Welding Engineering

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Module - 6
Design of Weld Joints
Lecture - 4
Design for Static and Fatigue Loading

This is the 4th lecture on the Design of the Weld Joint of the 40 lecture series on the Welding Engineering. And in this presentation mainly, we will be taking up the basic methods, which are used for designing the weld joints for the Static and the Fatigue Loading. And it is important to understand that the basic methods and the fundamentals, which are used in strength of material for determining the stress levels acting in a particular component under the external loading for a given cross sectional area.

So, those fundamentals are still applicable in case of the weld joints, but since the application of the heat during the welding. Affects the properties of the base material as well as the properties of the weld material are also significantly governed by the welding procedure, which is used for development of the weld joint. And therefore we have to consider some additional factors related with the design of weld joints, which significantly dictate the performance of weld joint under the static as well as dynamic loading conditions.

So, the thing important thing, which is here is that the performance of the weld joint under the static and dynamic loading conditions is primarily governed by the load resisting cross sectional area available with the weld joint, which is being made. But, in addition to that it is also important to see that, how property variation of the weld metal and the heat affected zone is taking place, due to the application of the heat during the welding. And it is also important to consider, if any weld discontinuities are present in the weld joint then how they will be affecting the effective load resisting cross sectional area of the weld joint.

So, and apart from this the, it is very important considerations to the various aspects related with the weld joint, especially when the weld joint is to be used for the fatigue loading conditions. Because the fatigue loading under the fatigue loading conditions the joint performance is found to be very poor as compare to the normal bulk materials. And that reduced performance of reduced fatigue performance of the weld joint is mainly, attributed to the effect of the weld thermal cycle experienced by the base material and the kind of weld joint, which is made during the welding.

So, and because of this the approach, which is used for designing the weld joints for fatigue loading is found. Significantly, different from, which is used for designing and the components for bulk materials, under the conventional properties and without any kind of the welding. So, starting with this background we will be taking up one by one the factors, which effect the load carrying capacity of the weld joint and based on that, we will see that how the design of the weld joint can be done. And what are the things, which are identified, when the weld joint is designed.

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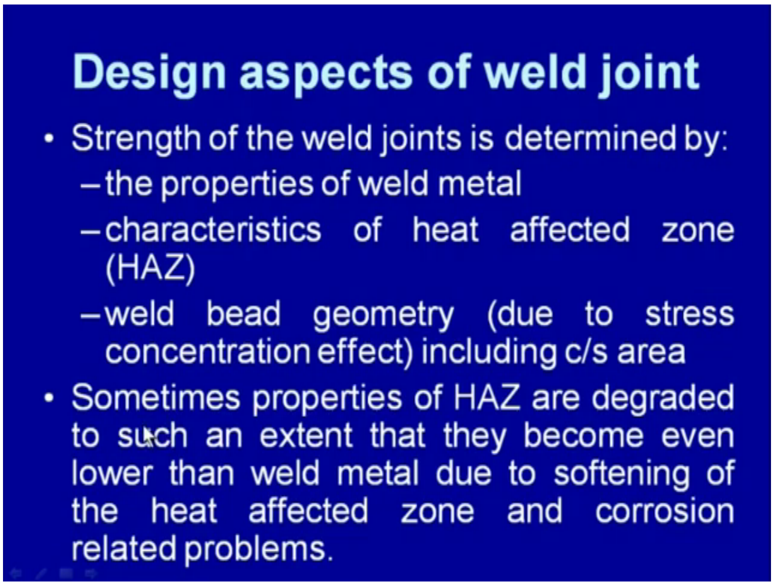

So, as for as design aspects of the weld joint is concerned, the strength of the weld joint is primarily, determined by the weld metal properties. But, sometimes what happens that even, if the weld metal properties are very good, but the deterioration in the properties of the heat affected zone takes place, then that will adversely effecting the load carrying capacity of the entire weld joint.

Because, these heat affected zone sometime acts as a weak link and failure sometimes take place from the heat affected zone, if the properties of the H A Z region has been very adversely effected and apart from the properties. And the if the effect of the weld thermal cycle on the heat effected zone is negligible, then the another important factor that affects the load carrying capacity or the strength of the weld joint is the weld bead geometry.

When the weld joint is made we frequently find that either, they are discontinuities of one or other kind in form of like partial penetration weld or some inclusions and the porosity or the weld bead geometry is improper. So, improper weld bead geometry sometimes leads to the excessive stress concentration at the toe of the weld and which frequently becomes the site for a stress concentration.

And facilitates the nucleation of the cracks and is and their easy growth and because of this the load carrying capacity of the weld joint is reduced significantly. Even if the weld resisting crosses sectional area is a good enough, but the poor weld bead geometry leads to the reduced a load carrying capacity and the reduced strength of the weld joint.

So, when the design of the weld joint is made it is important to consider, what are the properties of the weld metal. If there is any or what are the properties of the heat affected zone or if any deterioration in properties of the heat affected zone is taking place and that should be kept in mind, while designing the weld joint. And what kind of the weld bead geometry is being obtained, sometimes improper weld bead geometry despite of having the good resisting cross sectional area. And the desired weld metal properties the load carrying capacity of the weld joint is reduced significantly. Therefore, all these points must be kept in mind while deciding upon the load carrying capacity of the weld joint, which will be actually delivered by it during the service.

So, sometimes as we know that sometimes properties of the heat affected zone are degraded to such an extent that, they become even lower than the weld metal due to the softening of the heat affected zone. And the corrosion related problems and this deterioration in H A Z frequently leads to the failure of the weld joint premature failure of the weld joint even at the lower loads. So, if a considering that the effect of the weld thermal cycle on the properties of the base material close to the fusion boundary means the region means, the heat affected zone is negligible.

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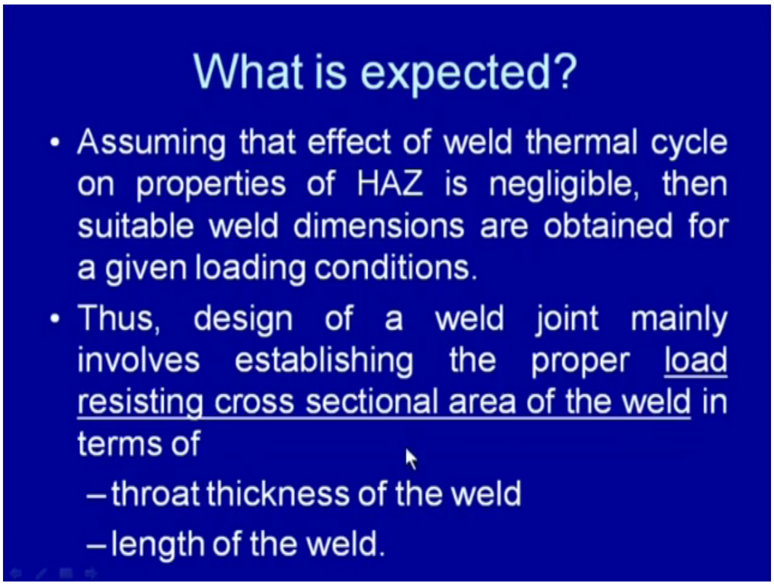

So, assuming that the effect of weld thermal cycle on the H A Z is negligible, then the suitable dimensions of the weld are obtained for the given loading conditions. So, primarily in the design of designing of the weld joint, it is identified what will be the dimensions of the weld load resisting cross sectional area. So, that it can sustain the service load.

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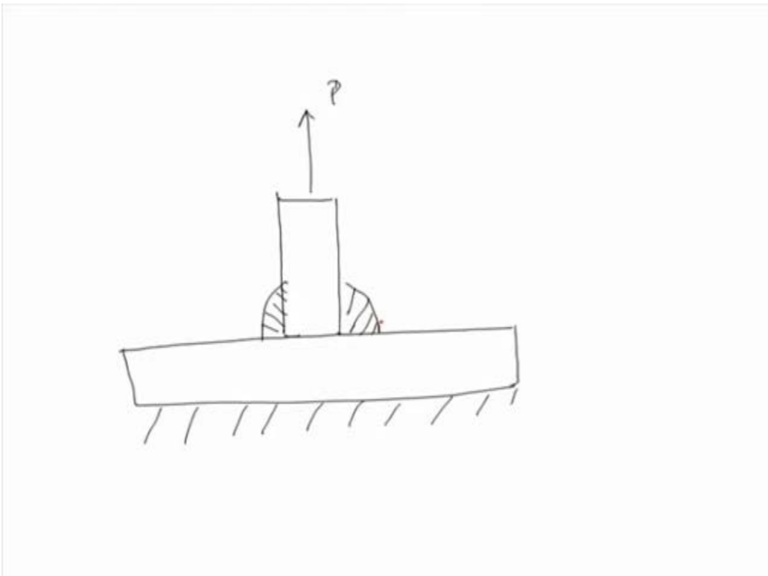

So, for given loading conditions basically, the weld dimensions are identified in terms of the weld throat thickness and the length of the weld. So, thus the designing of the weld joint mainly involves the establishing, the proper load resisting cross sectional area of the weld. And this load resisting cross sectional area of the weld is established in terms of the throat thickness of the weld and the length of the weld.

So, this is what we try to see using this simple diagram say, if the connection is to be made between the two plates say this is the t joint and weld is being made using the fillet welds like this. Running through the length of the weld for the load, which is acting this manner this end is say fixed. So, basically the this the load resisting cross sectional area of this joint will be identified in such a way, that it is able to take up this external load which is acting on it. Basically, for this fillet weld the shear load will be acting and for this shear load this load resisting cross sectional area is identified.

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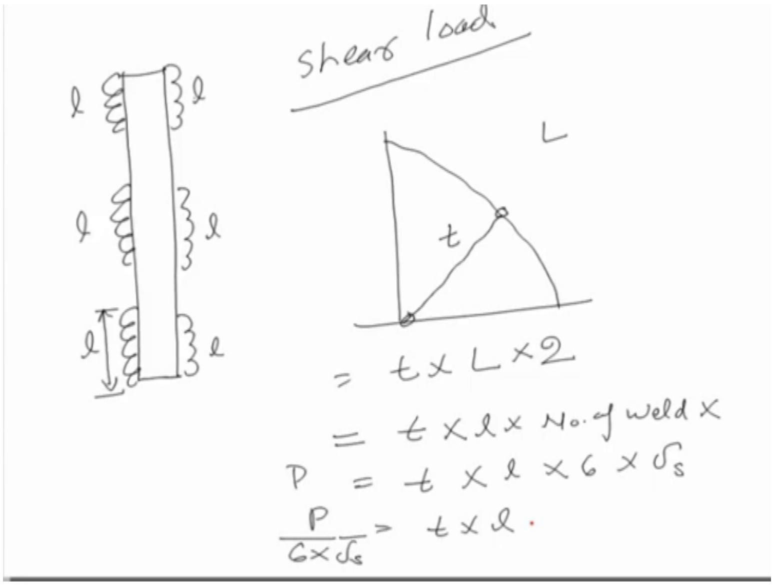

So, to identify the load resisting cross sectional area for fillet weld basically, we determine the throat thickness, which is obtained from the shortest distance of the line, which is passing through, the root and the face of the weld. And so this is the throat thickness say t and the length of the weld. So, length of the weld say if it is L then t into L gives the load resisting.

