.

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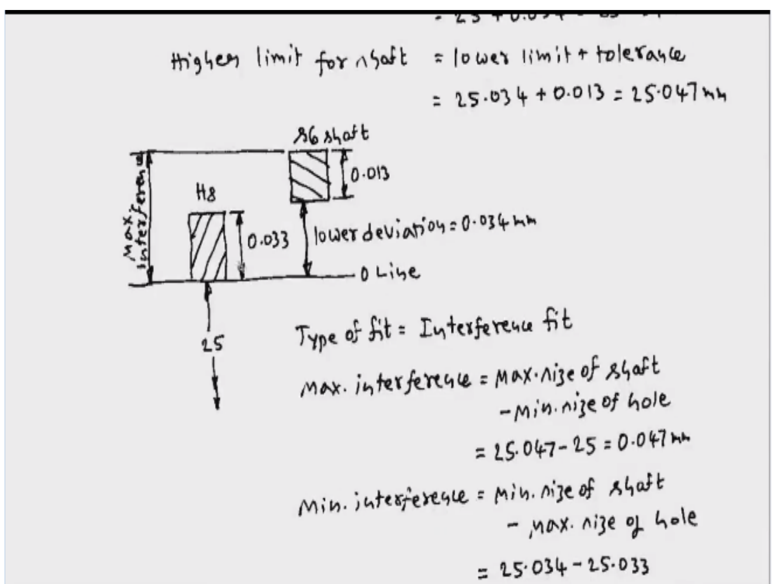

And minimum interference we can calculate by subtracting the maximum size of the hole by the minimum size of the shaft that is 25.034-25.033 millimetre this is equal to 0.001 millimetre.

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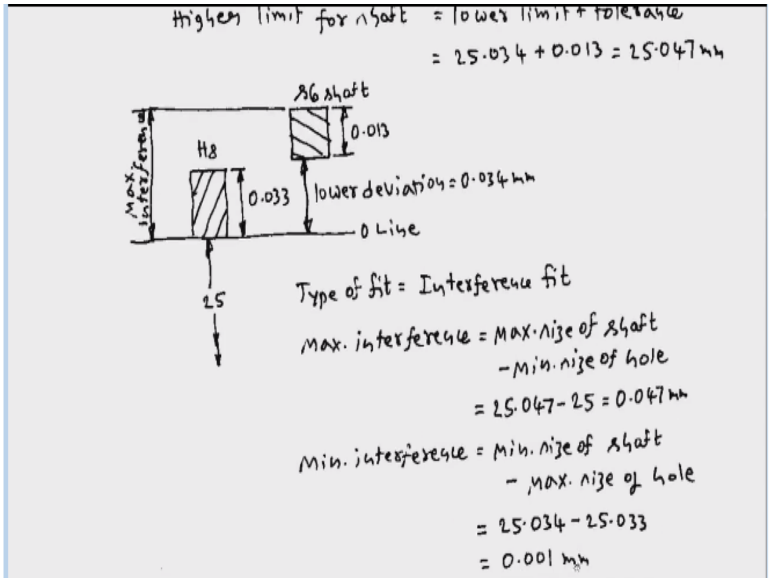

That means there is an interference of 1 micrometer. So, in order to fit the shaft s6 shaft into the H8 hole, we have to apply some force and then we can get the interference fit.

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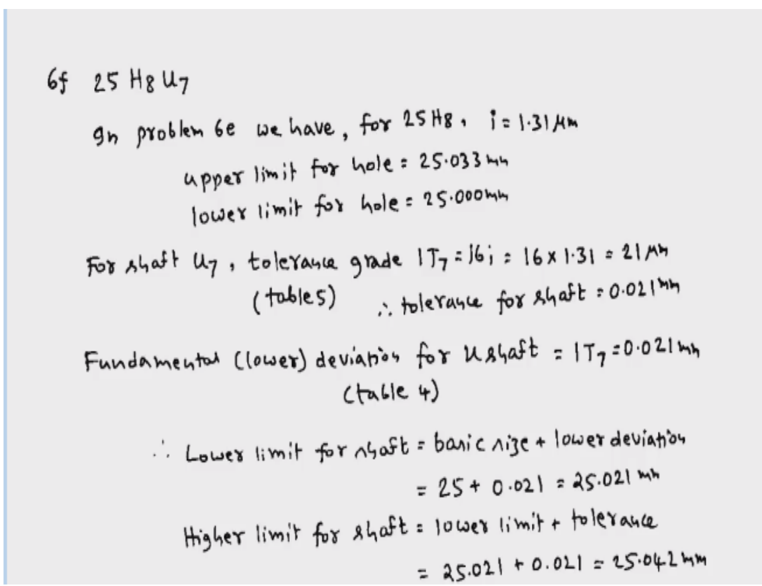

