Metrology

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Module-3
Lecture-3
Numerical problems on fit and tolerances

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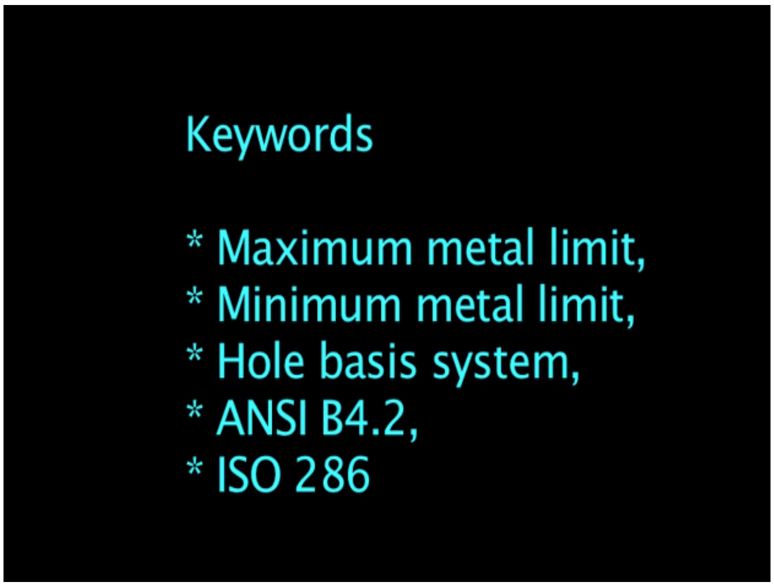

Hi, welcome you all for module 3 and lecture 3, now in this lecture we will solve some numerical problems on fit and tolerance. So, that we can understand the concepts more clearly. Now let us start the problem number 1.

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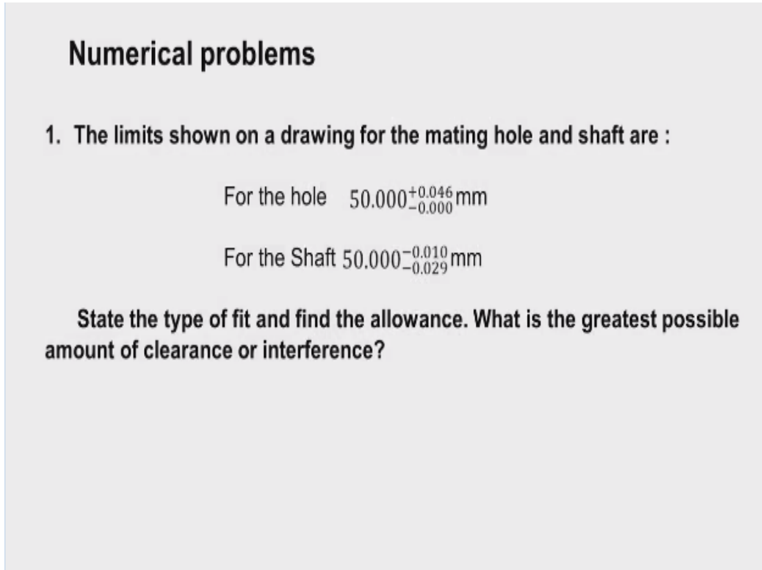

The limits shown on a drawing for the mating hole and shaft are given here for the hole basic size is 50 and the limits are shown here. And for the shaft again the basic size is 50 and these are the limits, upper limit and lower limit. Now we have to find the allowance and then we have to state, what is the type of fit, we have to calculate what is the greatest possible amount of clearance or interference over to black board.

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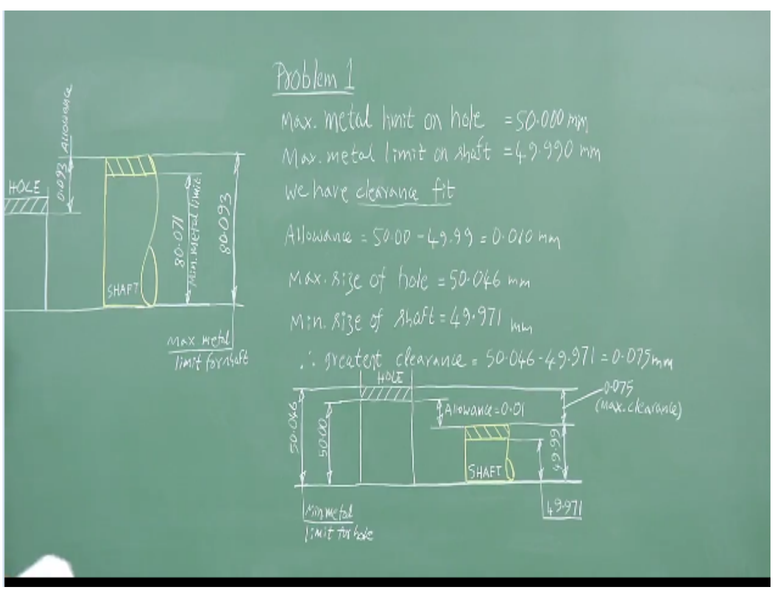

In the problem the basic size of the shaft are given, the basic size is 50 millimetre and limits for to upper limit and lower limit for hole and shaft also mention. So, the maximum metal limit on the hole is 50 millimetre. So, this is the maximum metal limit for the hole and the minimum metal limit for the hole is 50.046 millimetre. So, these are corresponds to the maximum metal limit and this is the minimum metal limit.

So, and then we have shaft weighing the basic size is 50 again the limits are given in the problem. The minimum size of the shaft is 49.971 millimetre. And the maximum size of the shaft is 49.99 millimetre and this is the tolerance zone for shaft. And this is the tolerance zone for the hole. Now since the minimum size of the hole is greater than the maximum size of the shaft we have a clearance fit.

And now the allowance is the difference between the maximum metal limits of hole and shaft. So, the maximum metal limit for the hole is 50 millimetre and maximum metal limit for the shaft is 49.99 millimetre. So, the difference algebraic difference gives the allowance, so that is 0.01 millimetre. Now the amount of clearance is the difference between the maximum size of hole that is 50.046 millimetre and minimum size of shaft that is 49.971 millimetre. So, this difference gives the greatest amount of clearance that is 0.075 millimetre.

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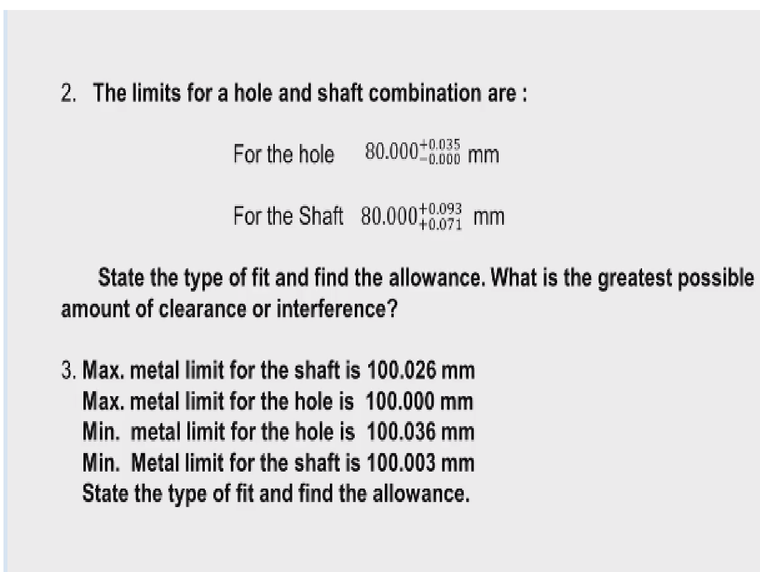

Now we will move to problem number 2 wherein the limits of hole and shaft combinations are given. The basic size of hole and shaft is 80 millimetre and then the limits are hole and shaft also mentioned in the problem. We have to find the type of fit and we have to find the allowance and also we have to determine the greatest possible amount of clearance or interference.

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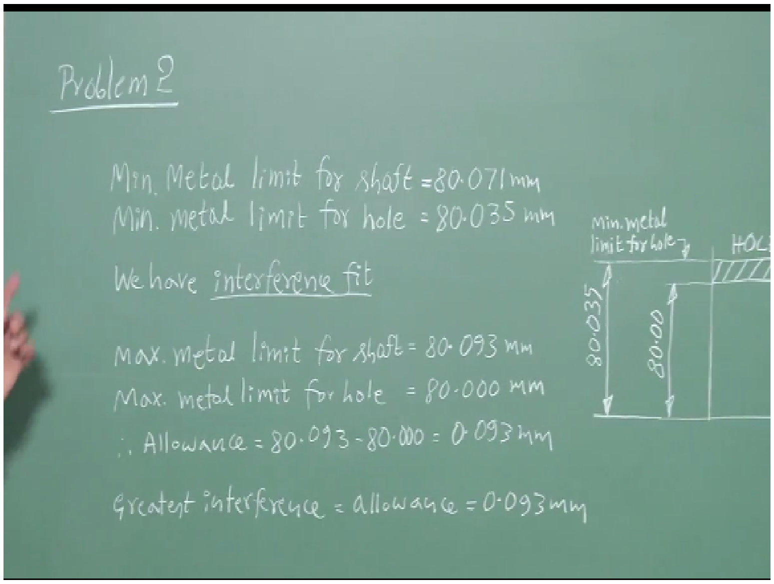

Now from the given problem you can understand that the minimum metal limit for shaft is 80.071 millimetre and minimum metal limit for hole is 80.035 millimetre. So, that is shown in the picture here, this is the hole.