Load resisting cross sectional area for one weld, since we are depositing the weld fillet welds on both the sides then to identify the total load resisting cross sectional area for this kind of the joint, it will be the 2 into t into L. So, where l is the length of the weld and t is the throat thickness of the weld, says instead of having the weld continuous weld throughout the length. If we are having says the weld of a particular length, then there is a gap another weld of the same length l, then gap then l. So, in this case means 3, there are three number of weld each of say a particular length.

So, in this case the total length of the weld will be identified from the t is weld throat thickness of the weld that is same multiplied by the length of the each weld. So, if the length of the one weld is l, then we have to multiply it with a number of welds, which are there. So, here we have 3 numbers of welds. So, 3 numbers of the welds will be multiplied and since, we have such kind of configuration in both the side of the plate say this is plate and again, we have 3 weld in other side.

So, in that case the number of welds will be 6 in total and. So, or if there is a just 1 weld of the full length, then l multiplied by 2, for both the sides or. So, here in that case we will have 3 t into l into 6. Because we are having 6 number of welds each of length l. So, if the length of each weld is l, then the throat thickness multiplied by the length of the weld will identify the load resisting cross sectional area.

This is how we can determine, the kind of throat thickness and the length of the weld, which will be required. Say, if we have the load P, then this is the known load and this is the load resisting Cross sectional area. Then on multiplying this with the allowable stress will give you, will give us a sigma s allowable shear stress then from this equation, we can determine t into l, that will be equal to p by 6 into sigma s.

So, basically, sigma s is the allowable stress that is identified first and the load for which weld is to be designed is also established. And thereafter we can see from this t into l that will give you the load resisting cross sectional area. So, this so either the value of the t is identified or the length of the weld is identified. So, this is how basically, we try to establish the load resisting cross sectional area, which is required to take up a particular external load. Now, using the type of the load we will try to establish that, what kind of allowable stress is to be used for designing the weld joint.

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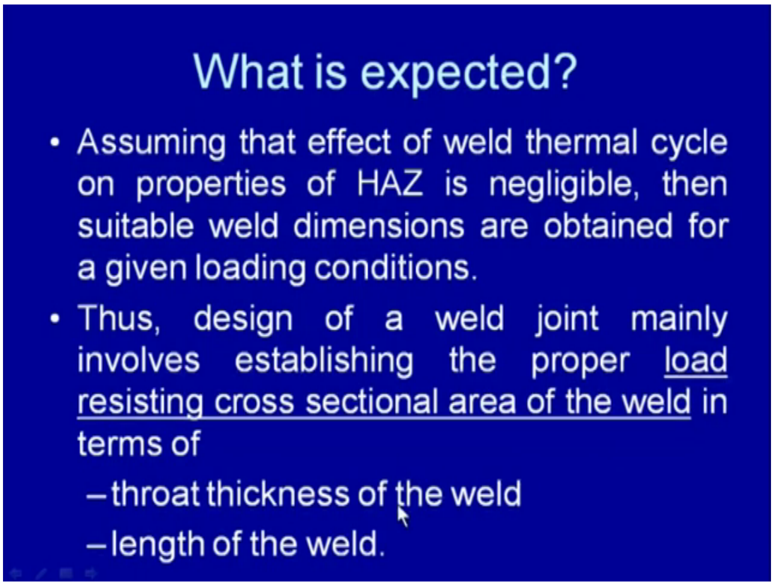

So, this is how we if we try to identify, the load resisting cross sectional area of the weld joint in terms of the throat thickness and the length of weld, which is to be deposited. Say the approach for determining the throat thickness and approach for determining the throat thickness for the butt weld is found to be different from that of the fillet weld.

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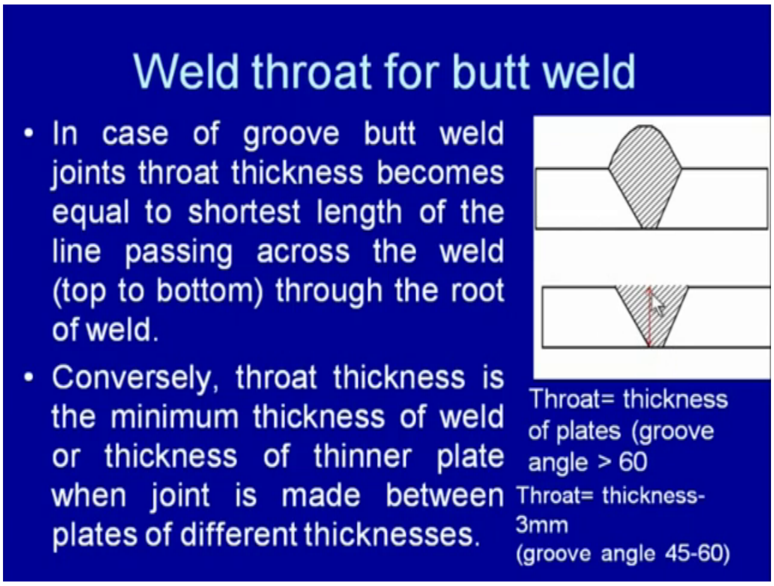

In case of the butt weld groove, but weld the joint throat thickness becomes equal to the shortest length of the line passing across the weld through the root, so the line which is passing the shortest line, which is passing through the weld and through the root. So, here if, we try to draw this line will be like this.

So, this is one case and the conversely, the throat thickness becomes minimum thickness of the weld or thickness of the thinner plate, if the weld is made between the 2 different thicknesses. To understand clearly any portion of the weld metal, which is above the surface of the base plate is not considered in for determining the throat thickness.

So, if say if the top layer has been ground flushed means machine and removed and in this situation, if you want to measure the throat thickness for the groove butt weld joint. Then the length shortest length of line, which is passing through the root and through the weld, will be equal to this length and this is almost same as that of the thickness of the plate.

So, for the groove butt welds, which are having the groove angle greater than the 60 degree normally, throat thickness is considered as a thickness of the plate, while for the situations. Where groove angle is between 50 to 60 throat thickness is taken as thickness of the plate minus 3 m m. This is how the throat thickness for the groove butt weld is obtained. So, mostly in case of the groove butt weld throat thickness of the weld becomes equal to the thickness of the thinner plate, if the dissimilar weld is to is if the weld joint has been made between the plates of the different thicknesses.

And if the plate thicknesses are equal then the throat thickness will be equal to the thickness of any plate. So, basically from this, if we see then the throat thickness for the weld is fixed only thing. We need to identify is the length of the weld, which will be required to be, which will be required for taking the service load. For which it is to be designed.

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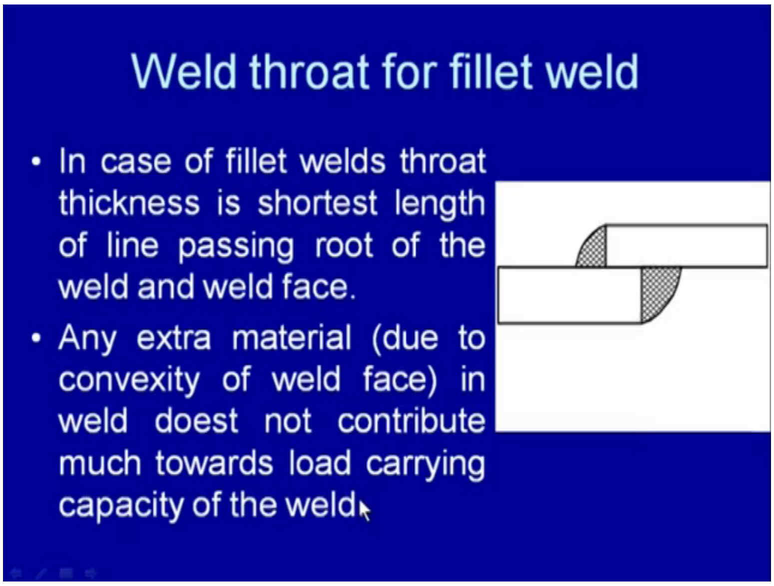

While in case of the fillet weld, the throat thickness is the shortest length of the line passing through the root of the weld and the weld phase. So, means this is the root of the weld and this is weld phase, so whatever line shortest line passing through the weld and the root of the weld that will be this one. So, any extra material due to the convexity of the weld phase in due to the convexity of the weld geometry in the weld does not contribute much towards the load carrying capacity of the weld that is why it is not considered for determining, the throat thickness of the weld.

So, if you want to consider this is the root and this is the face of the weld then shortest length of the line which is passing through the root and the weld will be considered as a throat thickness. So, that is this dimension is used for determining, the throat thickness of the fillet weld. So, if we see the fillet welds can be deposited.

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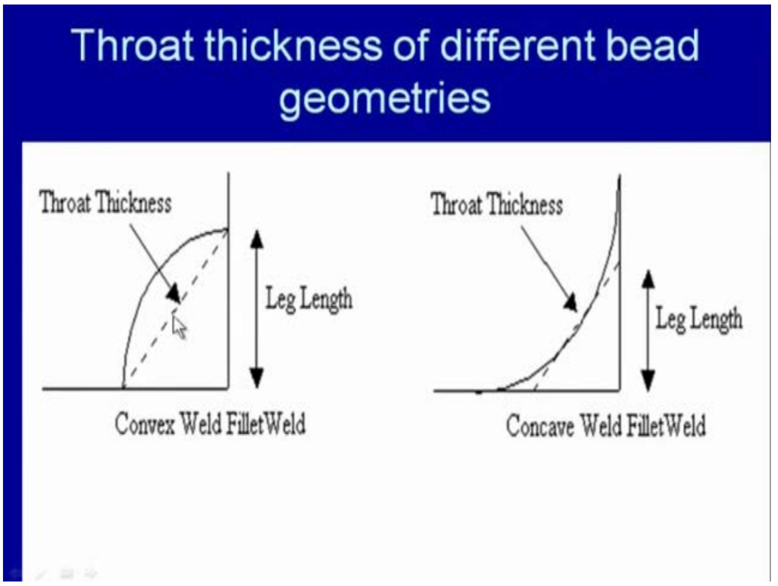

Using the various types of the geometries say for convex weld, the convex bead geometry is obtained in case of the concave fillet weld, this kind of geometry is obtained and to determine the throat thickness. One straight line will be which passing, through the fillet weld shortest length of a straight line passing, through the root of the fillet weld will give us the throat thickness.

So, length of this line which is passing through, the root will give us the throat thickness and in. So, if we see the this portion of the weld metal in case of the convex weld will not be considered for determining the throat thickness, while in case of the concave weld. This is the length of the straight line, which is passing through the root should be used for determining, the throat thickness and the length of the line from the root to the any one side of the weld is taken as the leg length.