Now we will move to the next problem wherein the basic size specified is 25 millimetre. So, in problem 6e we have calculated the i value that is 1.31 micrometer. And upper limit for the hole H8 hole, 25 H8 hole is 25.033 millimetre and lower limit for hole is equal to 25.000 millimetre. So, these values we have already calculated in problem number 6e for 25 H8 combination. And moving to shaft u7, the tolerance grade is IT7 this is equal to 16 times i.

So, we get the tolerance of value of 0.021 millimetre and fundamental deviation for u shaft is equal to IT7 and this is equal to again 0.021 millimetre.

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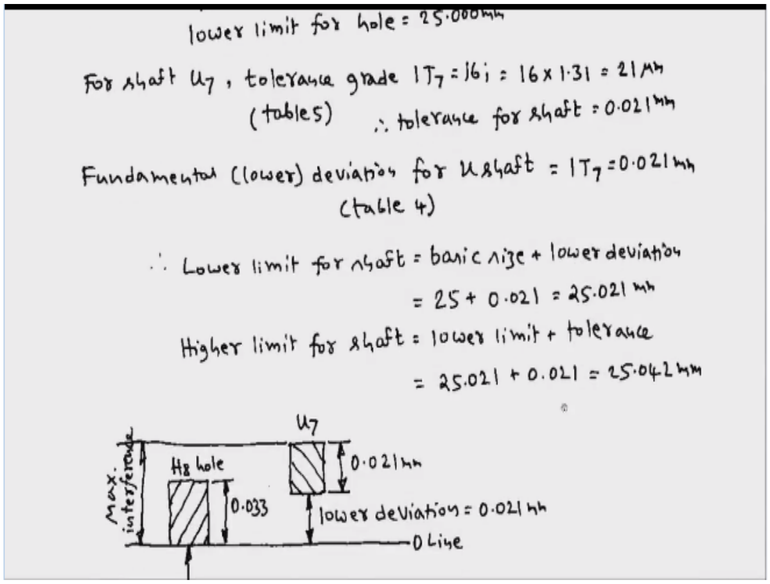

So, after finding the tolerance value for the shaft and fundamental deviation. Now we can find the lower limit for shaft this is equal to basic size of the shaft+lower deviation.

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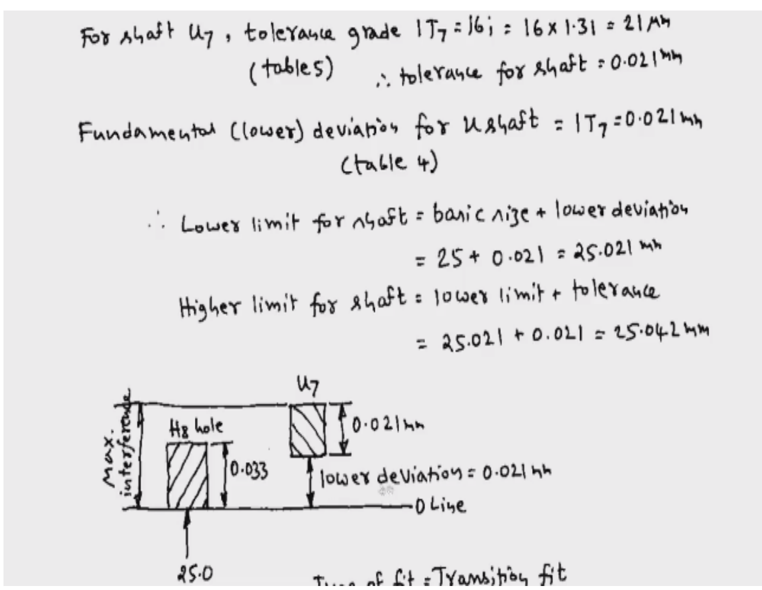

That means this is the shaft u7 shaft with tolerance of 0.021 millimetre and the lower deviation is 0.021 millimetre. Now we can find the lower limit for the shaft this is equal to basic size of shaft is 25 to the basic size we have to add this fundamental lower deviation that is 0.021mm, then we get lower limit for the shaft that is 25.021 millimetre. And then to get the upper limit of the shaft we have to add tolerance value to the lower limit of the shaft. Then we get higher limit of shaft to be 25.042 millimetre.

