Metrology
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Module-3
Lecture-2
Terminologies of limits fits and tolerances

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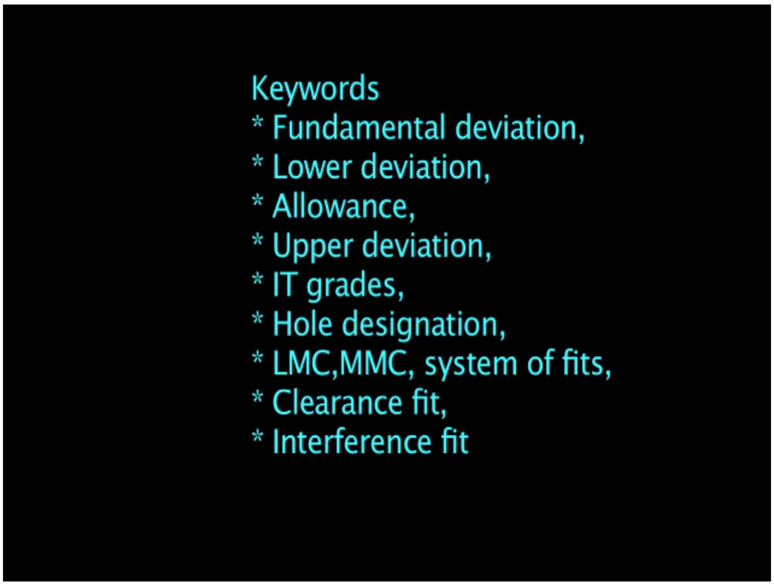

Hi welcome you all for the module 3 lecture 2, in the last lecture we start a discussion on the basics of limits fits and tolerances and we discussed about some of the terminologies used with reference to limits fits and tolerances, we will continue with the discussion.

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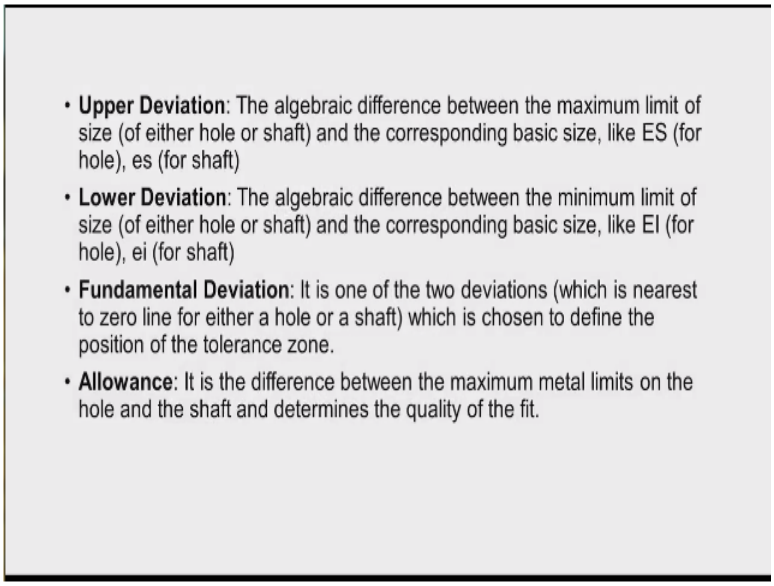

Now the next terminology is upper deviation so it is the algebraic difference between the maximum limit of size of either hole or shaft and the corresponding basic size, that is the designated by capital ES for holes and small es for shaft and similarly lower deviation it is the algebraic difference between the minimum limit of size of either hole or shaft and the corresponding basic size like capital EI for hole and small ei for shaft.

And next time is a fundamental deviation, it is one of the 2 deviations which is nearest to the zero line for either a hole or a shaft which is chosen to define the position of the tolerance zone and then we have another term allowance it is the difference between the maximum metal limits on the hole and shaft and this determines the quality of the fit.

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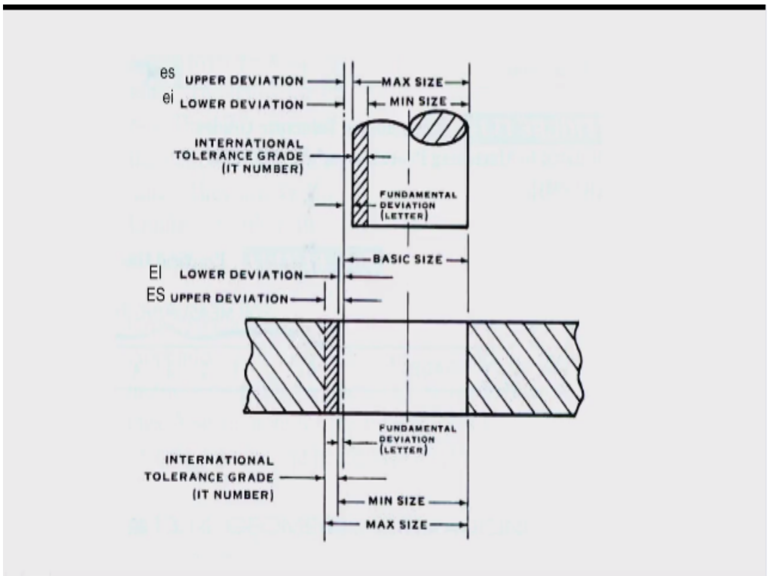

Now in this diagram we can understand the terms that are discussed just now we can see we have the hole and this is the basic size of the hole and then we have worth a shaft again the basic size of the shaft is the same value and then this is the minimum size of the shaft and then maximum size of the shaft. So, this indicates the tolerance that is allowed for the shaft and this tolerance is designated by international tolerance grade or we say IT number.

We will discuss this International tolerance grade in more detail after sometime and now similarly for the hole we have the this is the minimum size and then this is the maximum size. This difference between maximum size and minimum size gives the tolerance and this tolerance is again designated by international tolerance grade or IT number. Now we can see that this difference between the basic size and the tolerance or the maximum size of the shaft is the upper deviation and it is the designated by ES.

And similarly the difference between the basic size and the minimum size of a shaft is designated by ei lower deviation ei lower case ei. Similarly for the hole the algebraic difference between the basic size and the minimum size of the hole. So, this difference is known as lower deviation and it is designated by capital EI. And then the difference between the basic size and the maximum size of the hole.