The fillet weld is frequently identified from the leg length and theoretically, from the leg length we can directly determine the throat thickness. Because experimentally it is found difficult to measure this throat thickness of a the weld. So, for theoretically this throat thickness for the fillet weld is calculated with the help of the leg length. So, basically root 2 times of the leg length is used as a throat thickness of the weld.

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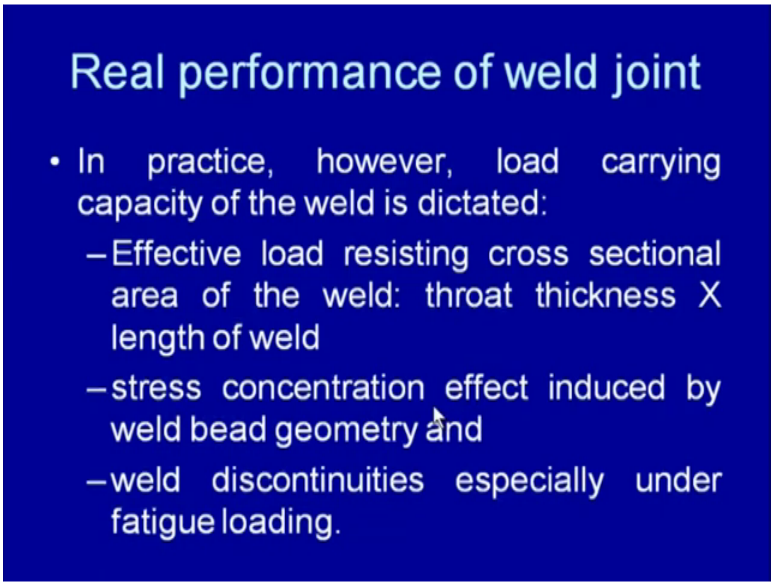

So, now the important factors that governed the real life performance of the weld joint are like effective load resisting cross sectional area of the weld, which is determined by the throat thickness and the length of the weld. So, throat thickness for the butt and fillet weld is identified in different stress as just has been described. Further, if any stress risers are present due either due to the weld bead geometry or the partial penetration or some defect is present then the stress risers will be having their effect on the real performance of the weld joint. And further the weld discontinuities will also be significantly affecting the mechanical performance under the fatigue load conditions.

So, not just the weld metal properties, but the weld cross sectional area, the stress represents of its stress risers and the discontinuities in the weld dictate the tensile as well as the fatigue load performance of the weld joint. And therefore, it becomes important to look into the step by step approach for designing, the weld joint and as far as the procedural steps required for designing the weld joint include, the identification of the need for designing the weld joint.

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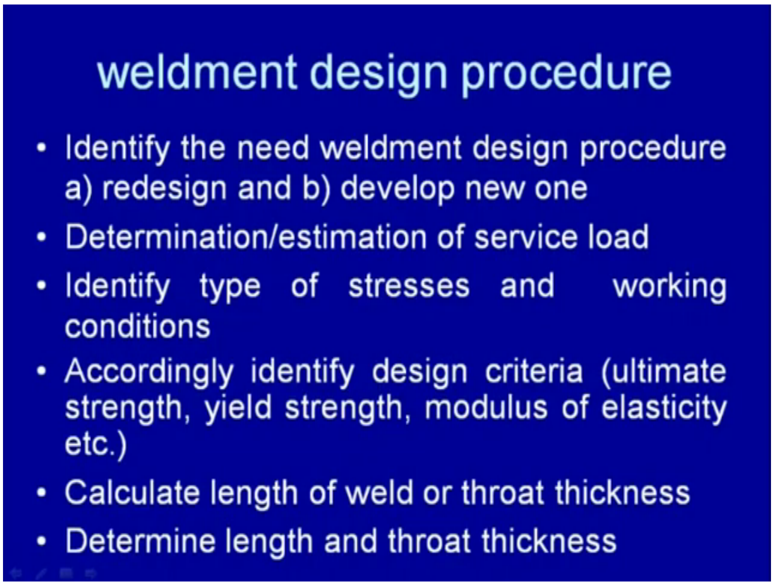

It means what is the need of the designing a particular joint. So, means whether the case is related with the redesigning of the weld joint due to the failure history of a particular existing joint or a new entire new joint is to be developed. So, depending upon the case based on the service conditions of the failed component, if designing is redesigning is required then based on the service conditions. That is load environment and the kind of metal system, kind of weld joint geometries, which have been used earlier all those are rig all those are considered.

While when redesigning of a particular joint, while for developing the new joint again keeping the service conditions in mind, the new the various aspects related with the weld joint design are considered. And this will involve first the determination of the service load means, what is the maximum load, which is expected in the weld joint during the service.

So, many times it becomes, it is available data regarding the service load is available, but sometimes it is to be estimated based on the experience. The second is the identification of the type of stress and the working conditions. So, means what type of stresses will be acting on the weld joint during the service will be, these will may be in form of tensile or the shear or the bending or the torsional kind of the load will be acting on the components.

So, accordingly we will be using the suitable the design criteria and the suitable kind of the allowable stresses for designing the weld joint. And the working conditions will are also identified to see that, whether the joint is suppose to work. Under the normal ambient conditions or it will be used at either low temperature or high temperature conditions or in the corrosive in atmosphere or in a particular specific kind of a environment.

So, based on those service conditions, the special property requirement for designing of the weld joint is also considered. Say material should have the load, should have the very low ductile to brittle transition temperature, if the weld joint is to be used under the sub 0 conditions. And it should have very good creep resistance, if it is to be used under the high temperature conditions, further if the weld joint is to be used in a corrosive environment then it should be checked whether the weld joint is sensitive for that environment or not.

So, according to the kind of environment, which is to be in, which weld joint is suppose to work the suitable weld material, base material and the filler materials are identified and the welding weld joint is designed. So, based on the kind of the loading and the type of the stresses and the service conditions suitable design criteria is identified. So, while identifying the design criteria, we tried to we will try to establish whether the ultimate strength will be used for the design purpose or it will be yield strength or the modulus of elasticity.

And based on this we will be identifying the allowable stresses, which will be used for calculating the load resisting load resisting cross sectional area of the weld joint for a given service load. So, for a given service load we determine, the allowable services, allowable stresses, for designing the weld joint and based on the allowable stresses. We try to determine the load resisting cross sectional area and from the load resisting cross sectional area using the available value of the throat thickness weld length is a calculated.

So, basically we tried to calculate the length of the weld for given throat thickness area. Because throat thickness area for the groove weld is normally, fixed which is taken as the minimum thickness of the plate or in case of the fillet weld. It is also the minimum fillet size of the welds are also fixed for the different thicknesses, so some most of the time throat thickness is fixed.

So, basically we try to determine the length of the weld. So, determination of the length of the weld and the throat thickness helps us in establishing, the load resisting cross sectional area as a part of the design of the weld joint. So, for designing the weld joint for the static loading on the procedural steps will be started first for the static loading.

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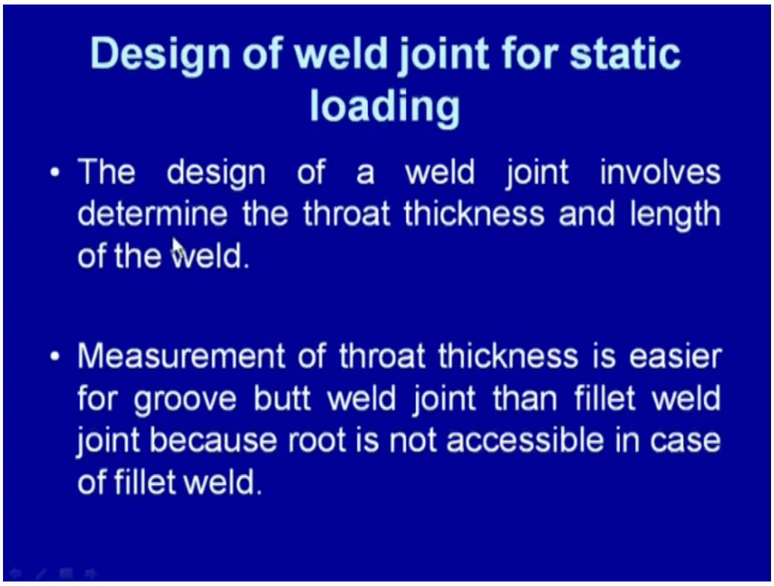

Design of the weld joint for a static loading, so as we have said that design of the weld joint involves determining, the throat thickness and the length of the weld. Measurement of the throat thickness is easier for the groove weld then the fillet welds. Because it is mostly found equal to the thickness of the thinner plate or the thickness of the plate in case of the equal plates, in case when the plates of the equal thickness are welded. But this kind of measurement of the throat thickness becomes difficult in case of the fillet weld, because the root is not accessible from the top for the measurement and that is why indirect calculations are done for determining.

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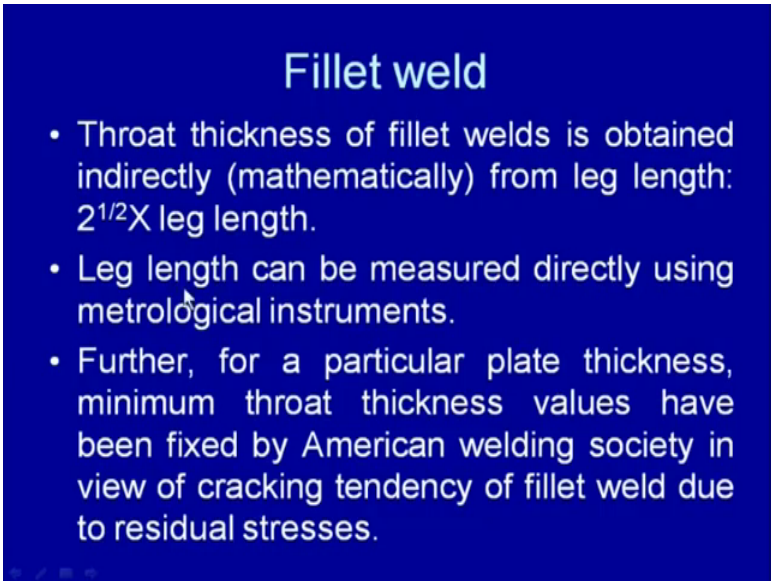

The throat thickness in case of the fillet weld, throat thickness of the fillet weld is obtained indirectly, mathematically from the leg length under the root 2 times the leg length is equation, which is used for measuring the throat thickness of the fillet weld. Leg length can be measured directly, using the suitable metrological instruments, further for a particular plate thickness minimum throat thickness values also have been fixed by the American welding society. In view of the cracking tendency of the fillet weld due to the residual stress development. So, this is a important aspect and this, we can understand from this diagram here.