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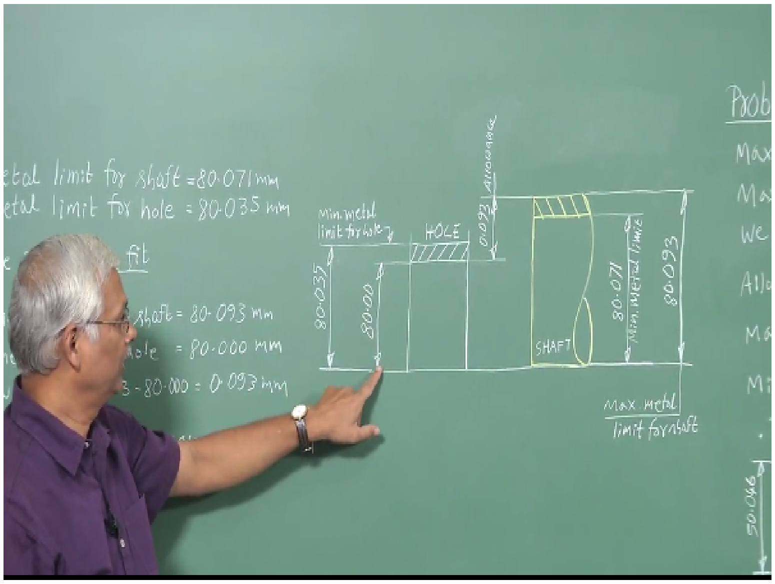

The minimum size of the hole is 80 millimetre and maximum size of the hole is 80.035 millimetre and this corresponds to the minimum metal limit for hole. And for shaft here and we have shaft and the minimum size of the shaft corresponding to minimum metal limit is 80.071 millimetre. And then the maximum size of the shaft is 80.093 millimetre corresponding to the maximum metal limit for shaft.

Now since the minimum size of the shaft is greater than the maximum size of the hole they have interference fit. Now maximum metal limit for shaft is equal to 80.093 millimetre and then maximum metal limit for hole is 80 millimetre corresponding to this. And then the difference gives the allowance difference between the maximum metal limit for shaft and maximum metal limit for hole gives us the allowance, that is 80.093 millimetre–80 millimetre=0.093 millimetre.

And then greatest interference is equal to allowance is equal to 0.093 millimetre. Now we will move to problem number 3 wherein the conditions given are maximum metal limit for the shaft is 100.026 millimetre, maximum metal limit for the hole is 100.0 millimetre, minimum metal limit for the hole is 100.036 millimetre and minimum metal limit for the shaft is 100.003 millimetre. We are required to find the type of fit and we have to find the allowance also, now over to black board.

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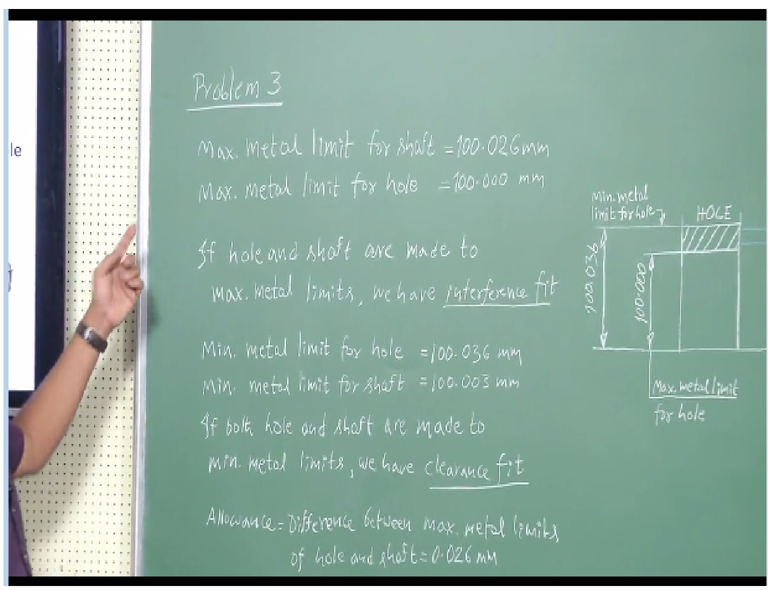

Now these are the given conditions maximum metal limit for shaft is 100.026mm, maximum metal limit for hole is 100 millimetre. So, if hole and shaft are made to maximum metal limits, then they have interference fit.

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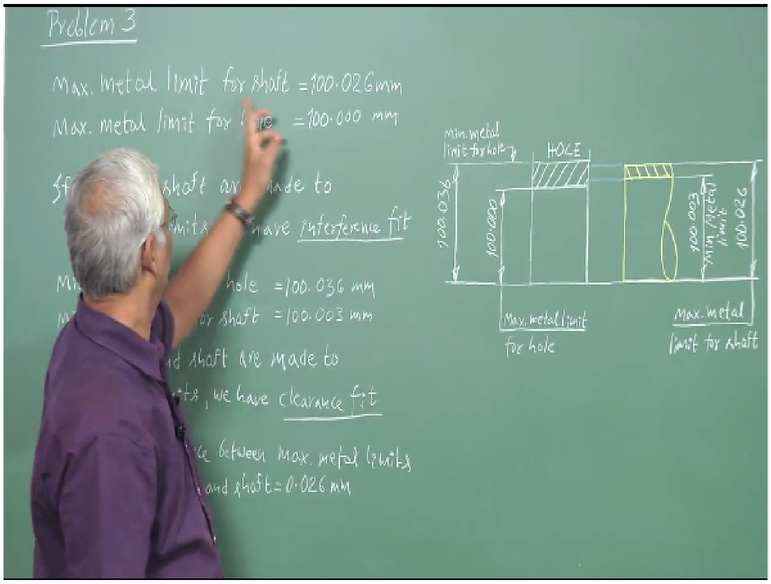

Now from this picture you can understand that the maximum metal limit for shaft is 100.026 and minimum metal limit for shaft is 100.003 millimetre and this is the hole. The maximum metal limit for hole is 100 millimetre and minimum metal limit for hole is 100.036 millimetre. This is the tolerance zone for hole and this is the tolerance zone for shaft. Now if both of the hole and shaft are made to maximum metal limits, then they will be having interference fit.

That is the if the hole is made to maximum metal limit, it will be 100 millimetre and the shaft is made to maximum metal limit it will be 100.026 millimetre. That means shaft will be greater than the hole size, so we will be having interference fit. And now minimum metal limit for hole is 100.036 millimetre, minimum metal limit for shaft is 100.003 millimetre. If both hole and shaft are made to minimum metal limits then they will be having a clearance fit.

That means minimum metal limit for shaft is 100.003 millimetre and minimum metal limit for hole is 100.036 millimetre. That means hole size will be bigger than the shaft size, so we will be having clearance fit. And then allowance is the difference between the maximum metal limits of hole and shaft, that is equal to 0.026 millimetre.

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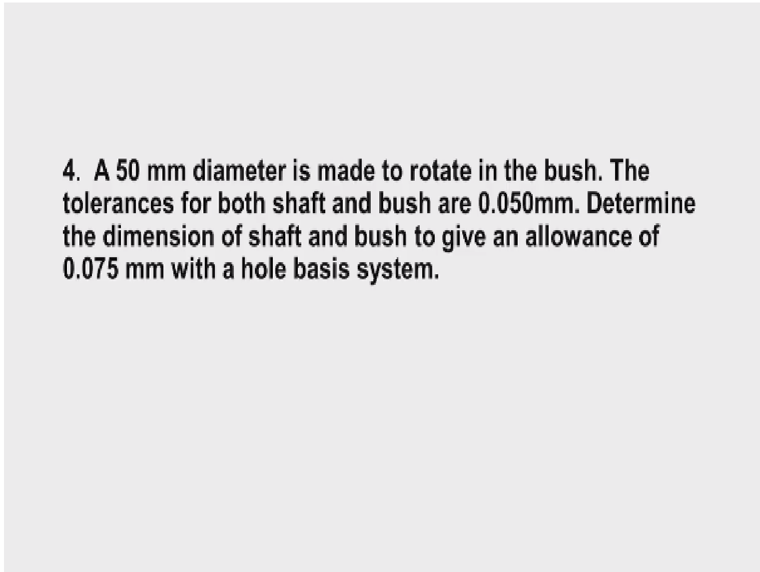

Now we will move to problem number 4. A 50 millimetre shaft is made to rotate in a bush, the tolerance is for both shaft and bush are 0.050 millimetre. Determine the dimension of the shaft and bush to give an allowance of 0.075 millimetre with a hole basis system, Over to board.