So, this difference is designated by capital ES, which is the upper deviation. Now there is another term fundamental deviation it is the nearest deviation. The deviation which is nearer to the basic size is known as the fundamental deviation. Now in this case the upper deviation is this is very close to the basic size. So, this gap is known as fundamental deviation and it is represented by a lowercase letters for short like a, b, c, d.

And in the case of holes the lower deviation that is capital EI is very close to the basic size and this gap is known as the fundamental deviation which is again indicated designated by capital letters for holes like a, b, c, d etc., this we will discuss in detail after sometime.

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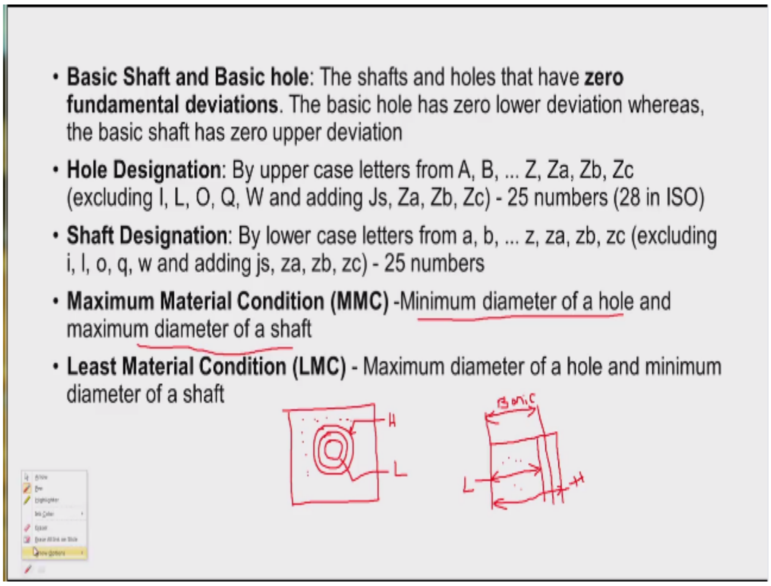

Now there are some more terms basics basic shaft and basic hole. The shafts and holes that have zero fundamental deviations. Now in the previous slide be there is some fundamental deviation for the shaft as well as for the hole. If this fundamental deviation is zero that means the basic size of the shaft is equal to the maximum size shaft. If that is the case that is known as the basic shaft.

Similarly for basic hole if this fundamental deviation is 0. That means basic size of the hole is equal to the minimum size of the hole. If that is the case then we say such a hole is known as basic hole. So, the shafts and holes that have zero fundamental deviations are known as basic shafts and holes. The basic hole has zero lower deviation whereas the basic shaft has zero upper deviation.

And then we have a hole designation we use a capital ABC etc., to designate the holes in ISO system by A, B up to Z and then Za, Zb, Zc excluding I, L, O, Q, W and adding Js these are the 25 numbers specified is specified in Indian Standard. Similarly shaft designation we use lowercase letters a, b, c, d etc., up to z then za, zb, zc excluding i, l, o, q, w and adding js. So, 25 shaft designations are there, in ISO there are 28 designations are there.

And then we have maximum material condition short form is MMC. So, this is the minimum diameter of hole and maximum diameter of shaft you know we can understand this by using some simple sketches say we have a plate like this some more piece with a hole okay. This is the basic size of the hole and then we have lower limit for the hole and then we have upper limit for the hole okay, this is a high limit for the hole and inner one is the lower limit for the hole.

Now when the size of the hole is equal to lower limit, then we have maximum material in this particular part. So, that is known as maximum material condition which is equal to minimum diameter of the hole. Now this is the size of the shaft and then we have the tolerance like this, so this is basic size and then this is the lower limit of the shaft and then we have higher limit of the shaft.

So, this is high limit and this is low limit. So, when the size of the shaft is equal to lower limit then the material content will be least. And then when the size of the shaft is equal to H higher limit. Then it has maximum material condition that is equal to the maximum diameter of the shaft. Similarly least material condition this is equal to maximum diameter of hole. So, when the diameter of hole is equal to the maximum size then the material content is the least.

And similarly when they shafts size is equal to the lower limit then the material content is least. So, that is known as the least material condition.

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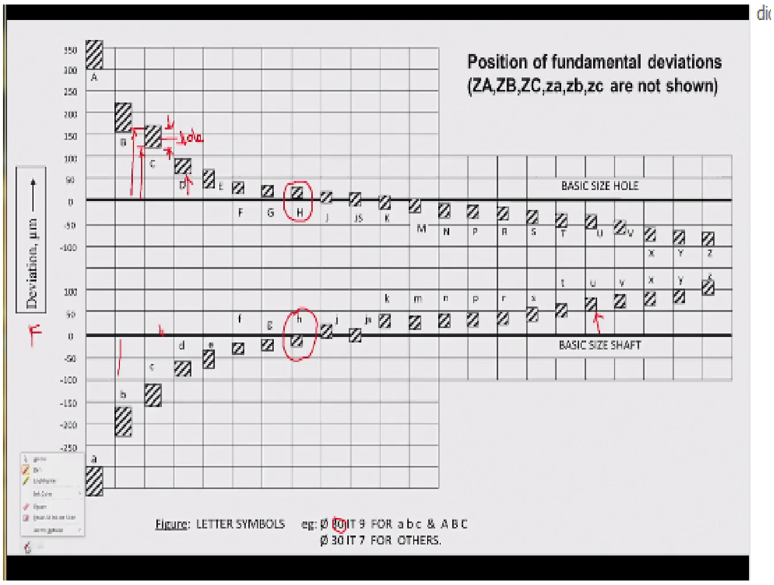

Now those hole and shaft designations we can understand here. So, this is this line indicates the basic size for the hole and this line indicates the basic size for the shaft and the y axis is fundamental deviation in microns. Now we have various designations for hole A, B, C, D etc., now we can see here at this particular point where the hole is designated by H, the deviation is zero, so this is taken as the basic hole**.**

And similarly if you observe here the deviation at this particular point is 0. So, deviation is zero, so this H shaft taken as the basic shaft. Now at this corresponds to the so These are holes all capital letters the correspond to holes now this is the tolerance zone this gap this zone indicating the tolerance zone and this corresponds to the lower limit of the hole and this corresponds the upper limit of the hole.