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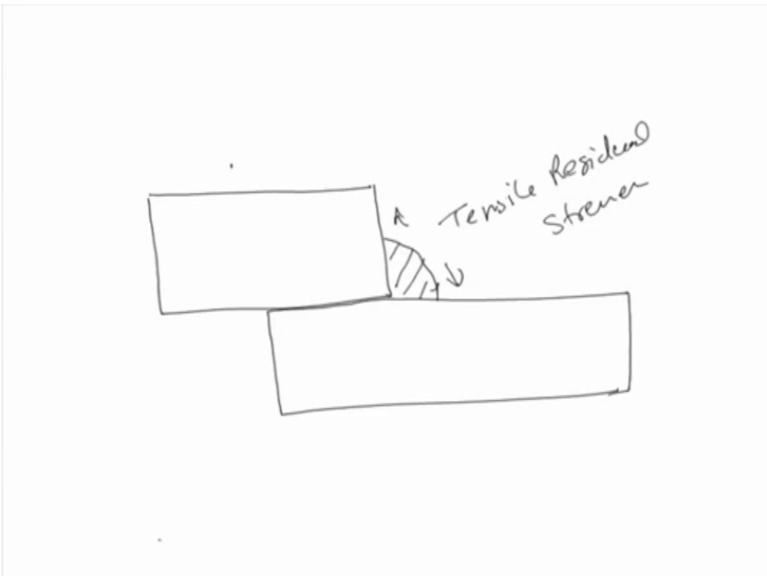

We can see that, if the plates to be welded are very thick and due to if we put in the fillet weld of very small in size, say of this. Then due to the development of the heavy tensile stresses, tensile residual stresses acting on the fillet weld will tend to crack it.

So, if the fillet weld is very small in size and deposited in very thick plate, then due to the differential expansion and contraction of the plates, which are being welded by the application of the heat during the welding will be resulting in heavy tensile residual stresses. And these tensile residual stresses tend to crack the weld from the phase or from the toe of the weld, so to avoid this kind of the cracking tendency.

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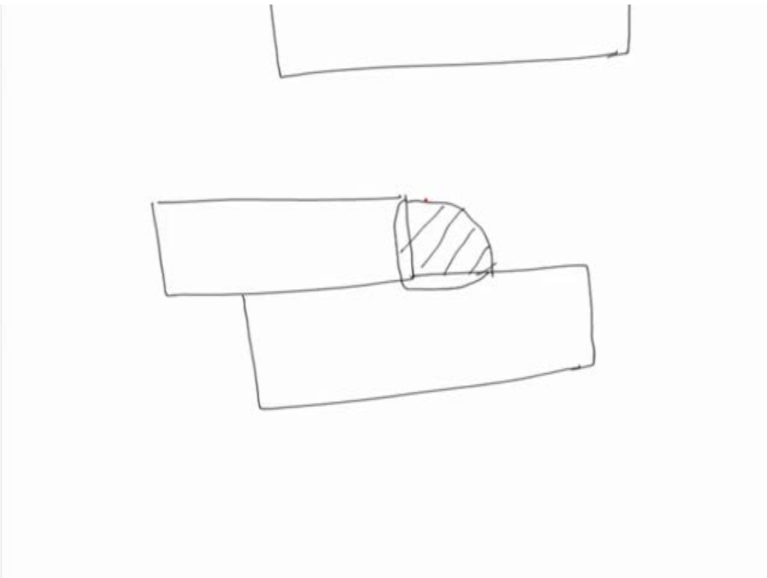

In case of the fillet weld minimum fillet weld sizes have been identified by and the American welding society and according to that some minimum size of the fillet weld must be deposited for the plate of the given thickness. And these dimensions minimum size of the fillet weld, which should be deposited according to as given by the American welding society will be shown in this in the next slide.

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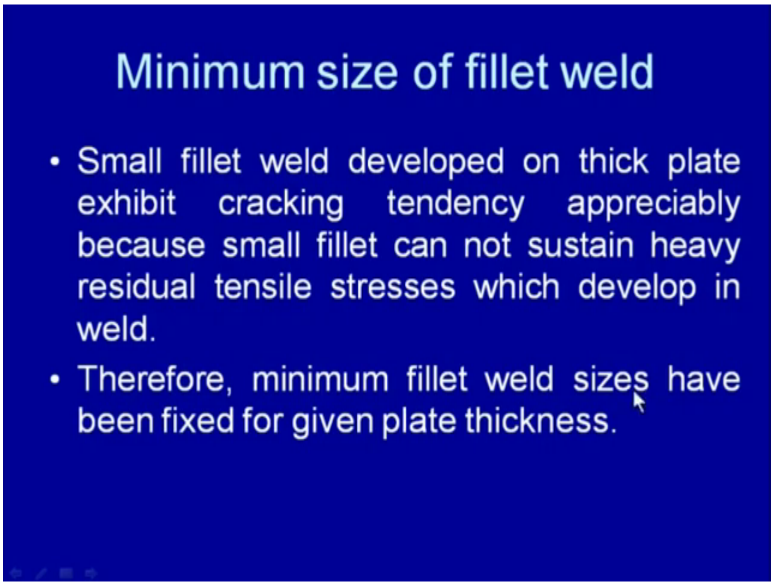

So, the minimum size of the fillet weld this is the reason, which has been explained the small fillet weld develop at, developed on the thick plate exhibit the cracking tendency appreciably. Because a small fillet cannot sustain the heavy residual stresses, which develop in the weld, and therefore minimum fillet weld sizes have been fixed for given plate thickness.

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We can see that this is the minimum the a fillet weld size up to 6 mm, it is 3 mm. Fillet size up to thick 6 mm, plate thickness 6 to 13 mm, it is 5 mm plate size and for 13 to 19 mm, it is 6 mm and above 19 mm, 8 mm, fillet weld size is fixed. If we can see the for further wider range of the plate thicknesses.

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Minimum effective throat

Plate thickness of thicker part jointed (mm)	Min. eff. throat(mm)
Up to 6	3
6 to 13	5
13 to 19	6
19 to 38	8
38 to 57	10
57 to 150	13
Above 150	16

Then up to 6 mm, 3 mm minimum effective throat thickness 3 to 6 to 13, 5 mm, 13 to 19 6 mm, 19 to 38, 8 mm, 38 to 57, 10 mm and 57 to 150 mm, 13 mm. These are the minimum effective throat thickness of the weld, which should be deposited for developing the sound weld joint without development of the crack. And above the 150 mm thicker plates minimum 16 mm weld fillet, weld size must be developed. So, now we will talk about the step by step methodology for designing the weld joint for the static loading.

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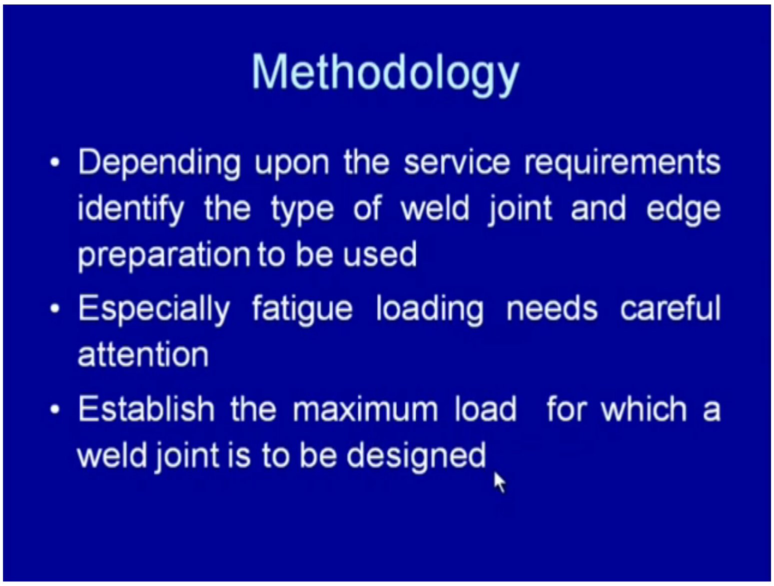

Now, depending upon the service requirements identify the type of the weld joint, which is to be used and the edge preparation to be used. These are the 2, very important things, because service requirements are of say static type, then we can work with even the fillet joints. But, if they are dynamic then frequently the groove butt weld joints are used. Similarly, the edge preparation is done in such a way that the full penetration can be achieved for a given plate thickness. So, the edge preparation must be in such a way that, it develops the minimum residual stresses. Requires a minimum weld metal at the same time full penetration is achieved effectively, for developing the full penetration weld joint.

So, especially under the fatigue loading conditions, these aspects require full consideration and proper consideration. Especially, as far as the selection of the type of weld joint is concerned and the edge preparation, which is to be used. And after selecting based on the service requirements and the selection of the type of the joint and edge preparation to be used, we will try to establish the maximum load for which the weld joint is to be designed.

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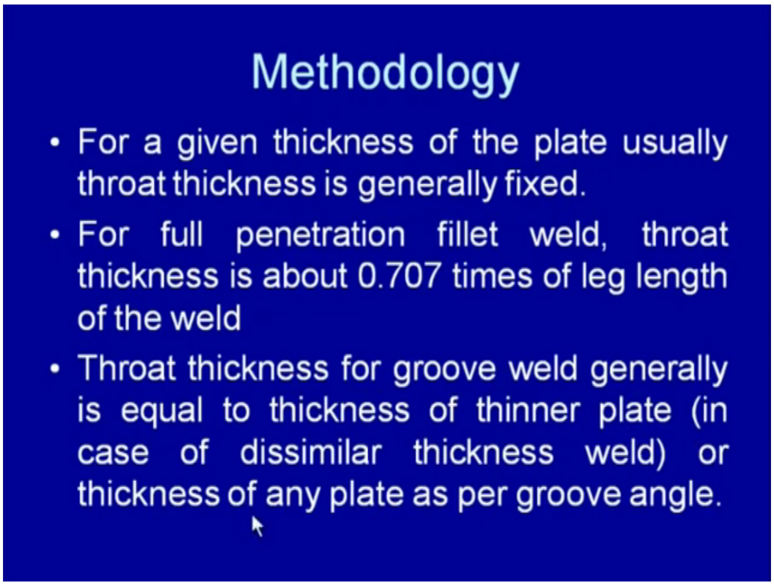

For a given plate thickness usually throat thickness is fixed. So, for full penetration weld throat thickness is usually about 0.07 of the leg length of the weld and throat thickness for the groove weld. Generally is equal to the thickness of the thinner plate in case of the similar thickness weld or the thickness of any or the thickness of the any plate as per the groove angle, when the plate of the equal thicknesses are welded.