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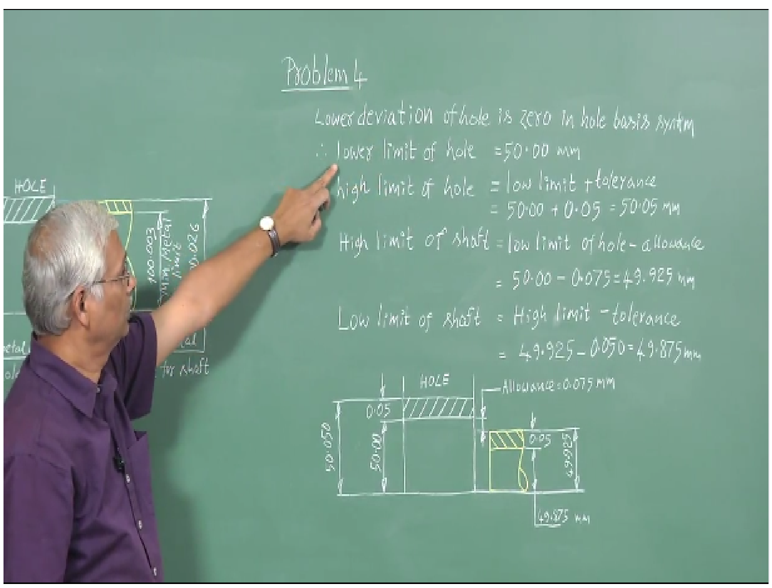

Now in the case of hole basis system lower deviation of hole will be 0. So, the lower limit of hole is equal to 50millimetre which is given in the problem. So, higher limit of hole is equal to lower limit of hole+tolerance. That is lower limit of hole is 50 millimetre to get the higher limit we have to add the tolerance then we get 50.050 millimetre. Now high limit of shaft that is this value, high limit of shaft is equal to low limit of hole–allowance.

Lower limit of hole is 50 millimetre and allowance is given in the problem that is 0.075 millimetre. So, we get higher limit of shaft is equal to 49.925 millimetre, so higher limit of shaft is 49.925 millimetre. Now in order to get the lower limit of shaft we have to subtract tolerance from the higher limit of shaft that is we have to subtract this tolerance of 0.005 millimetre from the high limit of shaft that is 49.925. Then we get the lower limit of shaft is equal to 49.875 millimetre.

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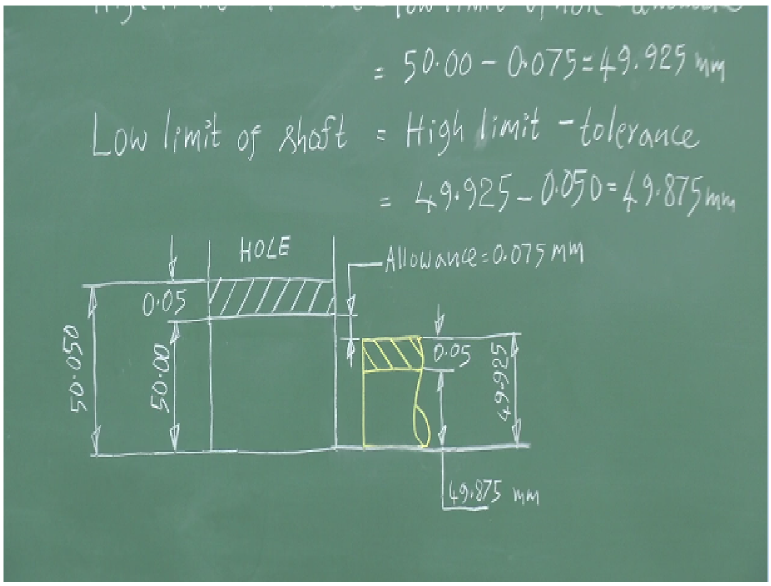

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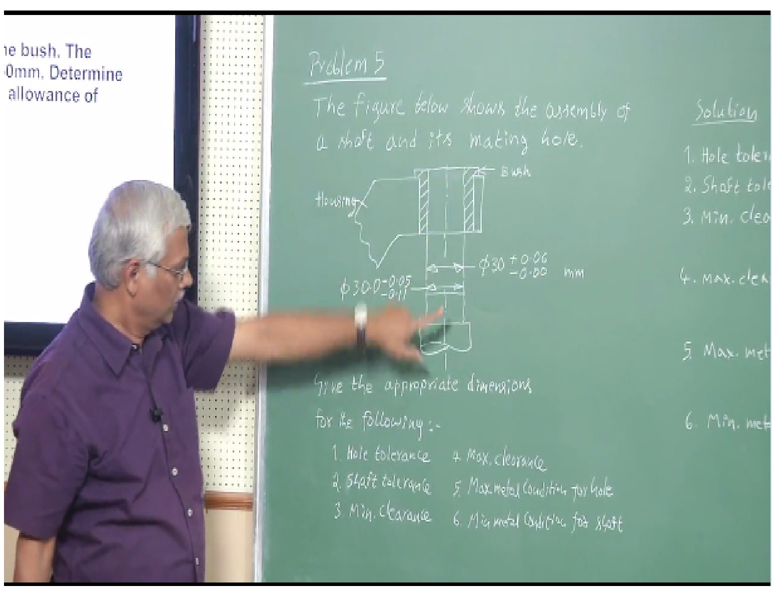

The problem is the figure below shows the assembly of a shaft and it is mating hole, this is the shaft, this is having a size of basic size of 30 millimetre and the limits are given. The minimum size of the shaft is 29.89 millimetre and the maximum size of the shaft is 29.95 millimetre and this is the bush fitted in the housing and the size of the hole are given here the basic size is 30 millimetre and the minimum size of the hole is 30 millimetre and maximum size of the hole is 30.06 millimetre.

Now we have to give the appropriate dimensions for the following that is hole tolerance we have to calculate, shaft tolerance we have to calculate and then we have to calculate minimum clearance, maximum clearance, maximum metal condition for hole and minimum metal condition for shaft.

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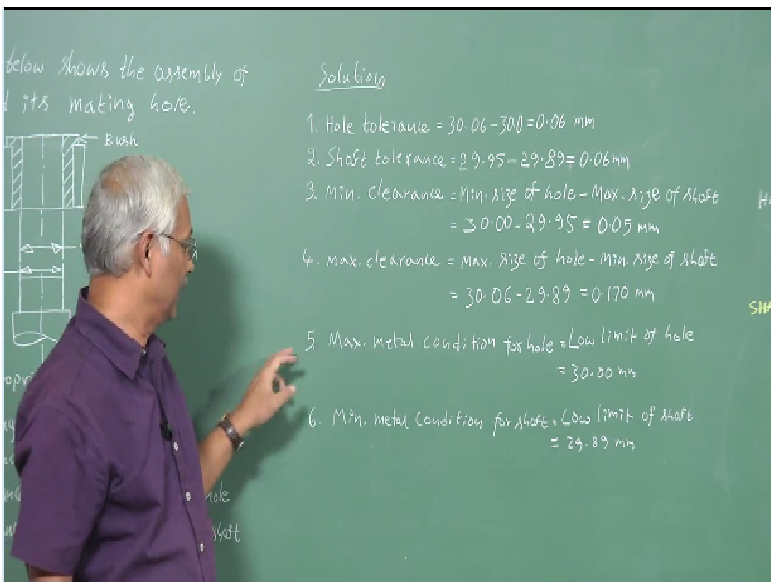

Now we have the solution here hole tolerance is the difference between these 2, that is 30.06 millimetre – 30 millimetre will give us the hole tolerance of 0.06 millimetre. Similarly to find the shaft tolerance we have to find the difference between the maximum size of the shaft and minimum size of the shaft. That is 29.95-29.89 will give us the shaft tolerance of 0.06millimetre.

And then we have to find the minimum clearance between the shaft and the hole. So, this is equal to minimum size of the hole that is equal to 30millimetre and–maximum size of the shaft that is equal to 29.95 millimetre. The difference gives us 0.05millimetre. And then maximum clearance is equal to maximum size of the hole–minimum size of the shaft. So, maximum size of the hole is 30.06 millimetre and minimum size of the shaft is 29.89 millimetre, the difference is 0.170 millimetre is the maximum clearance we get.