So, this difference is the tolerance now we can see here other than h the other holes have some fundamental deviation positive fundamental deviation for a, b, c, d, e, f, g up to this we have positive fundamental deviation then h has 0 fundamental deviation after that the Other holes have negative fundamental deviation. Similarly with respect to the shafts a, b, c, d, e, f, g they have negative fundamental deviation okay.

And they h shaft h has 0 fundamental deviation and other holes like a KM etc. they have positive fundamental deviation now this particular drawing it refers to the basic size of 30 and when the basic size varies again the fundamental deviation values will vary.

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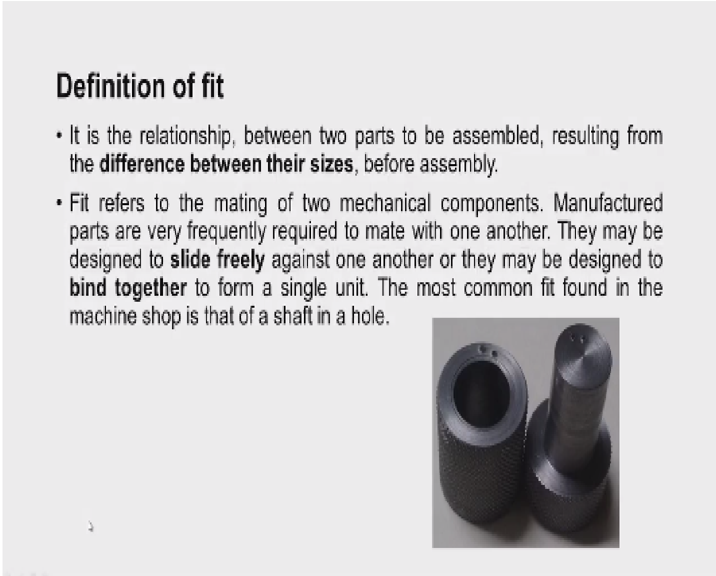

Then we will move to the fit definition of fit it is the relationship between two parts that are assembled, at this fit results from the difference between the size of shaft and size of one or any two mating parts. Now it they it also refers to the mating of two mechanical components manufacturer for all manufactured parts are very frequently required to make with one other there maybe design for slide freely.

That means the shaft size is smaller than the hole size so, that the shaft can move inside a hole freely it we can rotate in the hole or you can slide in the hole or there maybe design to bind together that means the shaft size is greater than the hole size, so that when we push the shaft into the hole by applying some force they two mating parts are held. So depending upon the application we may use the clearance fit.

Where in the size of the shaft is lesser than this size of the hole or we may use interference fit where the size of the shaft is greater than the size of the hole there is another kind of fit known as transition fit varying depend upon the shaft size and the hole size we may get either the clearance fit or interference fit so such things we will see after sometime.

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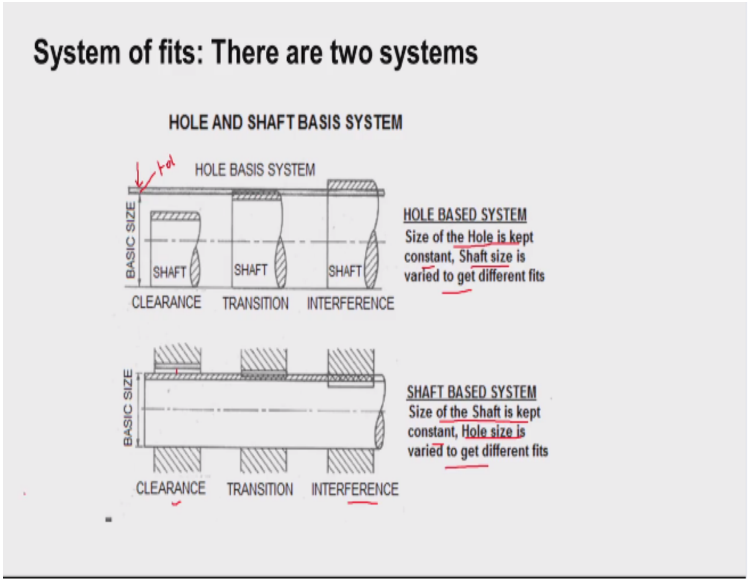

Now there are two systems of fits the first one is hole based system and second one is shaft basis system. Now we can observe in this picture the this is a hole based system varying size of the hole is kept constant and the short size is vary. So we have different shafts. Now this is the basic size of the hole and then this difference gives the tolerance for the hole, now to get different kinds of it.

Whether we the clearance fit or interference fit or transition fit we vary the shaft size and in the second system we have shaft based system varying size of the shaft is kept constant. We can see in this picture the size of the shaft is not varied it is constant and hole size is varied to get different fits. For example in the in this case the hole is bigger than the shafts so we have some clearance here, so we get the clearance fit.

And then here the shaft is bigger than the hole size. So we get the interference fit here in between they have transfer fit. Now normally hole basis system is prefer because see the machining of the inner surfaces. For example hole is always difficult and we need to have series of tools. For example say we required different sizes of holes then we should have multiple drill tools internal grinding tools.

And then reverse so, we have different hole sizes then the inventor of tool will increase where as shaft size can be varied using a single point cutting tool in turning process or using a single grinding wheel. We can grind the different the shaft sizes so, by using hole basis system. We can reduce the tool inventory so in manufacturing environment normally hole basis system is used.

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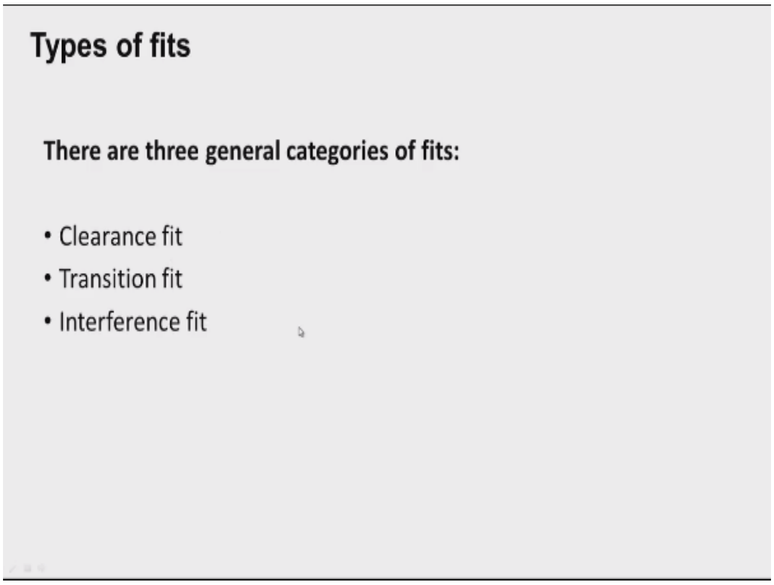

Now we have three categories of fits known as clearance fit, transition fit and interference fit. Now we will discuss about these three types of fits in detail.