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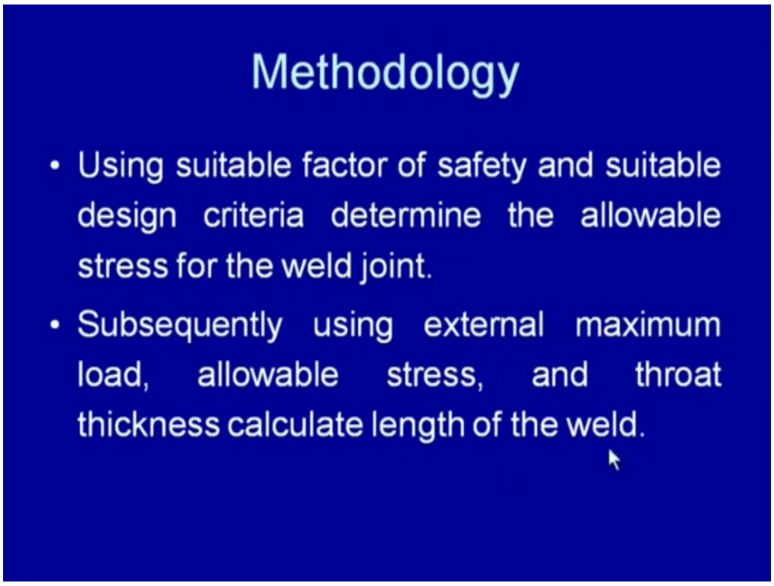

So, using suitable factor of safety and suitable design criteria like whether, it will based on the ultimate strength, yield strength or the modulus of elasticity the allowable stress is obtained for the weld joint. So, using factor of safety means using the that the yield strength or the ultimate strength or modulus of elasticity will be dividing the factor of safety to obtain the allowable stresses for designing the weld joint. And subsequently, the external maximum load allowable stress and the throat thickness is used to calculate the length of the weld.

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$$\frac{P}{t \times \delta} = L$$

So, basically what we do the load for, which the joint is to be designed that is p, then load divided by the throat thickness into the allowable stress. These 2 will be used to identify the length of the weld that is to be determined. So, this sigma basically allowable stress and that will be based on the kind of the property or the design criteria, which will be used for designing the weld joint. And the t becomes the throat thickness, which will be based on the type of the weld, which is to be used for a given plate thickness.

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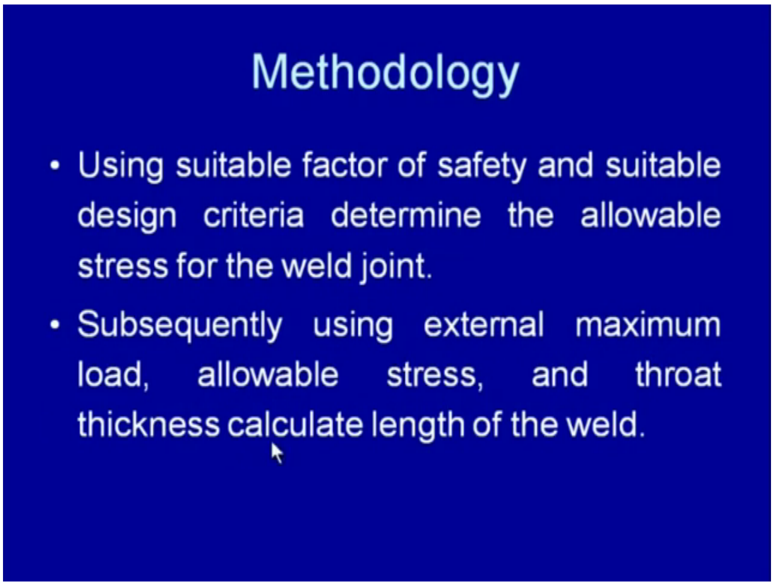

So, using the external means, the maximum load for which joint is to be designed allowable stress and the throat thickness, basically is the length of the weld is calculated.

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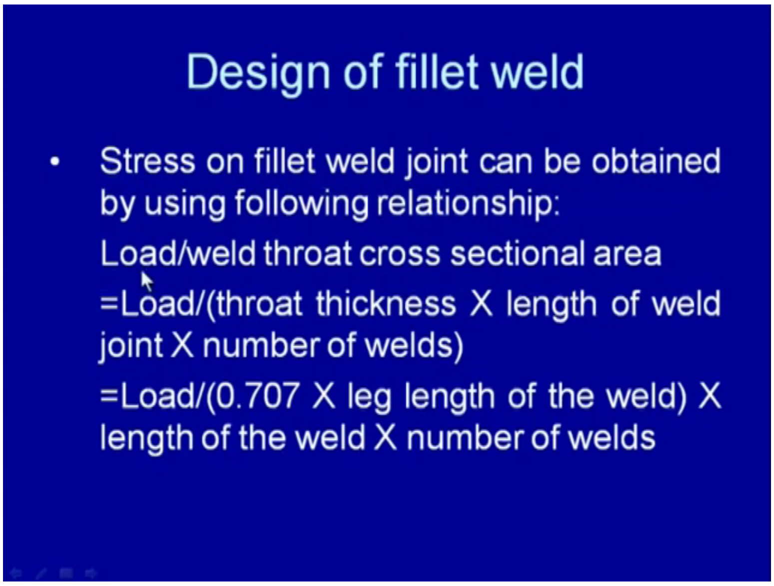

So, for designing the fillet weld the stress on the fillet weld joint can be obtained using the following formula that is the load divided by the load resisting cross sectional area and the load divided by the throat thickness multiplied by length of the weld into the number of weld. And the load divided by 0.0707 into length of the weld into the length that is the leg length of the weld and the total length of the fillet weld multiplied by the number of weld. So, this will give you the will give us the stress, which will be generated or which will be acting on to the component.

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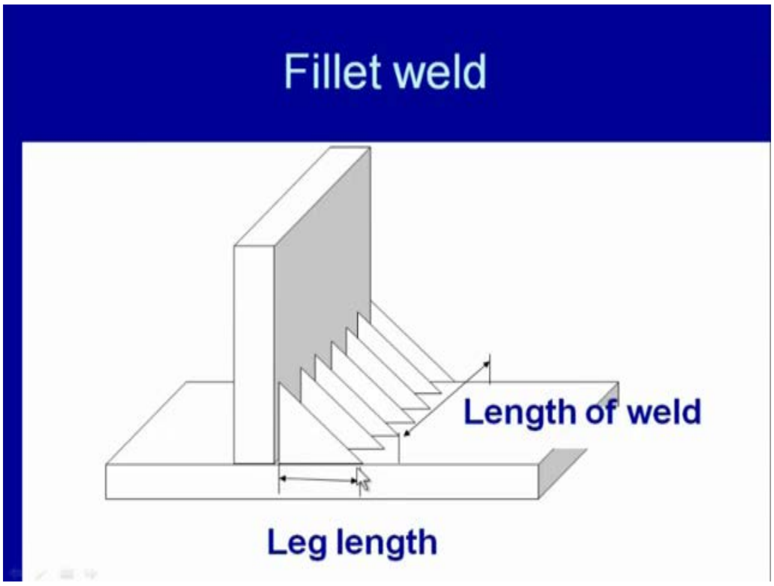

So, the leg length say this is the schematic diagram showing the say this is the fillet weld being fillet weld, where this is the leg length and this is the length of the weld. So, since the minimum the fillet weld size is fixed for a given plate thickness. So, that is to be deposited, which will give us the leg length and from this we can identify the throat thickness using the suitable equation. And this throat thickness will be used in combination with the external load for, which weld is to be designed to identify the length of the weld to be obtained. So, basically we use the external load for which weld joint is to be designed then allowable stresses and the throat thickness of the weld to determine the length of the weld.

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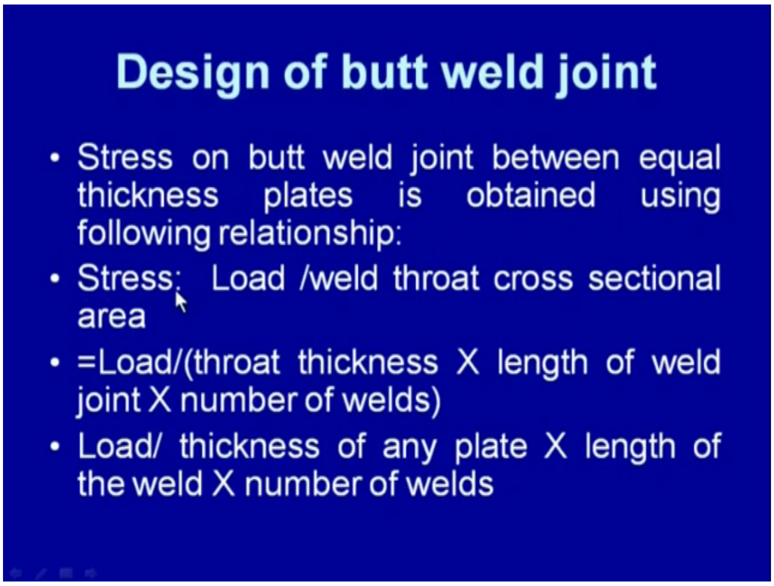

To design the butt weld joint, the stress on the butt weld joint between the equal plate thickness is obtained using this relationship, where the stress is equal to the load divided by the weld cross sectional, weld throat cross sectional area. Where and further the load divided by weld throat thickness multiplied with the length of the weld into the number of weld.

So, the number of the welds will be the case, when the weld is not deposited continuously, but the weld of the smaller then the length of the plate is to be is being deposited and the number of welds of the same lengths are being deposited. So, that is how that the load resisting cross sectional area for the butt weld is obtained. And using this the load divided by the thickness of any plate multiplied by the length of the weld, length of the each weld that is being deposited and the number of welds that are being deposited.

So, using this basically we try to see that, what is the stress, what will be the stress, which will be generated. Otherwise, for identifying the length of the weld, which is to be deposited, basically we use divide the load resisting cross sectional area. So, we divide the external load with the throat thickness and the allowable stress, which is allowable stress for which weld joint is to be designed. So, basically p divided by the throat thickness into the allowable stress that sigma will give us the length of the weld. For which it is to for a particular load for, which the butt weld joint is to be designed.

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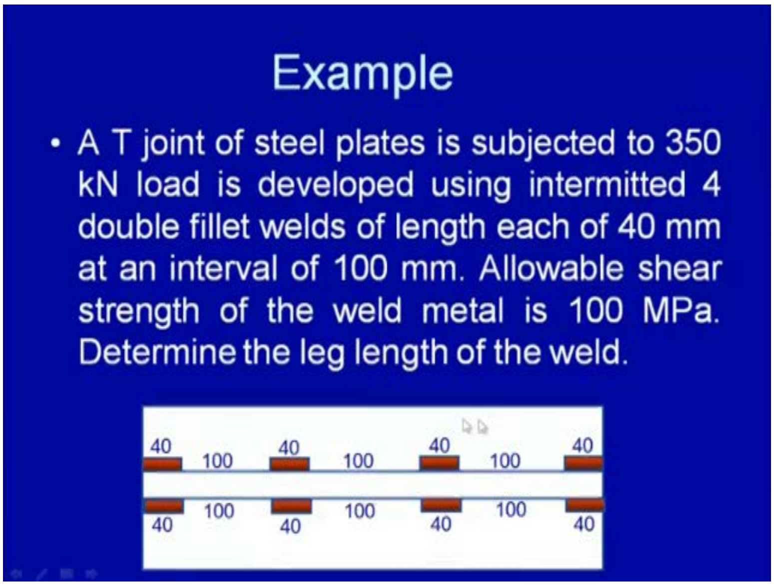

Now we will see one example, to show that how the design of the weld joints can be made. So, in the design of the weld joints, either we have to determine the throat thickness of the weld or the length of the weld. In such a way that the our weld load resisting cross sectional area can successfully, sustain the external load for a given allowable stresses.