And then maximum metal condition for hole is equal to lower limit of the hole that is 30 millimetre. And then minimum metal condition for the shaft is equal to lower limit of the shaft that is equal to 29.89 millimetre. So, all these values are indicated in the picture given here.

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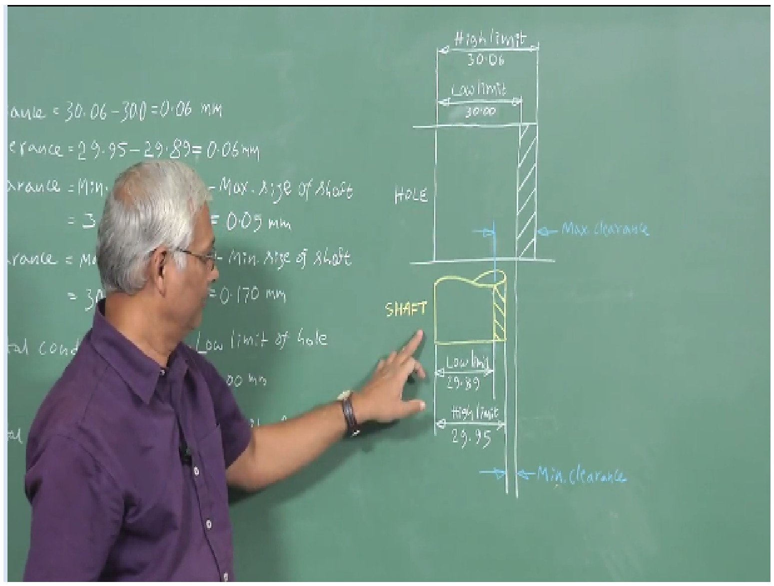

So, this is hole lower of hole is 30 millimetre, upper limit of the hole is 30.06 millimetre. And we have the shaft with lower limit, that is 29.89 millimetre and high limit of shaft is 29.95 millimetre. The difference between the minimum size of shaft and maximum size of hole gives us the maximum clearance and then the difference between the maximum size of the shaft and the minimum size of the hole will give us the minimum clearance.

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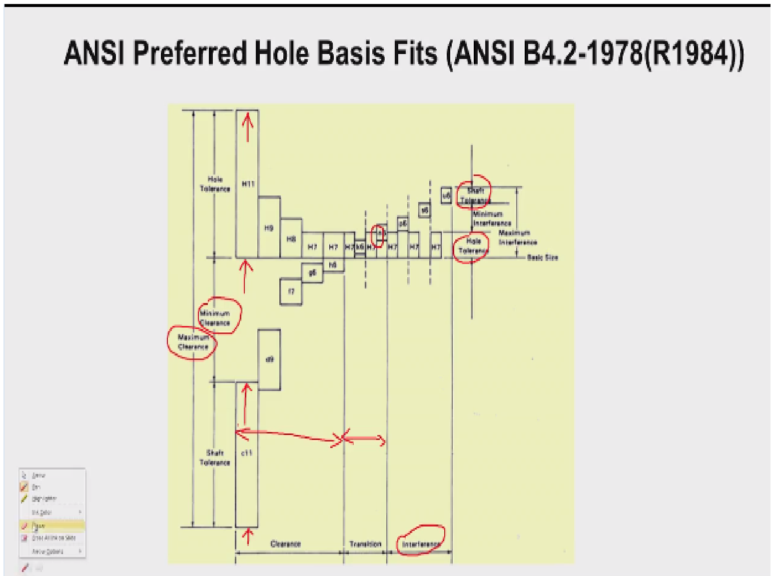

So, here we can see some of the preferred hole basis fits as per American standard B4.2. We can see here we have the basic hole that is H11, H9, H8 like this. We have taken the basic hole wherein the deviation is 0, that means the lower limit of the hole will be equal to the basic size. Similarly we have the preferred shafts here C11 and then D9, F7, G6, H6 you can see here again we have the basic shaft here, so wherein the deviation is 0.

If you take H11, C11 combination we can see that there is a large clearance here. So, this is the minimum size of the hole, so this is the hole and this is the minimum size of the hole. And this gives us the maximum size of the hole and similarly this gives us the minimum I am sorry. So, this will give us the maximum size of the shaft and this gives the minimum size of the shaft.

So, now the difference between the minimum size of the hole and maximum size of the shaft will give us the minimum clearance. And similarly the difference between the maximum hole and the minimum shaft will give us the maximum clearance here. Now for H7, capital H7 and lower case h6 we can see that the clearance is 0 and from c11, d9, f sign in these combinations.

These combinations will give us the clearance fits similarly these combinations of hole and shaft will give us for example H7 and 6 will give us transition fit. You can see here there is some overlap here, the tolerance zones of hole and shaft they are overlapping. So, we get the transition fits and then we have the combination H7 p6, H7 s6, H7 u6 the all these combinations will give us the interference fits.

So, again here the this is the maximum size of the hole and minimum size of the hole, and this is the hole tolerance, and similarly we have the shaft tolerance. So, this difference will give us minimum interference and this difference that is maximum size of the shaft and then minimum size of the hole. So, this distance will give us the maximum interference.

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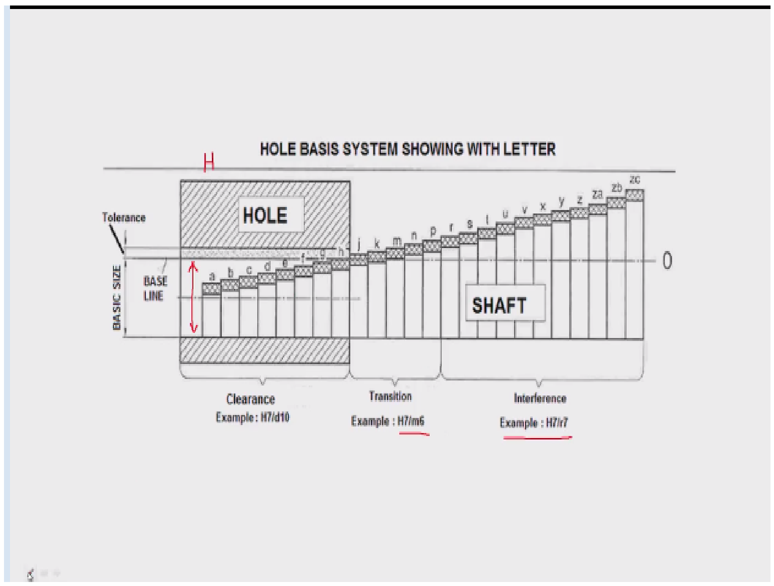

And here hole basis system shown with letters that means the H hole is considered here, the basic hole is considered here where deviation is 0. That means the basic size of the lower limit of the hole. So, this is the lower limit of the hole, so it is coinciding with the basic size. So, that is why this is the basic hole with letter 'H' and this is the tolerance for the hole and this line indicates the 0 line.

Now we can see that we have varying the shaft sizes we have a, shaft b, shaft c, shaft like this, so up to h we can have clearance fit. For one example is given here h7 d10, so this is h7 and then d10 this will give us the clearance fit. And then the other combinations like h7, j, k, m, n, p up to this we can have the transition fit 1 example is given here H7 m6, so this will provide us the transition fit.

Similarly this combinations r, s, t, u, v, x, y, z, za, zb, zc these shafts with H hole will give us interference fit. So, depending upon the application we can select appropriate fit.

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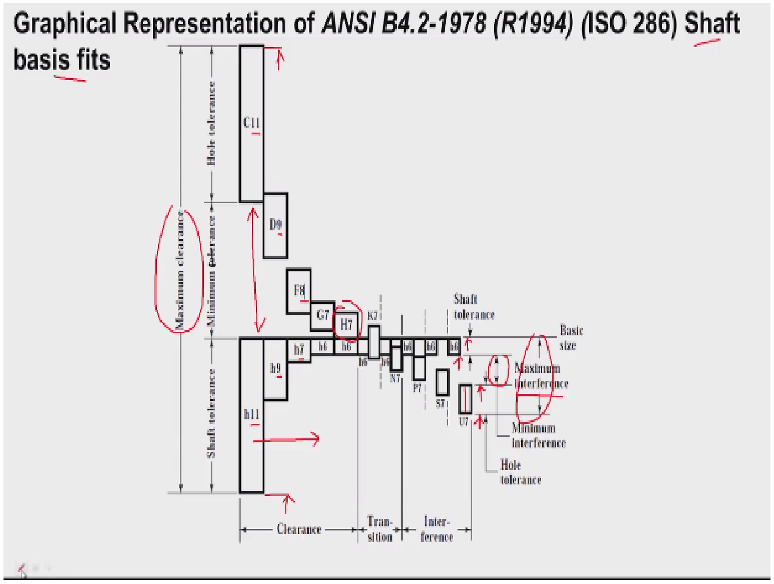

Now that is the graphical representation of the shaft basis system as per ANSI B4.2. You can see here the shafts are basic shafts, that means the deviation in this case is 0 that means upper size of the shaft is coinciding with the basic size hence the deviation is 0. Now we have various shafts h11, h9 and the different grades of tolerance that is different IT grades are as the number increases as the IT grade number increases we can see that the tolerance value will increase.