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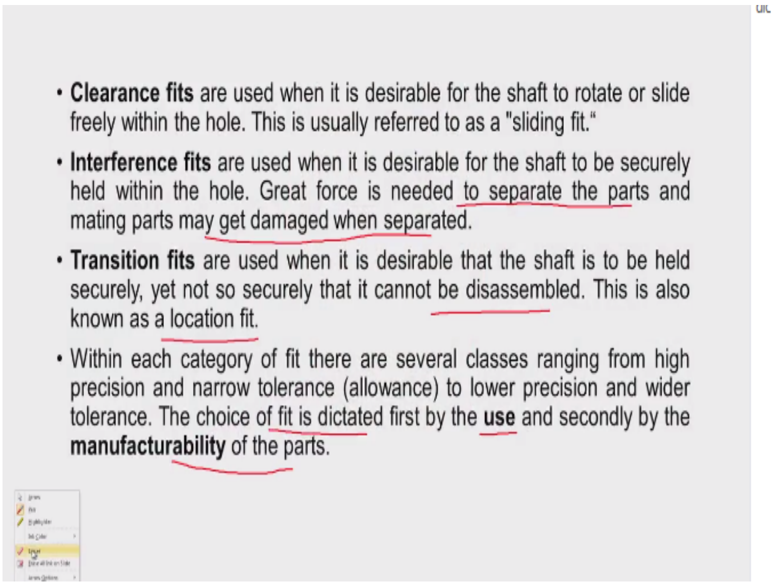

Now the clearance fits are used when it is desirable for the shaft to rotate or slight freely within the hole, this is also known as sliding fit. That means the hole size is bigger than the shaft size so that the shaft can freely move inside the hole and in the interference fit whenever the rigid we want to fix the shaft inside the hole rigidly. Then we go for interference fit.

Now a great amount of force is needed to see the parts which are fixed using interference fit, if you want to remove them then great amount of force is needed to separate them and so many times they may get damaged. When they are separated because they are rigidly held in the the parts of rigidly held in the interference fits. And in the case of transition fit when it is desirable that the shaft is to be held securely.

Yet not so securely that they cannot be disassembled that means sometimes we want to separate the two making parts. In such cases we go for transition fir. This also known as location fit, that is by appropriately assigning the tolerance values for the shaft and the hole. We can get the desired type of fits depending upon the application, within each category of fit there are several classes ranging from high precision to narrow tolerance to lower position.

And wider tolerance the choice of fits is dictated by the use what is the user what is the application of the fit and secondly by manufacturability by what type of manufacturing system. We have whether we have using the not so precision machine tools are very high precision tools. So there that aspect also is taken into consideration while selecting the fit.

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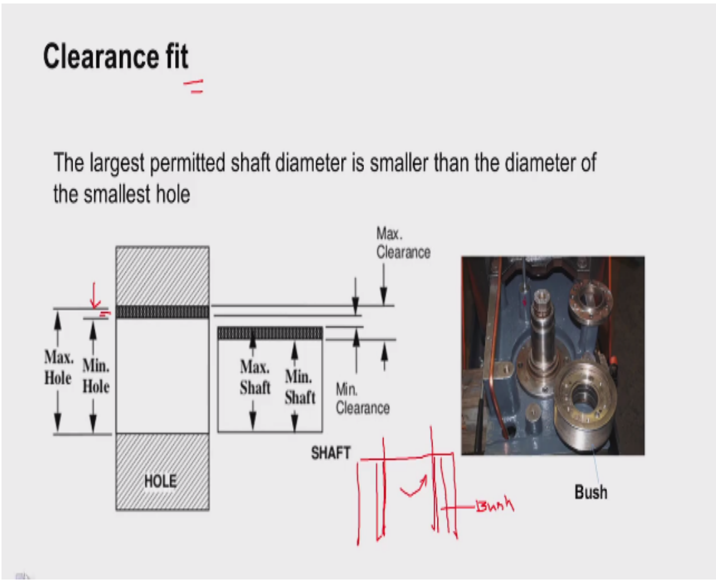

Now we will study the clearance fit in detail this picture shows that we have hole here with the minimum size of the hole and the maximum size of the hole. This algebraic difference gives the tolerance for the hole. So this gap represents the tolerance part of the hole. That means the hole size can be anywhere between the minimum hole and maximum it can be here, it can be here.

So it can take any size between these two limits upper and lower limit. So, similarly we have a shaft with the maximum size and the minimum size. And now when the shaft size is maximum and the hole size is minimum, so this algebraic sum gives algebraic difference gives the minimum clearance. And we get the maximum clearance when we have maximum size to holes and minimum sized shafts.

So this represents the maximum clearance and sometimes we need to see we have a bush bearing here. So this is the bush bearing and then we have a shaft inside, so it has to rotate or it has to move freely. So in such cases we go for clearance fit. So one application is shown here, this is the shaft and this is the bush bearing. So shaft is required to rotate freely inside. So in such cases we go for clearance fit.

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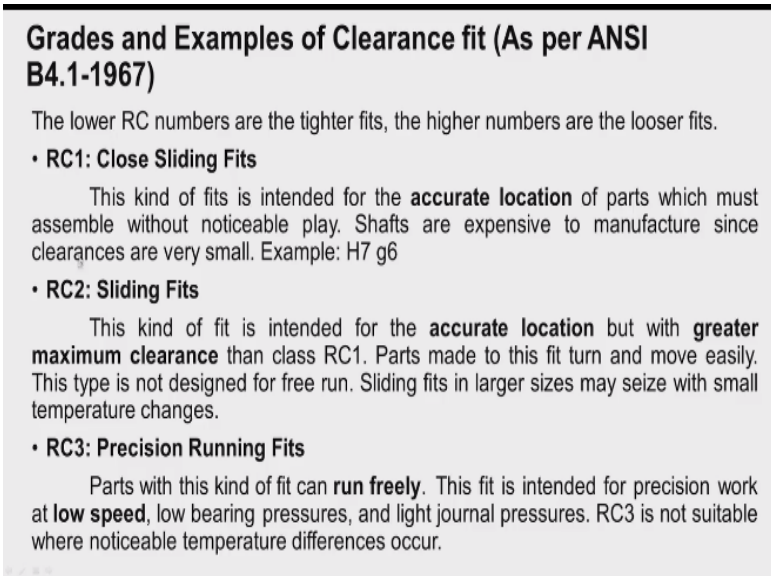

And then there are different grades of clearance fits as per the American standard B4.1. Now where are represented by RC1 RC2 etc. as the RC the layer RX numbers that means 1,2,3, etc there are very tighter fits and as the number increases like RC 5, RC6, etc there are present a loser fit, so RC1 wherein we has tighter fir and it is used and accurate location is intended without any noticeable play.