Say for in this example, if we have to develop a weld t joint of the steel plate, which is subjected to load of 3 50 Newton. And it is developed using the weld joint is developed, using the 4 intermitted double fillet welds of length of each 40 mm at an interval of the 100 mm and allowable shear strength of the weld metal is a 100 M P a then they determine the length of the weld.

So, the case is like this, where the one bottom plate is there and the another one horizontal plate is there and another plate is kept vertically and that the double fillet welds are made on both the sides of the vertical plate. And the length of the plate is of the weld is of 40 m m and the at this kind and in the 40 double fillet, a 4 double fillet welds are to be made. Each of the 40 m m length and there is a pitch of between the each weld is of the 100 m m. If the allowable stress, allowable shear stress, shear strength of the weld metal is of the 100 M P a, then we have to determine the leg length of the weld.

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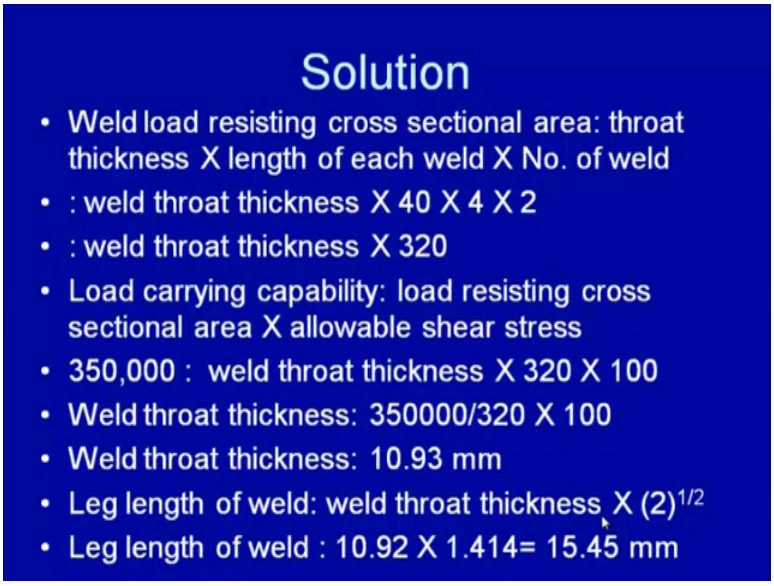

So, solution goes like this where we basically try to see that the how applied how to calculate, the load resisting cross sectional area. So, that it can sustain the external load which is being applied. So, weld load resisting cross sectional area is obtained from the throat thickness of the weld multiplied by length of the each weld and the number of welds, that are being made.

So, the weld throat thickness is not known, here in the initial stage and the 40 m m is the length of the weld and 40 m m is the length of the weld and 4 number of the welds in 1 side then the number of welds in both the sides is to be multiplied by 2. So, there will be 8 number of the fillet welds, each of the 40 m m length and the weld are throat thickness is to be obtained. So, weld throat thickness multiplied by 3 sorry, 320 which will be obtained from the calculation of this 40 multiplied by 4 into 8 and the load carrying capability of the fillet weld is obtained from the load resisting cross sectional area multiplied by the allowable shear stress.

So, we know that the external load, which is being applied is of the 3 50 Kilo Newton. So, that is converted into the Kilo into the Newton. So, here 350 1000 Newton load is being applied and that is being equated to the weld load resisting cross sectional area and for that, basically throat thickness multiplied by 3 20 and multiplied by the allowable shear stress that is 100.

So, throat thickness multiplied by 3 20, this shows the weld load resisting cross sectional area and multiplied by the 100 shows the shear strength of the weld joint. Since we do not know the weld throat thickness. So, this we can calculate from the 3 50 1000 divided by 3 20 multiplied by 100. So, from this we get weld throat thickness of the 10.93 m m.

So, to calculate the leg length of the weld, it is we use very simple equation, where weld leg length is formed the product of the throat thickness of the weld fillet, weld multiplied by the square root of the 2. So, here the leg length of the fillet weld multiplied, it is equal to the 10.92 multiplied by 1.414. So, that becomes equal to the 15.45, this is how the leg length of the fillet weld can be obtained. So, here in this case, first we have calculated throat thickness of the fillet weld and then leg length of the fillet weld.

So, this is how we can determine the leg length of the weld or throat thickness of the weld, if the length of the weld is given and in there can be reverse situation, where if the throat thickness is given, then we may be required to calculate the length of the weld.

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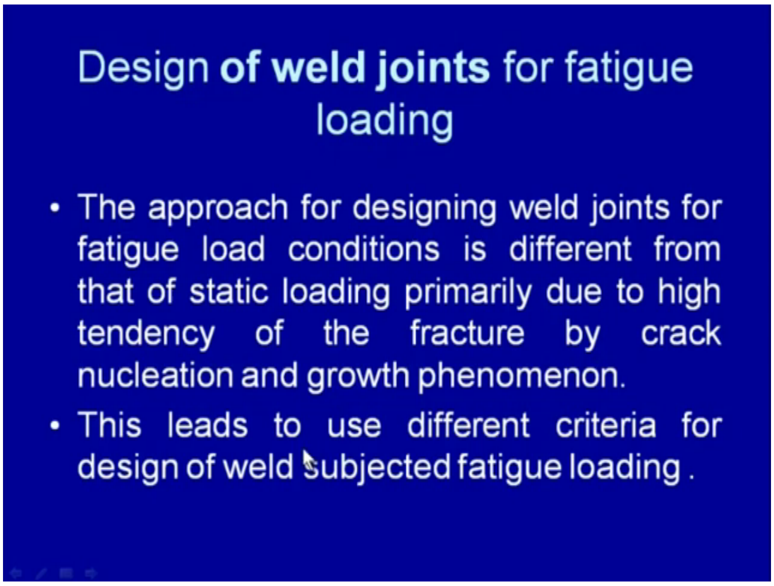

The approach of designing, the weld joint for fatigue loading conditions is found different from that of the static loading primarily due to the high tendency of the fracture by crack initiation and the growth phenomena. And this leads to the use of the different criteria for designing of the weld joint for fatigue loading. So, in for the design of the fatigue loading basically, starts with the identification of the class of the weld for, which it is to be designed.

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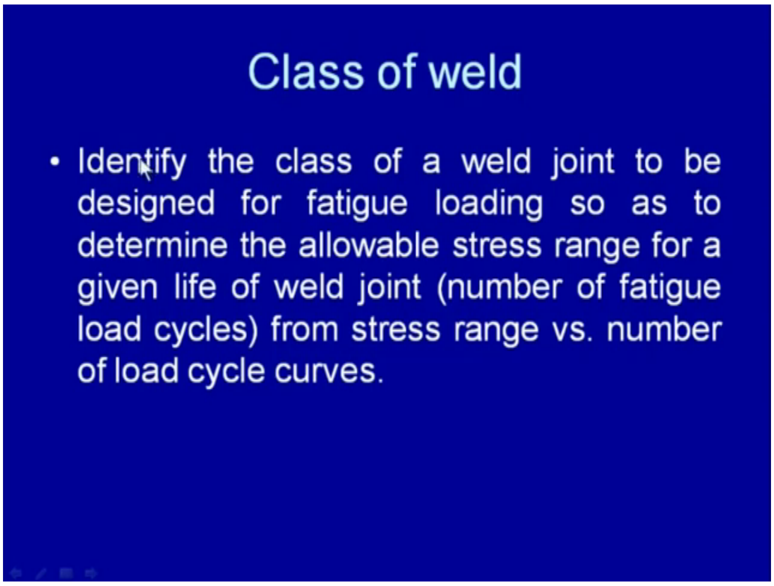

So, first we try to identify the class of the weld joint, which is to be designed for the fatigue loading. So, that allowable stress can be obtained for the given life of the weld joint. So, the weld joint for which the life for, which weld joint is to be designed the it is class is identified, first and based on the life for which weld joint is to be designed and it is class, the allowable stress is identified. And this identification is done based on the s n curve, which has been developed for the different classes of the weld of the different metal systems.

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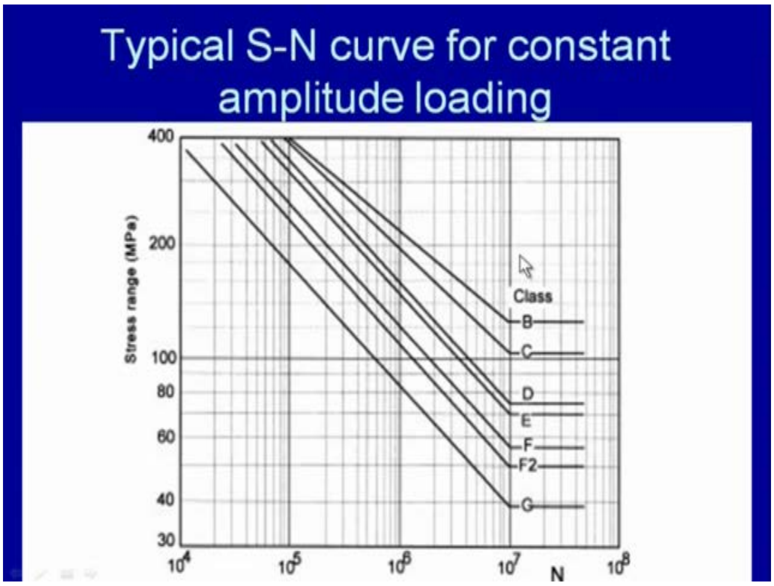

Say one typical, s n curve showing the relationship between the stress range and there the and means the number of cycles required for failure for different classes of the weld. So, higher is the class of weld means, the minimum severity, minimum effect of the weld on the performance fatigue, performance of the weld joint. So, higher is the class means, A class B class C class means, these are the different classes up to the f 2 and g. So, the B class indicates, that the effect of the welding on the fatigue performance is minimum and a class stands for those base metals, which are not yet welded or they are not carrying any load.

So, unwelded plates will be falling in case of in the A class category and while if the weld joint has been made on the plate, which is not carrying the load, but only the joint has been made, then it will be acting as A B class. So, there are various kind of situations where, whether the load is being taken by the weld or load is not being taken by the weld or the type of the weld, which is being made the severity of the loading the direction of the loading. There are various factors that affect the class of a particular weld.

So, that is what we will be looking in these subsequent slides, but the important thing is that based on the type of the loading. The type of the weld joint and the possibility of the failure by cracking of the weld and the kind of the joint, whether it is partial penetration or the full penetration the given weld joint is categorized into the different classes.