As the number reduces the tolerance band is reducing that means as then move as the decrease the IT grades from h11, 9, 7, 6 like this. We have to select the precision machine tools to control the sizes properly to provide the tight tolerances. So, when the tolerance grade increases like IT 8, 9, 10 like that, the tolerance gets widen. So, that we can select not so precision machine tools and the cost of production will decrease.

Again the selection of fit and tolerance it depends upon the application that is needed. Similarly we have we are varying the shaft sizes here C, D, F, G, H. Now you can see here this is the basic hole H, wherein the deviation is 0 that means the lower size of the hole is coinciding with the basic size. And this level indicates the IT grade IT 11, IT9, IT8, as the number decreases tolerance band reduces, as the number increases tolerance band increases.

So, for this particular IT11, this is C11 this is the hole tolerance and for this h11 this is the shaft tolerance, and you can see there is a wide gap between the C and h shaft and C hole and this is the minimum clearance what we can get. And this corresponds to the maximum size of the hole and this corresponds to the minimum size of the shaft. So, this will give us the maximum clearance.

And as we move towards right side you can see here the hole sizes are lesser than the shaft size, so we are getting interference. For example we have this hole u7 and this is the maximum size of the hole and this is the minimum size of the hole, and this is the tolerance hole tolerance and this is the h6 is the shaft wherein we have the shaft tolerance, this is the shaft tolerance and this is the maximum size of the shaft and this corresponds to the minimum size of the shaft.

And now the minimum size of the shaft is greater than the maximum size of the hole hence we are getting the interference fit. Now this is the minimum amount of interference and this gives us the maximum amount of interference. And again depending upon, what type of holes and shaft combination we get, we can get the clearance fit, transition fit and interference fit.

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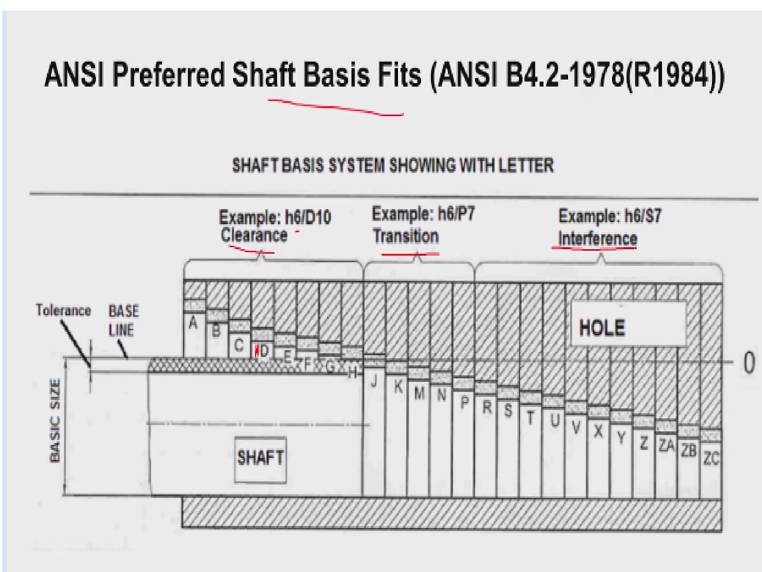

Now this is ANSI preferred shaft basis fits as per ANSI B4.2. Now we have taken the basic shaft and **we** the shaft size is fixed and this is the tolerance provided for the shaft. Now this is the basic line 0 line, it is corresponding to the basic size of the shaft. So, the deviation is 0 hence this is the basic shaft and then we have the shaft basis fits. Now we are varying the holes, hole sizes we are varying this is A hole, B hole with the tolerance zone.

Now from A to H we get the clearance fit, so h6/D10. So, this shaft is H shaft and 6 is the IT grade h6/D10 will give us the clearance fit. And from j2 P with H shaft will give us the transition fit and then from R, R hole to zc with the H shaft we can get interference fit.

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Table 1:Description of Preferred Fits

	ISO SYMBOL		DESCRIPTION	
	Hole Basis	Shaft Basis		
Clearance Fits	H11/c11	C11/h11	*Loose running* fit for wide commercial tolerances or allowances on external members.	↑ More Clearance
	H9/d9	D9/h9	*Free running* fit not for use where accuracy is essential, but good for large temperature variations, high running speeds, or heavy journal pressures.	
	H8/f7	F8/h7	*Close Running* fit for running on accurate machines and for accurate moderate speeds and journal pressures.	
	H7/g6	G7/h6	*Sliding fit* not intended to run freely, but to move and turn freely and locate accurately.	
	H7/h6	H7/h6	*Locational clearance* fit provides snug fit for locating stationary parts; but can be freely assembled and disassembled.	
Transition Fits	H7/k6	K7/h6	*Locational transition* fit for accurate location, a compromise between clearance and interferance.	
	H7/n6	N7/h6	*Locational transition* fit for more accurate location where greater interferance is permissible.	
Interference Fits	H7/p6[a]	P7/h6	*Locational interference* fit for parts requiring rigidity and alignment with prime accuracy of location but without special bore pressure requirements.	More Interferance ↓
	H7/s6	S7/h6	*Medium drive* fit for ordinary steel parts or shrink fits on light sections, the tightest fit usable with cast iron.	
	H7/u6	U7/h6	*Force* fit suitable for parts which can be highly stressed or for shrink fits where the heavy pressing forces required are impractical.	

[a]Transition fit for basic sizes in range from 0 through 3 mm.

Now this is description of preferred fits, summary of preferred fits, clearance fit, transition fit and interference fit and depending upon what type of fit required whether we require loose running fit or free running fit or close running fit, sliding fit, locational clearance fit. So, depending upon the type of fit whether we want clearance fit or transition fit or interference fit we can select the appropriate combinations and these combinations are the preferred fits.

And these combinations H11/c11 they give more clearance and H7/u6, U7/h6 they give the more interference.

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Table 2: Preferred hole basis metric clearance fits - ANSI B4.2-1978 (R1994)

Basic Size[a]		Loose Running			Free Running			Close Running			Sliding			Locational Clearance		
		Hole H11	Shaft C11	Fit[b]	Hole H9	Shaft d9	Fit[b]	Hole H8	Shaft f7	Fit[b]	Hole H7	Shaft g6	Fit[b]	Hole H7	Shaft h6	Fit[b]
1	Max	1.060	0.940	0.180	1.025	0.980	0.070	1.014	0.994	0.030	1.010	0.998	0.018	1.010	1.000	0.016
	Min	1.000	0.880	0.060	1.000	0.955	0.020	1.000	0.984	0.006	1.000	0.992	0.002	1.000	0.994	0.000
1.2	Max	1.260	1.140	0.180	1.225	1.180	0.070	1.214	1.194	0.030	1.210	1.198	0.018	1.210	1.200	0.016
	Min	1.200	1.080	0.060	1.200	1.155	0.020	1.200	1.184	0.006	1.200	1.192	0.002	1.200	1.194	0.000
1.6	Max	1.660	1.540	0.180	1.625	1.580	0.070	1.614	1.594	0.030	1.610	1.598	0.018	1.610	1.600	0.016
	Min	1.600	1.480	0.060	1.600	1.555	0.020	1.600	1.584	0.006	1.600	1.592	0.002	1.600	1.594	0.000
2	Max	2.060	1.940	0.180	2.025	1.980	0.070	2.014	1.994	0.030	2.010	1.998	0.018	2.010	2.000	0.016
	Min	2.000	1.880	0.060	2.000	1.955	0.020	2.000	1.984	0.006	2.000	1.992	0.002	2.000	1.994	0.000
2.5	Max	2.560	2.440	0.180	2.525	2.480	0.070	2.514	2.494	0.030	2.510	2.498	0.018	2.510	2.500	0.016
	Min	2.500	2.380	0.060	2.500	2.455	0.020	2.500	2.484	0.006	2.500	2.492	0.002	2.500	2.494	0.000
3	Max	3.060	2.940	0.180	3.025	2.980	0.070	3.014	2.994	0.030	3.010	2.998	0.018	3.010	3.000	0.016
	Min	3.000	2.880	0.060	3.000	2.955	0.020	3.000	2.984	0.006	3.000	2.992	0.002	3.000	2.994	0.000
4	Max	4.075	3.930	0.220	4.030	3.970	0.090	4.018	3.990	0.040	4.012	3.996	0.024	4.012	4.000	0.020
	Min	4.000	3.855	0.070	4.000	3.940	0.030	4.000	3.978	0.010	4.000	3.988	0.004	4.000	3.992	0.000
5	Max	5.075	4.930	0.220	5.030	4.970	0.090	5.018	4.990	0.040	5.012	4.996	0.024	5.012	5.000	0.020
	Min	5.000	4.855	0.070	5.000	4.940	0.030	5.000	4.978	0.010	5.000	4.988	0.004	5.000	4.992	0.000
6	Max	6.075	5.930	0.220	6.030	5.970	0.090	6.018	5.990	0.040	6.012	5.996	0.024	6.012	6.000	0.020
	Min	6.000	5.855	0.070	6.000	5.940	0.030	6.000	5.978	0.010	6.000	5.988	0.004	6.000	5.992	0.000
8	Max	8.090	7.920	0.260	8.036	7.960	0.112	8.022	7.987	0.050	8.015	7.995	0.029	8.015	8.000	0.024
	Min	8.000	7.830	0.080	8.000	7.924	0.040	8.000	7.972	0.013	8.000	7.986	0.005	8.000	7.991	0.000
10	Max	10.090	9.920	0.260	10.036	9.960	0.112	10.022	9.987	0.050	10.015	9.995	0.029	10.015	10.000	0.024
	Min	10.000	9.830	0.080	10.000	9.924	0.040	10.000	9.972	0.013	10.000	9.986	0.005	10.000	9.991	0.000
12	Max	12.110	11.905	0.315	12.043	11.950	0.136	12.027	11.984	0.061	12.018	11.994	0.035	12.018	12.000	0.029
	Min	12.000	11.795	0.095	12.000	11.907	0.050	12.000	11.966	0.016	12.000	11.983	0.006	12.000	11.989	0.000
16	Max	16.110	15.905	0.315	16.043	15.950	0.136	16.027	15.984	0.061	16.018	15.994	0.035	16.018	16.000	0.029
	Min	16.000	15.795	0.095	16.000	15.907	0.050	16.000	15.966	0.016	16.000	15.983	0.006	16.000	15.989	0.000
20	Max	20.130	19.890	0.370	20.052	19.935	0.169	20.033	19.980	0.074	20.021	19.993	0.041	20.021	20.000	0.034
	Min	20.000	19.760	0.110	20.000	19.883	0.065	20.000	19.959	0.020	20.000	19.980	0.007	20.000	19.987	0.000
25	Max	25.130	24.890	0.370	25.052	24.935	0.169	25.033	24.980	0.074	25.021	24.993	0.041	25.021	25.000	0.034
	Min	25.000	24.760	0.110	25.000	24.883	0.065	25.000	24.959	0.020	25.000	24.980	0.007	25.000	24.987	0.000