And shaft for very expensive to manufacture since they have very tight tolerance and de-clearance will be less, so one example is at X7 G6 combination gives us the RC1 clearance fit, so what is H7 g6 it is the hole designation and g is the designation for the shaft and 7 indicates the IT number International talent for the shaft, now we will discuss about these grade IT grades in detail in short line. So then we have RC2 is sliding fit and this kind of fit is intended for the accurate location but with great a maximum clearance as compared to RC1.

Parts made to this fit turn and move easily because of this higher clearance, so this type is not design for free run sliding fits in larger sizes may seize with smaller temperature changes. So this point we should know while using the sliding fits. Similarly we have RC3 wherein the parts can run very free because of higher clearances, if it is intended for Precision work at slow speed, low bearing pressure and light general pressure.

And is not suitable where noticeable temperature differences occur, if temperature rises there then again the seizer may occur.

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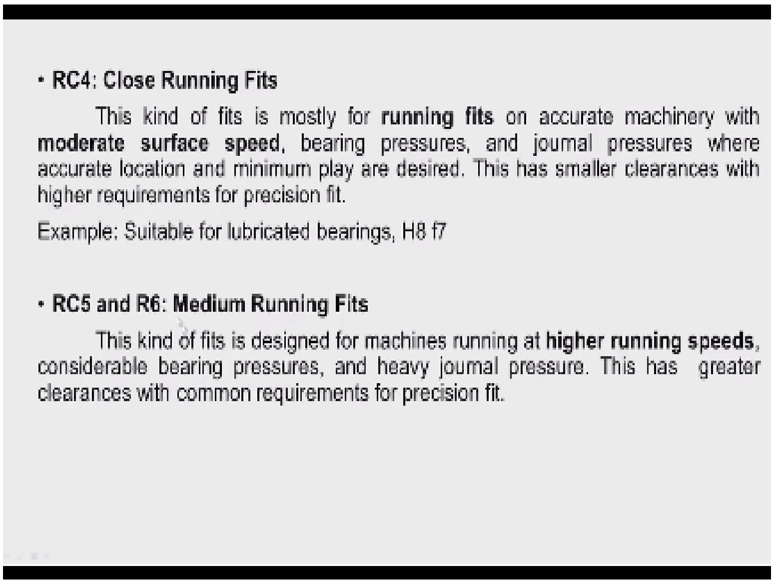

Then we have RC4 close running fits, so this is suitable for the machinery with moderate surface speed, the moderate bearing pressure and journal pressure where accurate location and minimum play are deicide or this has a small clearances with higher requirements for precision fit. So an example is this is suitable for lubricated bearings, we can get close running fit by using H8 and f7 combination.

And then we have RC5 and RC6 they are known as medium running fit and the design for machines running at higher running speeds considerable bearing pressure and heavy general pressure. This has greater clearances with common requirements for Precision fit.

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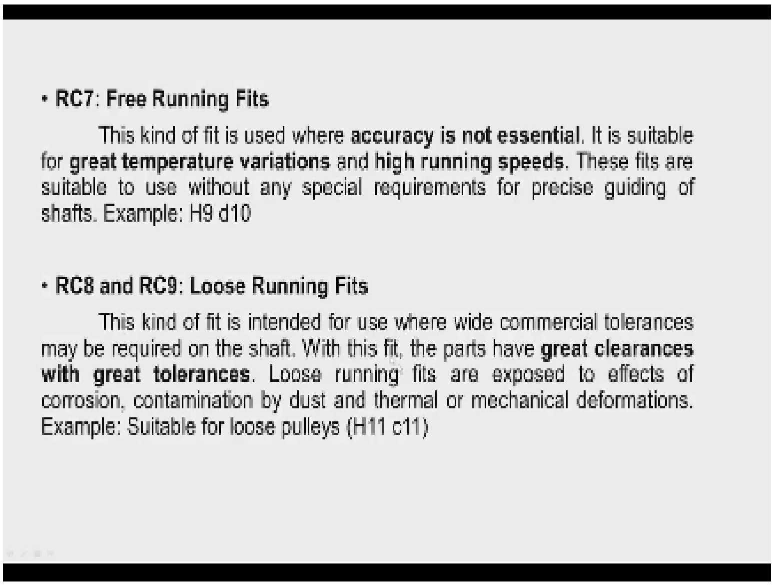

So next we have RC7 which is a free running fits where accuracy is not that much essential, so because of a no clearances then maybe small play maybe present, this is suitable for grade temperature variations and higher running speeds. These fits are suitable to use without any special requirements for precise guiding of shaft. For example H9 d10 combinations gives us the free running fits.

And then they have RC8 and RC9 that very loose running fits, they are not intended for intended for use where wide commercial tolerances may be required to shaft with this past have great amount of clearances with the great tolerances and fits exposed effects of corrosion contamination by dust and thermal or mechanical deformation. That means since clearance are more their parts are exposed to such conditions like corrosion and duster.