So, once the class of the weld for, which it is to be designed is identified, we try to establish the allowable stress range. Say if the weld joint is to be designed for the life of 10 to the power 5 number of cycles for g class weld, then the allowable stress will be somewhere, say this 190 M P a. But, if the same class of the weld is to be designed for 10 to the power for 7 number of cycles, then the class then the allowable stress range will be some will be about 40 M P a.

So, while for the same the life say, that is 10 to the power 7 number of the load cycles. If we compare the different classes of the weld then the minimum the then the maximum stress range for 10 to the power 7 number of cycles. For B class of the weld is say around a 100 10 M P a, while for the f 2 class of the weld, it is around 50 M P a, while for g class of the weld, it is about 40 M P a.

So, the class of the weld significantly, affect the allowable stress range for which the weld joint can be designed. So, basically designing of the weld joint for fatigue loading starts with the classification of the weld of classifying, the weld of a particular for a particular class. And based on the life for, which weld joint to be designed and it is class, we try to establish the stress range, allowable stress range and this allowable stress range is used for determining the load resisting cross sectional area. We know that the throat thickness is fixed for the butt groove butt weld joint and for the fillet weld joints. So, basically using a throat thickness we try to determine the length of the weld for a given external loading. So, the so basically, this s n curve is used to identify the what will be the allowable stress range, for a given class of the weld, when it is to be designed for a particular number of the load cycles.

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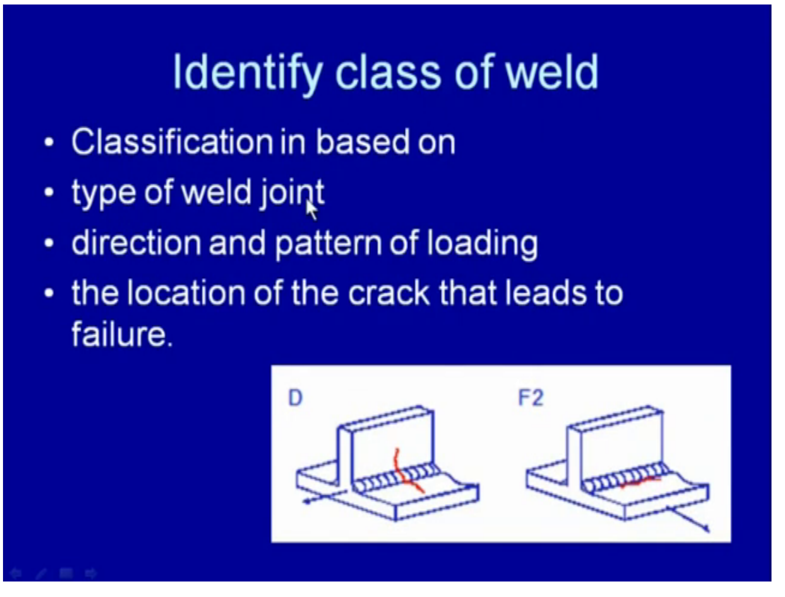

So, so as far as identification of the class of the weld is concerned the, we need to see the type of the weld joint to be made and whether it is the butt joint or the lap joint or the fillet joint the t joint. So, depending upon the type of the weld joint, we classify the welds in the different class, we put the weld joints in the different classes. And the direction and the pattern of loading means, the load is tensile shear or the load is acting on the on the base material only or it is acting on the weld metal, itself or in which direction crack is growing.

Say just for example, this is the t joint, where the fillet weld has been made to have the t joint and in one case the load is acting in the direction of the weld, while in other case load is acting perpendicular to the weld. So, the situation when load is acting perpendicular to the weld crack grows along the say along the length of the weld, while in another case crack grows perpendicular to the direction of external loading. Although growth in both the cases is perpendicular to the external loading, But in this case the crack grows parallel to the weld, while in case crack grows perpendicular to the weld.

So, if we have to classify these 2 situations, where same type of the weld joint is made, but depending upon the kind of loading direction and the way by which crack grows in the 2 cases. This joint is categorized as a the joint, where load is acting along the length of the weld, it is categorized as A or D class and the when the load is acting perpendicular to the weld length or the direction of the weld the joint is categorized as f 2 class. We know that higher is the class greater will be the allowable stress range and the say lower is the class means, A is considered as a higher class and B C D F G all these are considered as the lower and the lower classes.

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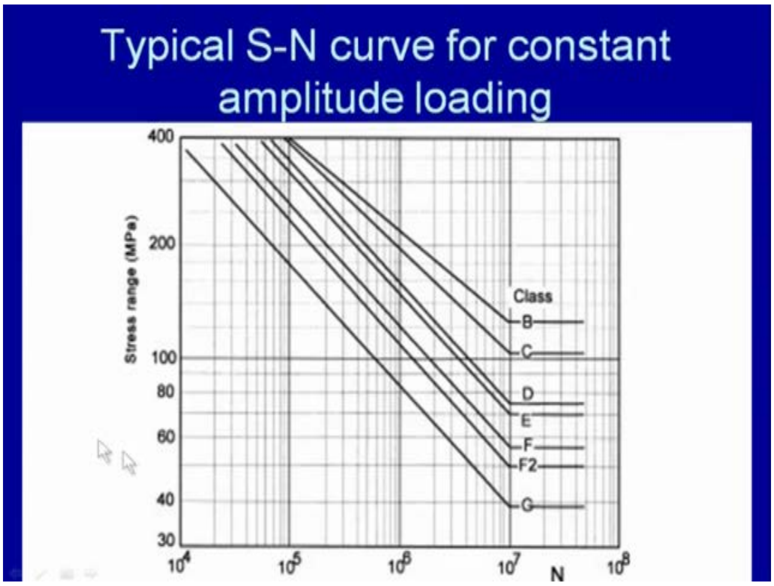

So, if we can see here, further this diagram B will be considered in the higher class and C D E F F 2 G will be considered in the lower class. So, lower is the class of the weld lower will be the allowable stress range and this allowable stress range will be used for determining, the load resisting cross sectional area for the fatigue joint for designing the weld for fatigue joint.

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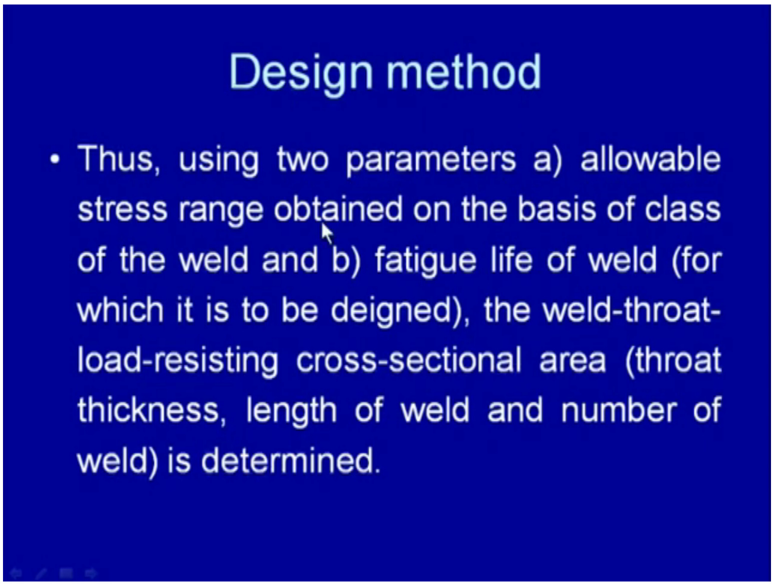

So, designing methods for the fatigue loading is concerned, using the two parameters that have been identified like the allowable stress range obtained on the basis of the class of the weld. And the life for which, the weld joint is to be designed basically, we try to establish the weld throat load resisting cross sectional area. So, the primary aim is to identify the weld load resisting cross sectional area. For designing of the weld joint, we know that the throat thickness and length of the weld and number of the weld.

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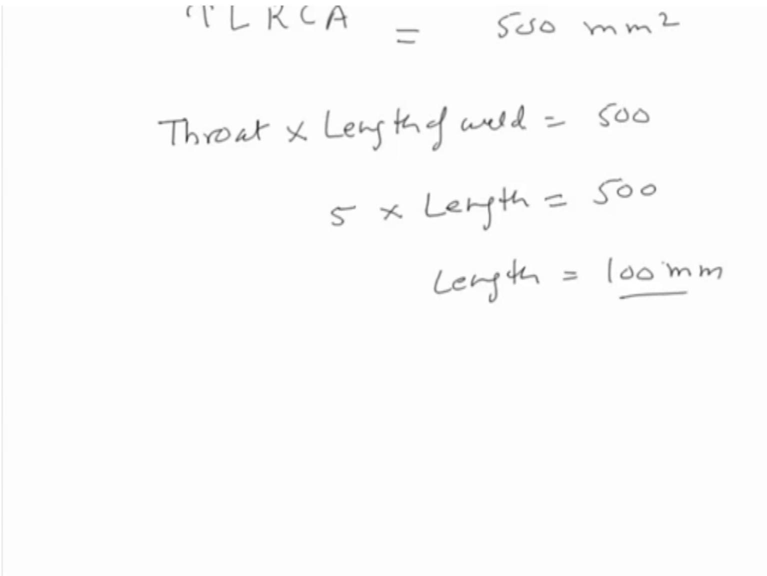

So, the weld resisting cross sectional area will be composed of the throat thickness length of the weld and the number of weld that is to be developed. So, if the throat thickness is fixed then we can determine the total length of the weld, which is to be made. So, if we are going to develop the weld of a smaller length, then number of the weld is also identified say for example, if the throat say we can see here this example.

Say the load resisting cross sectional area, which comes out to be after the designing is 500 mm square, this is the total load resisting cross sectional area, so 500. So, basically this is composed of throat thickness and the length of weld say 500 mm square. So, if say for a given weld throat thickness is fixed of 5 mm, then the length of the weld that will be deposited can be obtained from this. So, length of the weld will be say 100 mm. So, if we either, we can deposit the entire length of the weld in one go or if you have to deposit.

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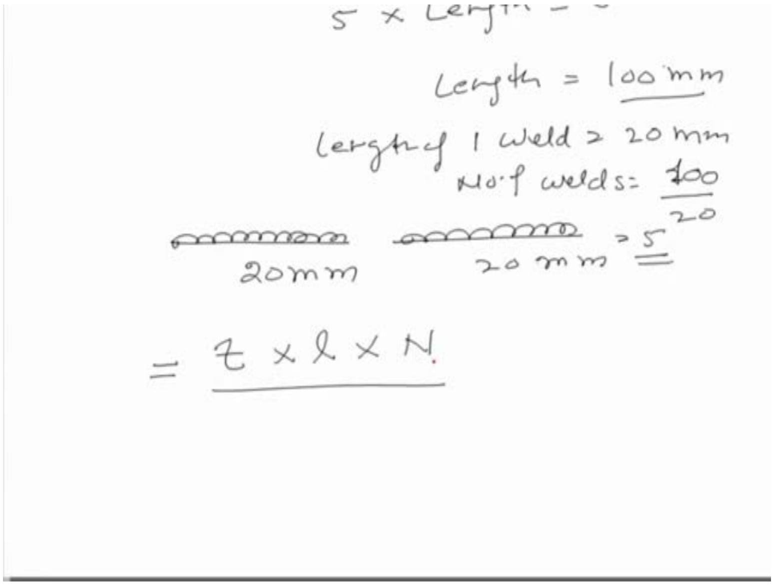

If you want to deposit the weld of the smaller length in order to control the residual stresses then say, if you have identified that only 10 mm length of the weld will be deposited in 1, go then this kind of 5 different number of welds. We need to made each will be of the 20 mm.