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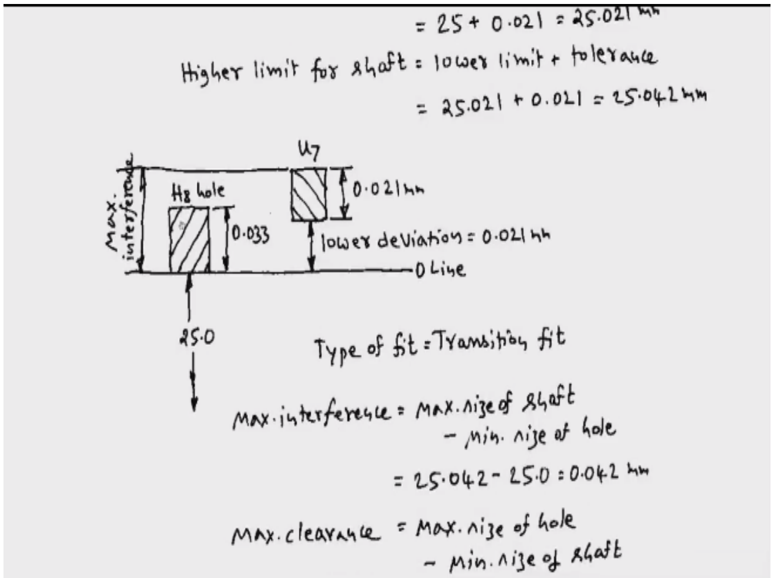

Now all values are indicated on this picture this is H8 hole with tolerance value of 0.033 millimetre and the lower size of the hole is equal to basic size and by adding tolerance value to the basic size we get upper limit of the hole. And then the since there is overlapping of the tolerance zone for u shaft with the tolerance zone for H8 hole we have transition fit.

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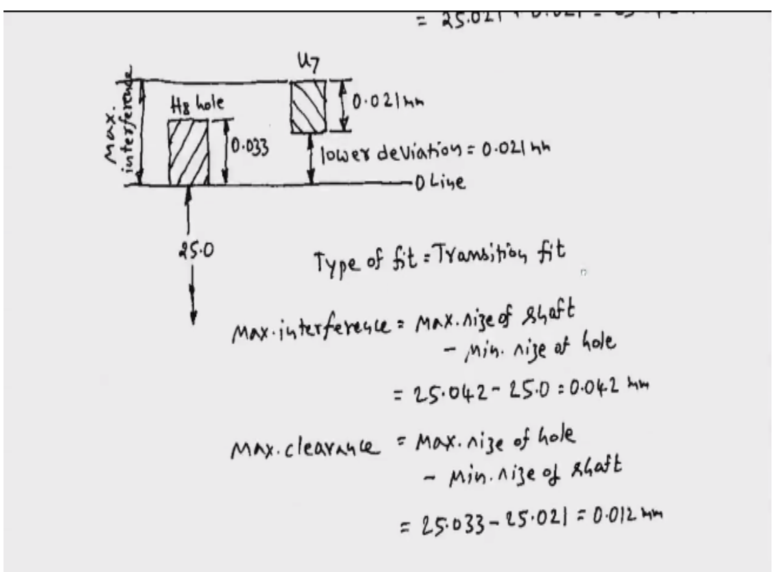

Now the maximum interference we can get by adding lower deviation, that is 0.021mm with the tolerance value for the shaft. So, that is equal to 0.0442 millimetre and by subtracting the lower limit of the shaft from maximum hole size we get the maximum amount of clearance that is equal to 0.012 millimetre.