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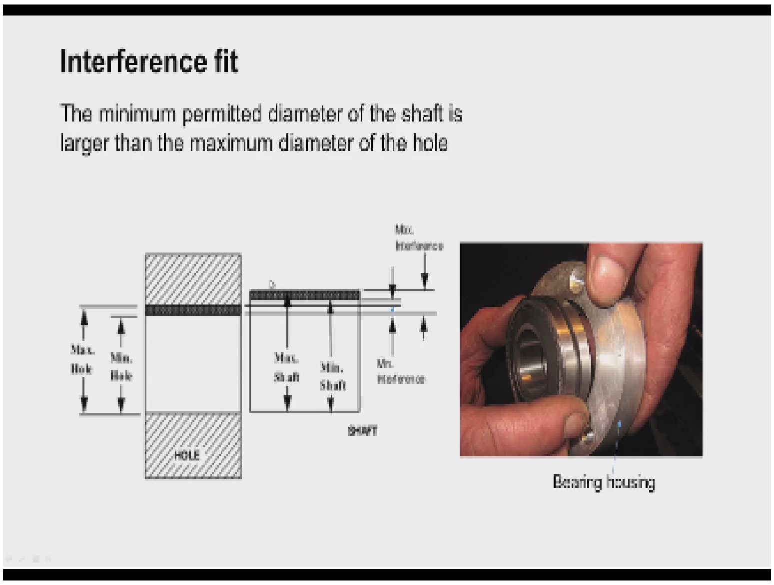

So an example is they are suitable for loose pulleys, so can get loosening fit by H11 c11 combination. Then they have the interference fit so this will get the minimum permitted diameter of the shaft is larger than the maximum the hole we can see this picture, this is the maximum size at hole, so this is the smaller than the minimum size of the shaft.

In such cases we get interference fit, so we get minimum interference when we have the maximum size hole and minimum size shafts and interference will be maximum when we have a minimum sized hole and maximum sized shaft. So when such a difference fits you can see in this diagram we have a bearing housing and we want to fit this particular bearing into the bearing housing.

So this outer ring of the bearing should be tightly held in the bearing housing there should not be any relative motion between these two, in such cases interference fits are used, so varying at the outer diameter of the string will be bigger than the diameter of this housing.

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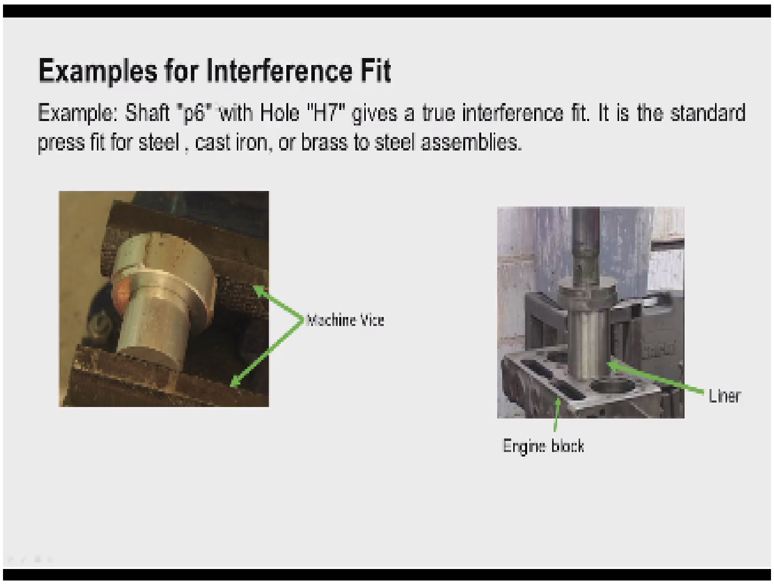

Now we have some more examples for interference fit, we can see here a great amount of force and pressure is required to fit today parts to get the interference fit you can see here why such machine are used to fit this shaft into the hole and we have another example of engine block there in the way have to insert liner, so we have to play a great deal of pressure used hydraulic presses for putting liners into the engine block.

The diameter of the hole diameter of a shaft and then there is a test conditions etc. etc. now we can always calculate what is the amount of pressure or force required by using the equations available.

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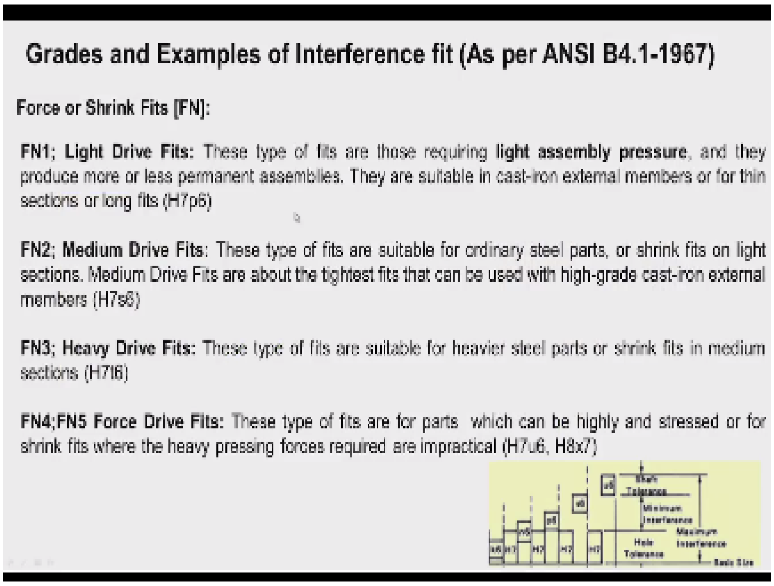

Now there are the different grades of interference fit as per American standard ANSI B4.1, so there force and shrink fit, so we have FN1 and FN2 etc. etc. FN1 is light drive fit, so these types of fits are those requiring light assembly pressure, so as the memory increases 1,2,3 sector the amount of pressure required will also increase and the these fix light driver fit they produce more or less permanent assembly the suitable in castor iron external members for a particular section or long fits.

So H7p6 combination gives us FN1 fit and then we have FN2 medium dry fit, these types of fits are suitable for ordinary steel parts or shrink fits on light sections and medium dry fits are about the tightest fits that can be used with a great castor-iron external members, we can get the medium dry fit by using H7s6 combination and then we have FN3 heavy drive fits and these are suitable for heavier steel parts or shrink fits in medium section.

The combination H7t6 gives us heavy drive fit and we have FN4 and FN5 force drive fits, these types of fits are for parts which can be highly stressed. Now the H7u6 or H8x7 combination gives us force drive fits. Now we can understand from this picture that we have been all these examples using H7 the basic hole H7 hole wherein the deviation is 0 and this is the hole tolerance and then we are using p6, s6, t6 shafts.

So we have p6 shaft and s6 shaft. Now we can see here the diameter minimum diameter of so this represents the size represents minimum size of the shaft, so this is greater than the maximum size of the hole. So we get interference fit, similarly if we take for example of H7s6, H7s6 which gives variant drive fit this s6 shaft and S7 hole, so this is the minimum size of the shaft and this gives us the maximum size of the hole.