Now this table shows preferred hole basis metric clearance fits as per ANSI B4.2. Now we can this is the readymade table depending upon the type of fit required we can select the appropriate fits the basic sizes are given here 1, 1.2, 1.6, 2 like this up to 500 millimetre.

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Table 3: Preferred hole basis metric clearance fits - ANSI B4.2-1978 (R1994)(Continued)

Basic Size[a]		Loose Running			Free Running			Close Running			Sliding			Locational Clearance		
		Hole H11	Shaft C11	Fit[b]	Hole H9	Shaft d9	Fit[b]	Hole H8	Shaft f7	Fit[b]	Hole H7	Shaft g6	Fit[b]	Hole H7	Shaft h6	Fit[b]
30	Max	30.130	29.890	0.370	30.052	29.935	0.169	30.033	29.980	0.074	30.021	29.993	0.041	30.021	30.000	0.034
	Min	30.000	29.760	0.110	30.000	29.883	0.065	30.000	29.959	0.020	30.000	29.980	0.007	30.000	29.987	0.000
40	Max	40.160	39.880	0.440	40.062	39.920	0.204	40.039	39.975	0.089	40.025	39.991	0.050	40.025	40.000	0.041
	Min	40.000	39.720	0.120	40.000	39.858	0.080	40.000	39.950	0.025	40.000	39.975	0.009	40.000	39.984	0.000
50	Max	50.160	49.870	0.450	50.062	49.920	0.204	50.039	49.975	0.089	50.025	49.991	0.050	50.025	50.000	0.041
	Min	50.000	49.710	0.130	50.000	49.858	0.080	50.000	49.950	0.025	50.000	49.975	0.009	50.000	49.984	0.000
60	Max	60.190	59.860	0.520	60.074	59.900	0.248	60.046	59.970	0.106	60.030	59.990	0.059	60.030	60.000	0.049
	Min	60.000	59.670	0.140	60.000	59.826	0.100	60.000	59.940	0.030	60.000	59.971	0.010	60.000	59.981	0.000
80	Max	80.190	79.850	0.530	80.074	79.900	0.248	80.046	79.970	0.106	80.030	79.990	0.059	80.030	80.000	0.049
	Min	80.000	79.660	0.150	80.000	79.826	0.100	80.000	79.940	0.030	80.000	79.971	0.010	80.000	79.981	0.000
100	Max	100.220	99.830	0.610	100.087	99.880	0.294	100.054	99.964	0.125	100.035	99.988	0.069	100.035	100.000	0.057
	Min	100.000	99.610	0.170	100.000	99.793	0.120	100.000	99.929	0.036	100.000	99.966	0.012	100.000	99.978	0.000
120	Max	120.220	119.820	0.620	120.087	119.880	0.294	120.054	119.964	0.125	120.035	119.988	0.069	120.035	120.000	0.057
	Min	120.000	119.600	0.180	120.000	119.793	0.120	120.000	119.929	0.036	120.000	119.966	0.012	120.000	119.978	0.000
160	Max	160.250	159.790	0.710	160.100	159.855	0.345	160.063	159.957	0.146	160.040	159.986	0.079	160.040	160.000	0.065
	Min	160.000	159.540	0.210	160.000	159.755	0.145	160.000	159.917	0.043	160.000	159.961	0.014	160.000	159.975	0.000
200	Max	200.290	199.760	0.820	200.115	199.830	0.400	200.072	199.950	0.168	200.046	199.985	0.090	200.046	200.000	0.075
	Min	200.000	199.470	0.240	200.000	199.715	0.170	200.000	199.904	0.050	200.000	199.956	0.015	200.000	199.971	0.000
250	Max	250.290	249.720	0.860	250.115	249.830	0.400	250.072	249.950	0.168	250.046	249.985	0.090	250.046	250.000	0.075
	Min	250.000	249.430	0.280	250.000	249.715	0.170	250.000	249.904	0.050	250.000	249.956	0.015	250.000	249.971	0.000
300	Max	300.320	299.670	0.970	300.130	299.810	0.450	300.081	299.944	0.189	300.052	299.983	0.101	300.052	300.000	0.084
	Min	300.000	299.350	0.330	300.000	299.680	0.190	300.000	299.892	0.056	300.000	299.951	0.017	300.000	299.968	0.000
400	Max	400.360	399.600	1.120	400.140	399.790	0.490	400.089	399.938	0.208	400.057	399.982	0.111	400.057	400.000	0.093
	Min	400.000	399.240	0.400	400.000	399.650	0.210	400.000	399.881	0.062	400.000	399.946	0.018	400.000	399.964	0.000
500	Max	500.400	499.520	1.280	500.155	499.770	0.540	500.097	499.932	0.228	500.063	499.980	0.123	500.063	500.000	0.103
	Min	500.000	499.120	0.480	500.000	499.615	0.230	500.000	499.869	0.068	500.000	499.940	0.020	500.000	499.960	0.000

a -The sizes shown are first choice basic sizes; b – All fits shown have clearance; All dimensions in mm

The basic sizes are given with the maximum value of the maximum value and minimum for both shaft and hole they are mentioned here. And we have loose running if you want loose running fit what is the combination we should select, if you want free running fit what combination we can select all those things we can get here. And for example if the basic size is 20 and if we select H11 hole, then the hole minimum size will be 20 since it is H hole the deviation is 0.

So, the minimum size of the hole will be equal to the basic size, so minimum size is 20 millimetre and maximum size will be equal to 20.130. So, the clearance hole tolerance will be 130 microns. Similarly depending upon the type of fit required we can select the locational clearance, sliding clearance etc., etc., and one more thing we can understand is as the number is reducing H11, H9, H8, H7 the amount of tolerance also reduces.

For example here for H11, 20 basic size the tolerance for the hole is 130 microns, whereas for the basic size if you select H9 hole that is IT grade IT9 tolerance grade. You can see the tolerance is reduced to 52 microns form 130 micro metres. And then if you go to H8 hole we can see the tolerance becomes 33 micro metres and H7 hole with the same basic size of 20 millimetre we have the tolerance of 21 microns.

So, as the IT grade number reduces the tolerance becomes tight. Now this table gives the basic sizes from 30 millimetre to 500 millimetres.