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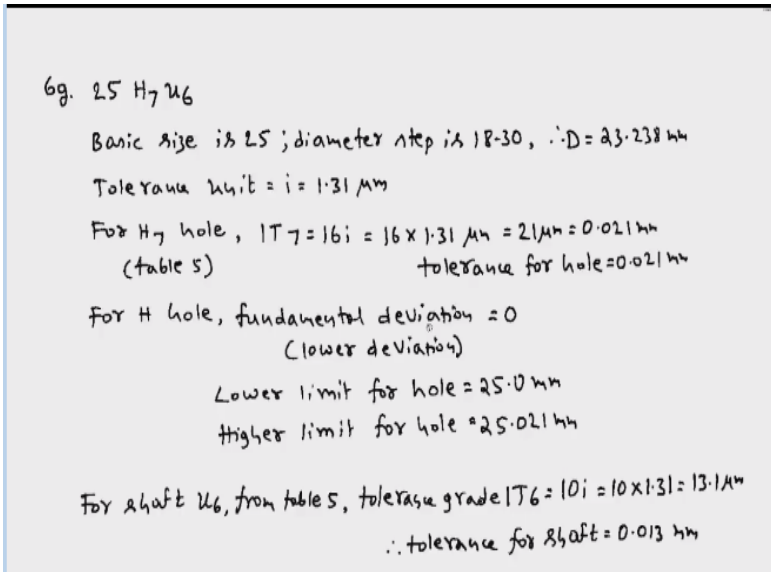

We will move to the next problem 25 H7 u6. So, the basic size is 25 millimetre and it is in the step of 18 to 30. So, mean diameter is 23.238 millimetre and the tolerance unit can be calculated and it is equal to 1.31 micrometer for H7 hole the tolerance grade is IT7, this is equal to 16 times i, this is equal to 21 micrometer. So, tolerance value for hole is 0.021 millimetre and for H hole fundamental deviation is equal to 0.

So, the lower limit for hole is equal to basic size that is 25 millimetre and higher limit for hole is equal to basic size + tolerance that is 25.021 millimetre. Now moving to the shaft u6 from table number 5 the tolerance grade suggested is IT6. So, IT6 is equal to 10 times i, so tolerance value for the shaft is 0.013 millimetre.

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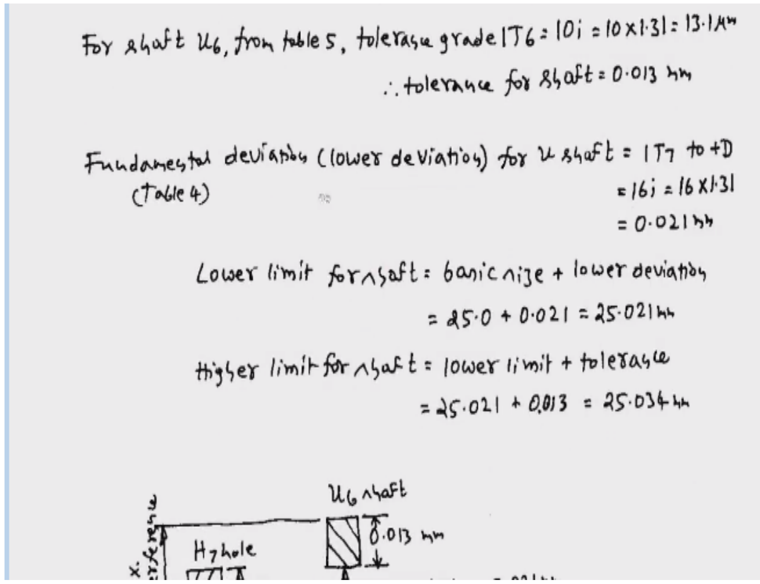

Now fundamental deviation for the shaft can u shaft can be calculated by using this relationship which is available in table number 4. So, the fundamental deviation varies from IT7 to +D, so here I am taking only IT7 only. So, this is nothing but 16 times i, is equal to 0.021 millimetre.