You can see here there is lot of interference between these two so we have to apply great amount of force to get this medium or driver fit and here this is a date shaft tolerance and this is there a hole tolerance and distance give the minimum interference and this gives the maximum interference.

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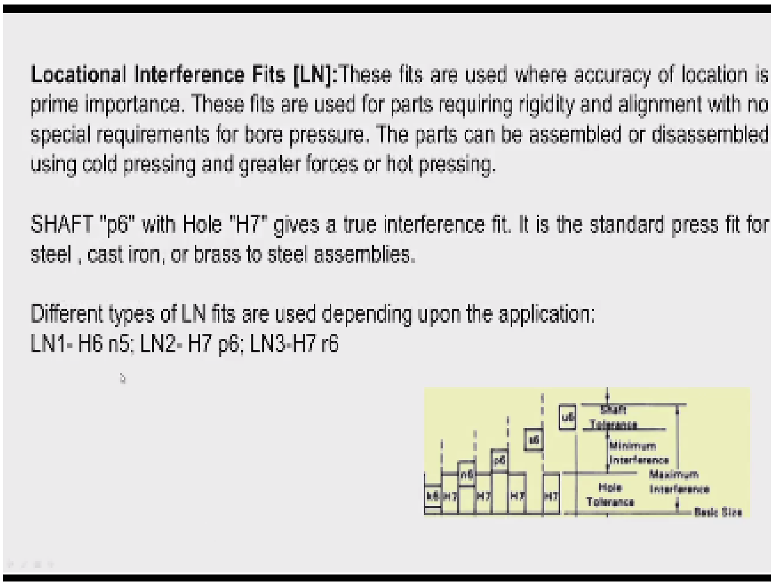

Then we have locational interference fits there designated by LN, these fits are used where accuracy of location is prime important. These fits are used for parts requiring rigidity and alignment with no special requirements for both pressure, the parts can be assembled or dissembled, the parts can be assembled and disassembled using cold pressing and great for the hot pressing.

That means the hole is heated, so that the diameter increases and then the shaft can be inserted and when both the shaft and hole are cool down we get the location interference fits. So shaft p6 and with the hole H7 we can get the tool interference fit, it is a standard perfect for steel cast iron or brass or brass to steal assemblies and different types of LN phase are used depending upon the application.

One can use LN1, LN2, LN3, etc. etc. now this diagram shows that we have H7 hole this is hole tolerance and then we have u6 and shaft tolerance or if we take this example H7p6, so we have H7 hole, this is the hole tolerance and then we have p6 shaft. So we can understand and then we have H7s6, H7u6, so this is the interference that is minimum deference that is available.

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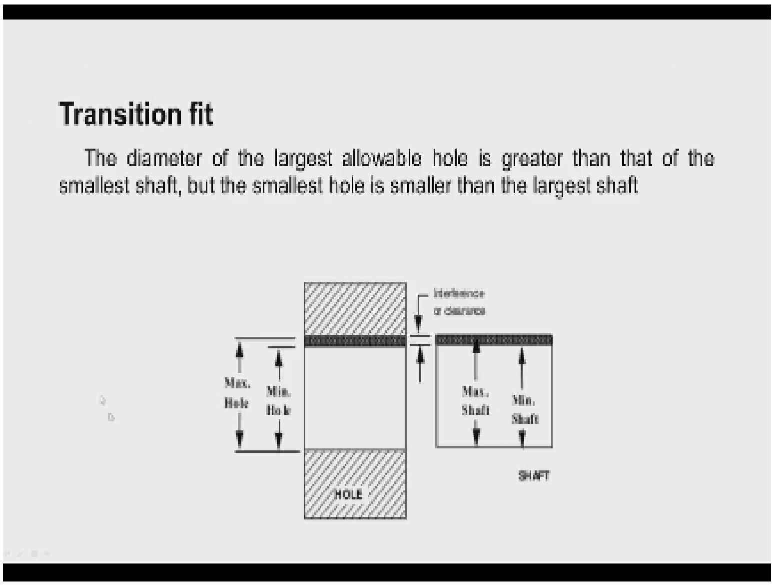

Now we will move to the transition fit the diameter of the largest allowable hole is greater than that of the smallest shaft, but the smallest hole is smaller than the largest shaft that means in this case, the tolerance zone of the shaft and the tolerance zone for the hole they overlap each other, then over lap completely or they may over lap partly as shown here. So this is tolerance zone for hole, tolerance for hole and then the tolerance for shaft you can say that over lapping in this particular case or it may partly overlap like this or like this.

So this is tolerance for shaft, these smaller rectangle the indicator tolerance zone for shaft, so depending up on the actual size of hole and actual size of shaft we make it clear it or we make it interference fit.

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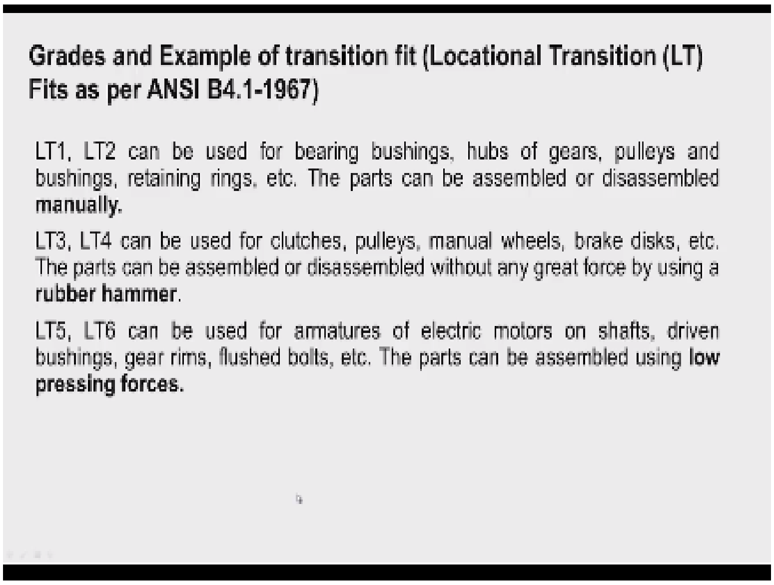

Now again there are different grades of transition fit we say locational transition LT fit as per ANSI B4.1, so we have LT1, LT2 to transition fits locational transition fit and this can be used for bearing bushings, hubs or hubs of gears, pulleys and bushings retaining rings, etc. etc. The parts can be assembled or dissembled manually that means the amount of force that is needed to fit the parts is not too much.