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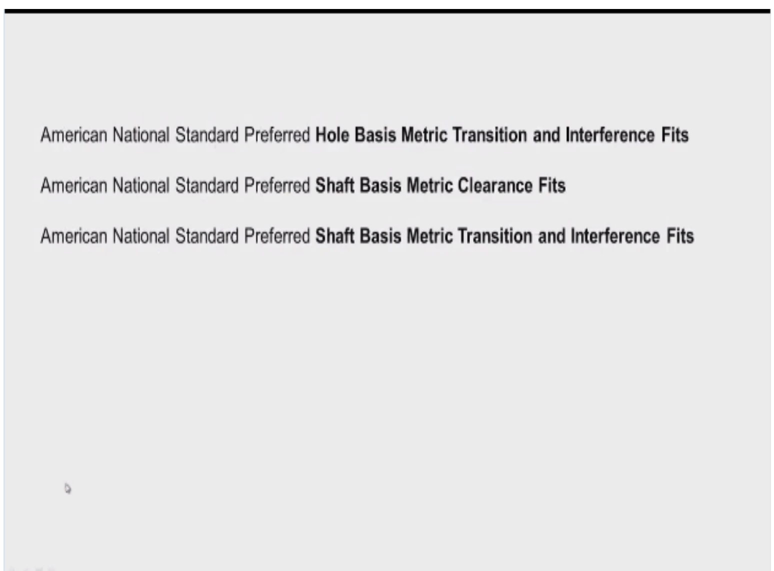

Similarly we can readymade tables in the ANSI standard for hole basis metric transition and interference fits. And then shaft basis metric clearance fits, shaft basis metric transition and interference fits. So, one can get the readymade tables from the standard and can use it.

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Table 4:FORMULAE FOR FUNDAMENTAL DEVIATION FOR SHAFTS SIZES UP TO 500 mm

UPPER DEVIATION (es)		LOWER DEVIATION (ei)	
Shaft Designation	In Microns (for D in mm)	Shaft Designation	In microns (for D in mm)
a	= -(265 + 1.32D) for D ≤ 120 ;and = – 3.52D for D > 120	j5 to j8	No formula
		js	ITx1/2
		k4 to k7	=+ 0.6x $^3\sqrt{D}$
b	= – (140 + 0.852D); for D <160 ;And = – 1.82D for D > 160	k for Grade ≤3 and ≥4	=0
		m	= + (IT7-IT6)
c	= – 52$D^{0.2}$ for D ≤ 40 = -(95 + 0.82) for D> 40	n	= + 5$D^{0.34}$
		p	= + IT7 + 0 to 5
cd	G.M. of values for c and d	r	= geometric mean of values for p and s
d	= – 16$D^{0.44}$	s	= IT8 + 1 to 4; for D ≤50 = + IT7 to + 0.4D; for D > 50
e	= -11$D^{0.41}$		
ef	G.M. of values for e and f		
f	= -5.5$D^{0.41}$	t	= + IT7 + 0.63D
fg	G.M. of values for f and g	u	= + IT7 to + D
g	= -2.5$D^{0.34}$	v	= + IT1 + 1.2525D
h	= 0	x	= + IT7 + 1.62D
		y	= + IT7 + 2D
		z	= + IT7 + 2.52D
		za	= IT8 + 3 + 3.152D
		zb	= + IT9 + 4D
		zc	= + IT10 + 4D

Now this is a table 4 it gives the formulae for fundamental deviation for shafts, shaft size is up to 500 millimetre. So, depending upon shaft designation whether we are using A shaft, B shaft, C shaft etc., etc., what is the upper deviation and what is the lower deviation, so that we can find in micro meters. For example if you select the shaft d the upper deviation will be equal to – 16 times D power of 0.44 micrometre where D is in millimetre. So, like this using this table one can find the formulae for the fundamental deviation.

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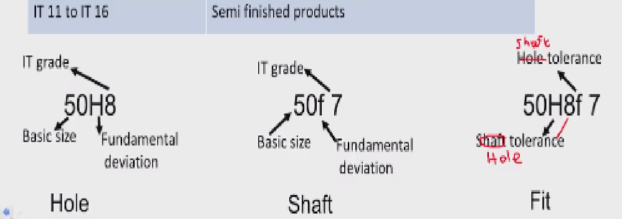
Table 5: Grades of Tolerance (IS:919)

Tolerance Grades	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16
Values	7i	10i	16i	25i	40i	64i	100i	160i	250i	400i	640i	1000i

Table 6: 18 grades of tolerances as per IS: 919

IT Grade	Field of use
IT 01, IT 0, IT 1 to IT 6	For limit gauges and measuring instruments
IT 5 to IT 12	For precision and general engineering fits
IT 11 to IT 16	Semi finished products



Now this table shows the various grades of tolerances used as per IS:919 standard. So, these are the tolerance grade IT5, IT6 of to IT16 and the second row indicates the values of the tolerance values in terms of tolerance unit international tolerance unit I. Now this table gives us 18 grades of tolerances as per IS: 919 . Now also this table gives the field of use of these grades.

For example IT 01, IT 0, IT 1 up to IT 6 these grades for used for limit gauges and measuring instruments wherein very very tight tolerances are specified. And IT 5 to IT 12 they are used for precision and general engineering fits like the bush bearing and then for fitting the bearings in the housings for the fitting the pulleys on to the shaft etc., etc., and IT 11 to IT 16 they are used for semi finished products.

And how do we designate the holes and shafts and the combination of hole and shaft is shown here. So, this is the way in which the hole is designated this 50 H8, so here it is first number 50 indicates the basic size of the hole and then H indicates the fundamental this letter indicates the fundamental deviation. For H hole the fundamental deviation is 0 that we have already studied and this number 8 indicates the IT grade.

So, this dictates as what is the tolerance that is allowed on the hole. Similarly for the shaft this 50 indicates the basic size in millimetre and f indicates the fundamental for f hole and 7 indicates the IT grade. So, IT grade 7 using this we can what is the tolerance. And then for the combination of hole and shaft that is for fit this is how we represent the fit. This number indicates the basic size of hole, and shaft this indicates the what type of hole.

This 8 is IT grade for hole and this small f this is for shaft so, 7 indicates the international tolerance grade.

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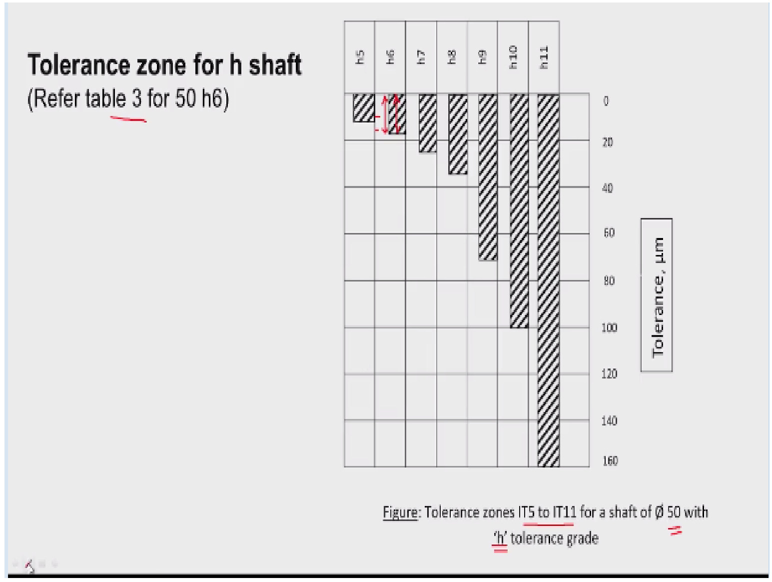

Now so tolerance zone for h shaft, so h shaft is considered here wherein the deviation fundamental deviation is 0 okay. Now for h shaft various tolerance grades are shown here like 5, IT 5, IT 6, IT 7 up to 11, IT 5 to IT 11. Now as the number increases IT number increases the tolerance value will also increase we can see here for IT 5 this is the amount of tolerance for IT 6 this is amount of tolerance IT 11 you can see we have a very large tolerance of 160 microns.

And this tolerance value it also depends upon what is the basic size, so this particular draw picture is drawn for a basic of 50 millimetre with h shaft and with IT grade IT 5 to IT 11. So, this these numbers indicate the tolerance. Now we can see here for h6 this is the amount of tolerance, so from here to this is the 20 micrometre tolerance. So, this will be this is 10 micron and then this is 15 micron.

So, this tolerance value will be approximately 16 or 17 microns, so that we can check with the table 3, h6 50 millimetre basic size 50 h6, 50 is the basic size.