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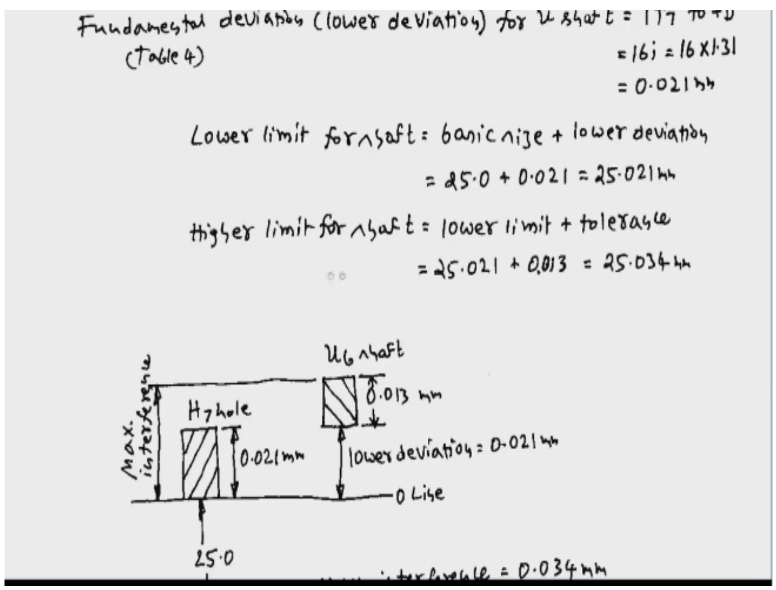

So, now we can find limits for the shaft lower limit for the shaft is equal to basic size of the shaft that is 25 millimetre and then we have to add lower deviation that is 0.021 millimetre. Then we get lower limit of the shaft as 25.021 millimetre. Now higher limit for the shaft is equal to lower limit + tolerance value that is 25.021 millimetre + 0.013 millimetre then we get higher limit of shaft is equal to 25.034 millimetre.

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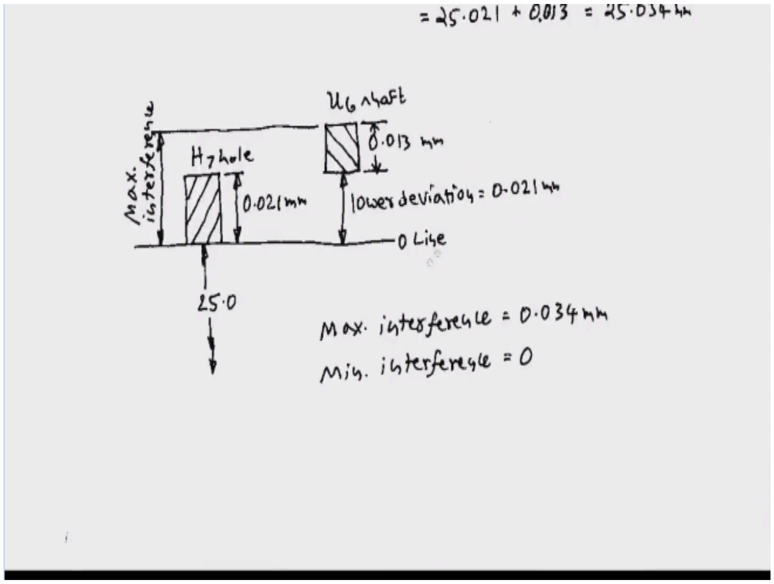

Now all these values are indicated here, this is the basic size 25 millimetre 0 line and H7 hole with the tolerance value of 0.021 millimetre and the lower deviation for u shaft is 0.021 millimetre and tolerance value for u6 shaft is 0.013 millimetre. Now we can see here the lower limit of the shaft is equal to the upper limit of the hole. So, there is the minimum interference is 0.

There is no clearance and no interference and maximum difference we can calculate by adding lower deviation with the tolerance value for the shaft then we get maximum interference of 0.034 millimetre. Now in all these problems we discussed about how to find the tolerance value then how to find the fundamental deviation and then how to calculate the tolerance value for both shaft and hole.

And how to find the limits for shaft and hole and then how to calculate the maximum interference or maximum clearance whatever it is. Now we have taken the examples of different basic sizes like 25mm, 50mm, 60mm. And then we have considered the basic hole of H with different IT grades like IT7 and IT8 and also we have taken different shafts m shaft, D shaft, p shaft, s shaft, u shaft with different tolerance grades of 7, 6, 9 etc.

So, we have covered all the types of the clearance fits, all the types of fits like clearance fit, transition fit and interference fit. In this lecture we discussed about the positional tolerances and what is their effect on pattern of holes etc., and then we also saw some numerical problems to understand different fits and met that, thank you.