And then we have LT3 and LT4 these are used for clutches, pulleys, manual wheels, brake disks, etc. the parts can be assembled or disassembled without any great force that we can use a rubber hammer to fit the parts and then we have LT5 and LT6, these can be used for armatures of electric motor on shafts, driven bushings, gear rims, flushed bolts, etc. the parts can be assembled using low pressing forces.

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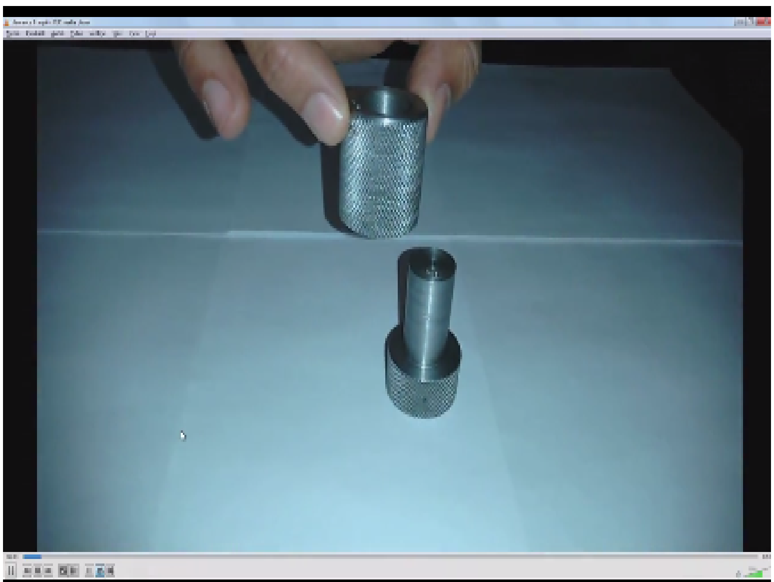

We may have to use a little bit of pressure to get LT5 and LT6 pressure which is greater than that can which can be applied by rubber hammer. We is we have stopped and then we have a hole now the shaft, so if we can observe that the combination is 2 dots are there.

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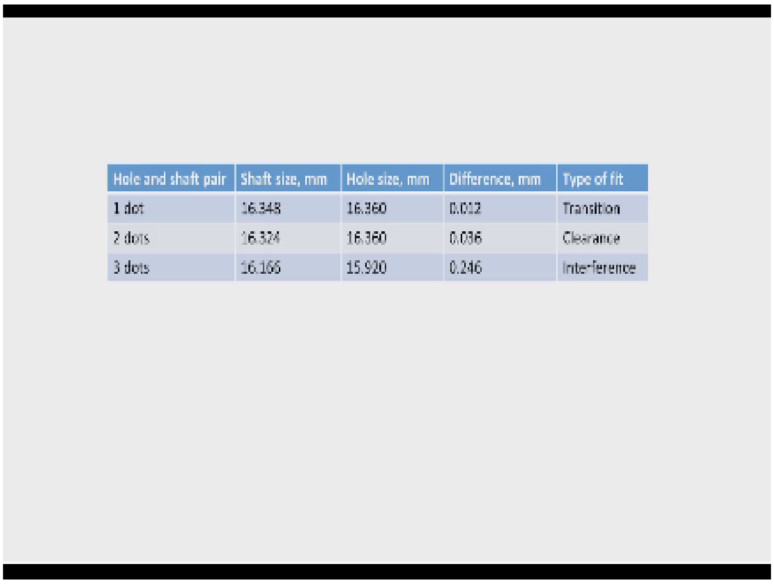

Hole and shaft pair	Shaft size, mm	Hole size, mm	Difference, mm	Type of fit
1 dot	16.348	16.360	0.012	Transition
2 dots	16.324	16.360	0.036	Clearance
3 dots	16.166	15.920	0.246	Interference

Since the shaft size smaller than the hole size, the hole end short entrance into hole very easily. Now we have another combination bearing has single dot, so this is a shaft and hole, now I am putting the hole on to the shaft I can see the smaller layer of oil, now we have a transition fit. So we have to apply a little bit of pressure on to this bush, so that it enters fully. So this is an example for transition fit.

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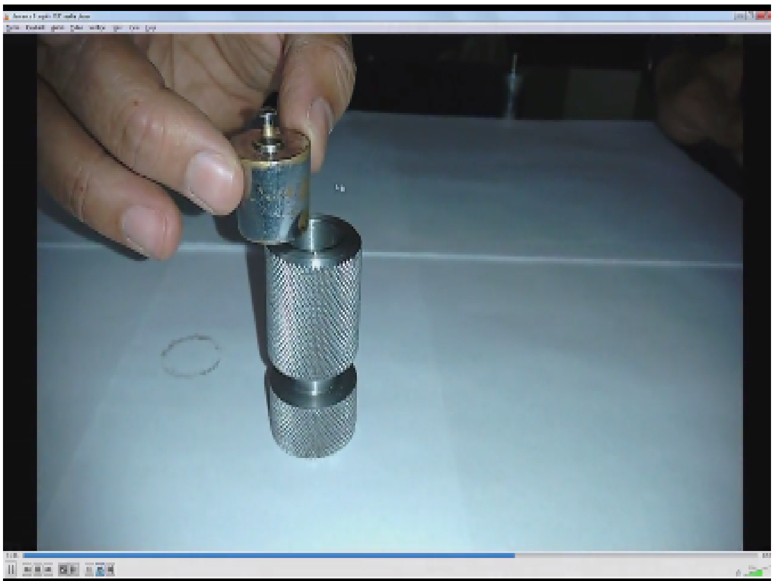

Now I will show you put some weight on to this bush, so that it will fully enter. So I am applying the weight of 50 gram, now you can see after applying 50 grams it has entered fully.

So depending upon the actual size of a shaft and hole in a bit different kinds of interference fits. Now we have another experiment with this is a 3 dot combination.

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Now in this case we can observe am putting the bush on to the shaft, is not entering even when we apply force it is not entering. The reason is the shaft size is greater than the hole size. So we have the interference. We will conclude this lecture number 2. In the lecture number 2 we discussed about the different kinds of the fits, clearance fit, transition fit and interference fit. We also discussed about different the bandits available with respect to the limits fits and tolerances and in the next class we will solve some numerical problems, thank you.