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Table 3: Preferred hole basis metric clearance fits - ANSI B4.2-1978 (R1994)(Continued)

Basic Size[a]		Loose Running			Free Running			Close Running			Sliding			Locational Clearance		
		Hole H11	Shaft C11	Fit[b]	Hole H9	Shaft d9	Fit[b]	Hole H8	Shaft f7	Fit[b]	Hole H7	Shaft g6	Fit[b]	Hole H7	Shaft h6	Fit[b]
30	Max	30.130	29.890	0.370	30.052	29.935	0.169	30.033	29.980	0.074	30.021	29.993	0.041	30.021	30.000	0.034
	Min	30.000	29.760	0.110	30.000	29.883	0.065	30.000	29.959	0.020	30.000	29.980	0.007	30.000	29.987	0.000
40	Max	40.160	39.880	0.440	40.062	39.920	0.204	40.039	39.975	0.089	40.025	39.991	0.050	40.025	40.000	0.041
	Min	40.000	39.720	0.120	40.000	39.858	0.080	40.000	39.950	0.025	40.000	39.975	0.009	40.000	39.984	0.000
50	Max	50.160	49.870	0.450	50.062	49.920	0.204	50.039	49.975	0.089	50.025	49.991	0.050	50.025	50.000	0.041
	Min	50.000	49.710	0.130	50.000	49.858	0.080	50.000	49.950	0.025	50.000	49.975	0.009	50.000	49.984	0.000
60	Max	60.190	59.860	0.520	60.074	59.900	0.248	60.046	59.970	0.106	60.030	59.990	0.059	60.030	60.000	0.049
	Min	60.000	59.670	0.140	60.000	59.826	0.100	60.000	59.940	0.030	60.000	59.971	0.010	60.000	59.981	0.000
80	Max	80.190	79.850	0.530	80.074	79.900	0.248	80.046	79.970	0.106	80.030	79.990	0.059	80.030	80.000	0.049
	Min	80.000	79.660	0.150	80.000	79.826	0.100	80.000	79.940	0.030	80.000	79.971	0.010	80.000	79.981	0.000
100	Max	100.220	99.830	0.610	100.087	99.880	0.294	100.054	99.964	0.125	100.035	99.988	0.069	100.035	100.000	0.057
	Min	100.000	99.610	0.170	100.000	99.793	0.120	100.000	99.929	0.036	100.000	99.966	0.012	100.000	99.978	0.000
120	Max	120.220	119.820	0.620	120.087	119.880	0.294	120.054	119.964	0.125	120.035	119.988	0.069	120.035	120.000	0.057
	Min	120.000	119.600	0.180	120.000	119.793	0.120	120.000	119.929	0.036	120.000	119.966	0.012	120.000	119.978	0.000
160	Max	160.250	159.790	0.710	160.100	159.855	0.345	160.063	159.957	0.146	160.040	159.986	0.079	160.040	160.000	0.065
	Min	160.000	159.540	0.210	160.000	159.755	0.145	160.000	159.917	0.043	160.000	159.961	0.014	160.000	159.975	0.000
200	Max	200.290	199.760	0.820	200.115	199.830	0.400	200.072	199.950	0.168	200.046	199.985	0.090	200.046	200.000	0.075
	Min	200.000	199.470	0.240	200.000	199.715	0.170	200.000	199.904	0.050	200.000	199.956	0.015	200.000	199.971	0.000
250	Max	250.290	249.720	0.860	250.115	249.830	0.400	250.072	249.950	0.168	250.046	249.985	0.090	250.046	250.000	0.075
	Min	250.000	249.430	0.280	250.000	249.715	0.170	250.000	249.904	0.050	250.000	249.956	0.015	250.000	249.971	0.000
300	Max	300.320	299.670	0.970	300.130	299.810	0.450	300.081	299.944	0.189	300.052	299.983	0.101	300.052	300.000	0.084
	Min	300.000	299.350	0.330	300.000	299.680	0.190	300.000	299.892	0.056	300.000	299.951	0.017	300.000	299.968	0.000
400	Max	400.360	399.600	1.120	400.140	399.790	0.490	400.089	399.938	0.208	400.057	399.982	0.111	400.057	400.000	0.093
	Min	400.000	399.240	0.400	400.000	399.650	0.210	400.000	399.881	0.062	400.000	399.946	0.018	400.000	399.964	0.000
500	Max	500.400	499.520	1.280	500.155	499.770	0.540	500.097	499.932	0.228	500.063	499.980	0.123	500.063	500.000	0.103
	Min	500.000	499.120	0.480	500.000	499.615	0.230	500.000	499.869	0.068	500.000	499.940	0.020	500.000	499.960	0.000

a -The sizes shown are first choice basic sizes; b – All fits shown have clearance; All dimensions in mm

So, basic size is 50 millimetre and h6 is the hole we have h6 here. Now since we are using basic shaft the deviation is 0, that means the maximum size of the shaft is equal to the basic size that is 50 millimetre and you can see here the minimum size of the shaft is 49.984, so the difference between these 2 is 16 microns. So, this 16 microns is the tolerance provided on the shaft.

So, that we can observe in this picture 16 microns is the tolerance, so we can use the readymade graphs like this or readymade tables for getting the tolerance value.

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Calculation of International Tolerance Grades:

"i" is standard tolerance unit. **"i"** for IT5 to IT 16 values can be calculated with the formula below;

$$i = 0.45 \times \sqrt[3]{D} + 0.001 \times D$$

Unit of tolerance is μm.
To calculate D;

$$D = \sqrt{D_1 D_2}$$

Where, D (mm) is the geometric mean of the lower(D1) and upper(D2) diameters of a particular diameter step within which the chosen the diameter D lies. As the size increases, the tolerance within which a part can be manufactured also increases.

Table 7: Geometric mean of diameter steps in mm

0-3, 6-10, 18-30, 30-50, 50-80, 80-120, 120-180, 180-250, 250-315, 315-400,400-500

Now we have to calculate the international tolerance grades depending upon what is the grade that is provided whether it is IT 5, IT 6 or IT 16 like that depending upon this we have to find the standard tolerance unit. For that we use the formulae that is given here "i" that is standard tolerance unit is equal to 0.45 times + 0.001 times D where D is the geometric mean of the diameter step.

So, what is the diameter of diameter step we can understand from these, D is millimetre it is the geometric mean of lower diameter and upper diameter. That means you can see here table this table gives geometric mean of diameter steps various steps that are allowed as per standard. So, 0 to 3 is one step, 6 to 10 is other diameter step. So, this is D1 first number is D1 and second number is D2.

So, if we have diameter of 25 it falls within this step of 18 to 30 millimetre. Then D1 becomes 18 millimetre and D2 will be 30 millimetre then using this relationship we can find the geometric mean D.

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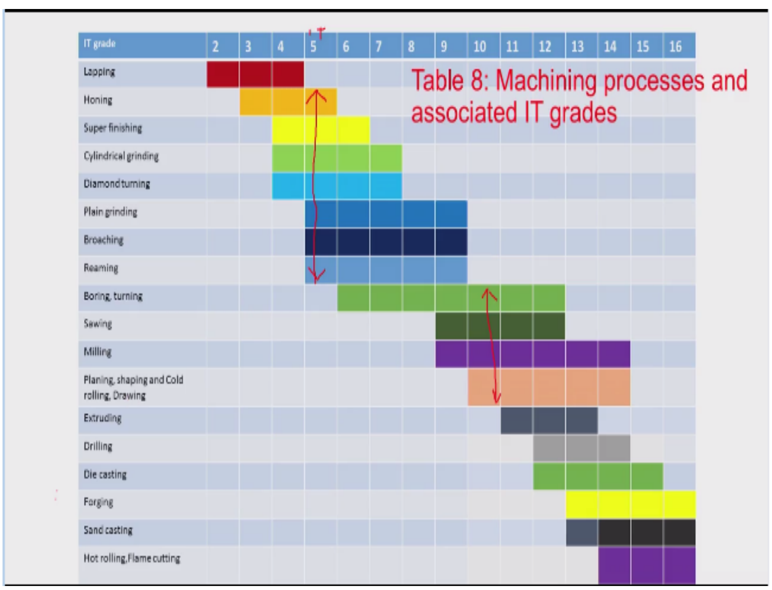

Now this particular picture shows the various machining processors and associated IT grades. Now we can see here different processors are listed here. So, starting from very precise machining like lapping, honing etc., super finishing, cylindrical grinding, diamond turning and then very not so precision operations like drilling, die casting, forging etc., etc., now when we say IT grade 5 immediately we can select, what is the process which is suitable for the to produce that IT 5 grade.

You can see here, if you say IT 5 then we have so many machining operations which can satisfy the tolerance values specified by IT 5. We can select honing, super finishing reaming like this. So, the fine machining processes we have to select, if you say IT 10, then these are the machining processes we can select to get the tolerance value which is specified by IT 10.

The processes like boring, sawing, milling etc., we have to select that means when the designer says the particular IT grade immediately we can use this table and we can find what is the appropriate machining operation. Now we will conclude at this point in this lecture we studied about the various tables, readymade tables and charts using which we can find the tolerance values define the upper limit and lower limit of shaft and holes.

And then we studied about the IT different IT grades and what are the applicable machining processes suitable for various IT grades. In the next lecture we will continue with some numerical problems thank you.