So, that will give us the total number of welds. So, if the length identified is 100 mm. So, so say if length of 1 weld is 20 mm, then the number of welds required 100 divided by 20. So, we need to deposit in that case the 5 different numbers of welds. So, this is how, we can determine the total load resisting cross sectional area, which will be basically the total load resisting cross sectional area will be, basically the throat thickness length of 1 weld multiplied by the number of weld, that are to be deposited.

So, so there can be the internal adjustment between the length of the weld and the number of welds, which are to be made, there can be a single weld of a particular length which is desired. But, in order to control the residual stresses and distortion tendencies, it is preferred to deposit the weld of the smaller length.

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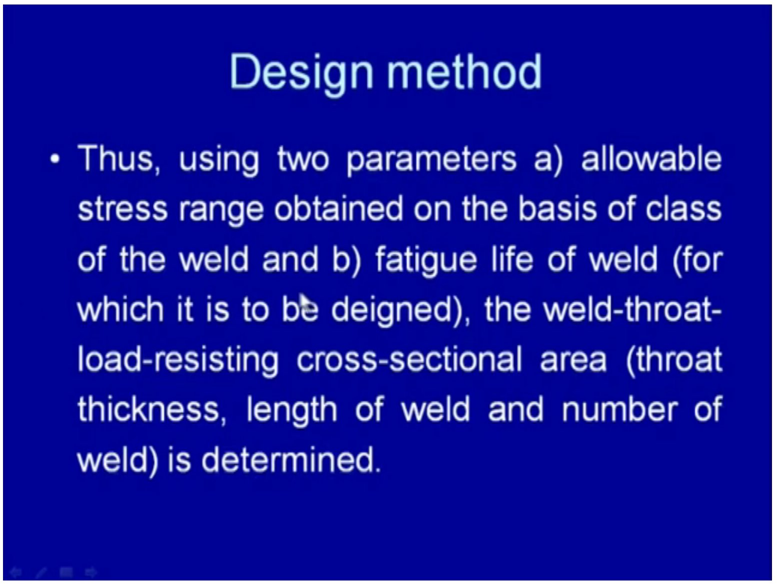

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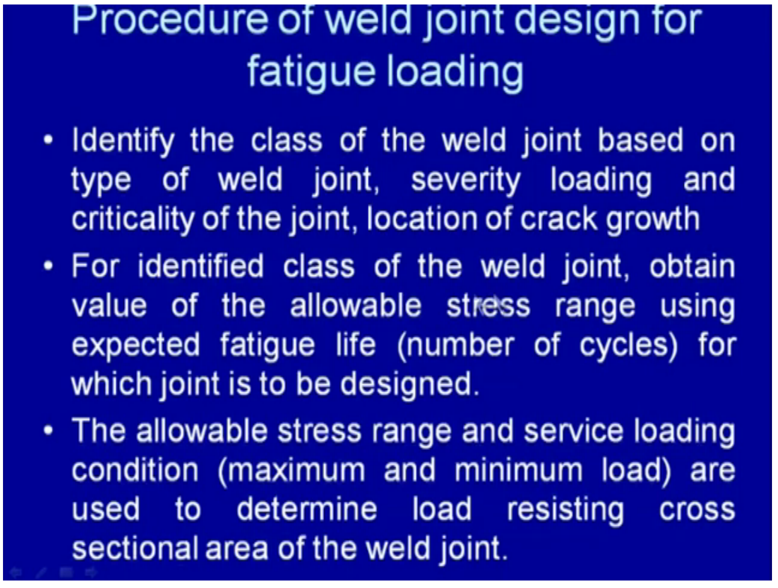

So, this is what is done for designing, the weld joint for the fatigue loading, basically using the allowable stress range obtained on the basis of the class of weld and the fatigue of the life for, which weld joint is to be designed. Basically, the weld throat resisting load resisting cross sectional area is identified and which is used to establish the length of the weld, which is to be deposited for a given throat thickness. So, procedurally steps are concerned for designing, the weld joint for fatigue loading.

First identify the class of the weld joint based on the type of the joints severity of loading criticality of joint and location of the crack growth. Then identify the class of the weld joint for identified class of the weld joint obtain the value of allowable stress range, using the expected fatigue life. For which joint is to be designed and then allowable stress range and the service loading conditions maximum and minimum loading are used to determine, the load resisting cross sectional area of the weld joint.

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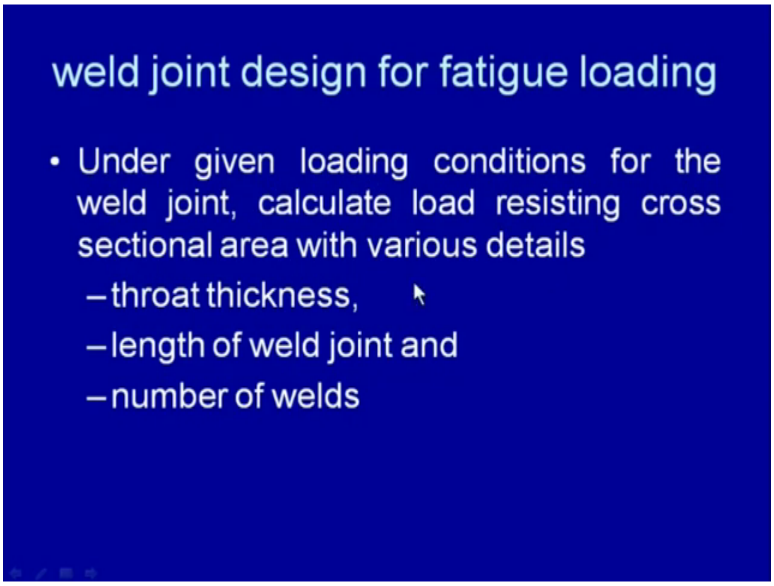

For then under the given loading conditions, for the weld joint calculate the load resisting load resisting cross sectional area with the various details like throat thickness, the length of the weld and the number of weld, which is to be developed. Generally the maximum length of the weld becomes same as the length of the plate to be welded. The number of the welds for butt weld is 1 and that for fillet weld can be 2, but if the weld is to be deposited in the shorter length then there can be number of the welds, which can be deposited in order to control the residual stresses and distortion tendency. This suggest that the primarily, the throat thickness of the weld is obtained, if the length of the weld and the number of plates are if the number of weld are fixed.

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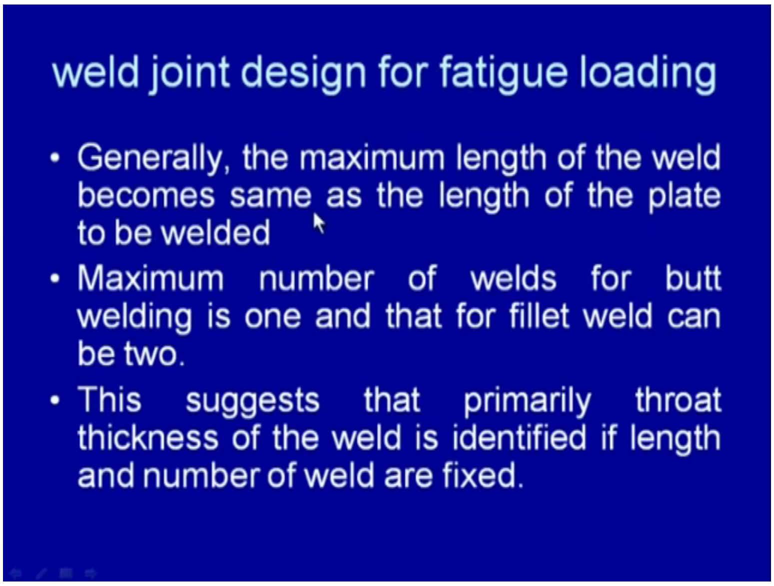

So, if due to the given constraint that the length of the plate or length of the weld cannot be greater than a certain length then throat thickness of the weld is identified. So, for a given load resisting cross sectional area depending upon the constraint, we can identify as a throat thickness or the length of the weld. So, if the length of the weld is fixed then the throat thickness is adjusted or if the throat thickness is fixed for given situation then the length of the weld is identified.

Else the weld joint parameters, such as throat thickness length of the weld, and number of the welds can be obtained in such a way that their product is same as the load resisting cross sectional area. So, this is the kind of internal adjustment, which is possible between the throat thickness length of the weld and the number of welds that can be deposited. In such a way that the it that they satisfy the requirement of the load resisting cross sectional area provided. The throat thickness requirement is fulfilled in case of the fillet welds, the important to note that the strength of the weld metal does not play any big role. Especially, under the severe stress conditions, which generally exist in the weld joint due to the presence of the notch and discontinuities.

So, the reasonably good strength of the weld metal is found, good enough for developing the weld joint for the fatigue load conditions, but too high strength of the weld metal does not help in enhancing the fatigue performance of the weld joint appreciably. So, for designing the weld joint for fatigue loading, what are the important requirements.

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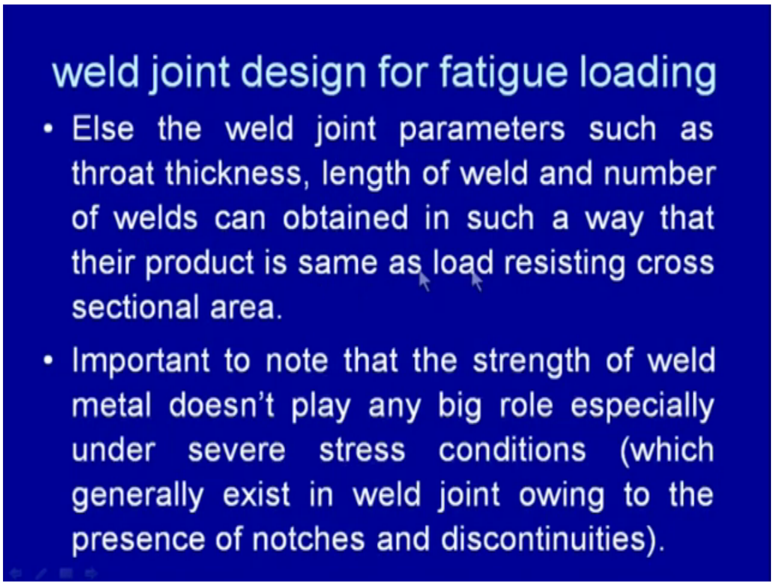

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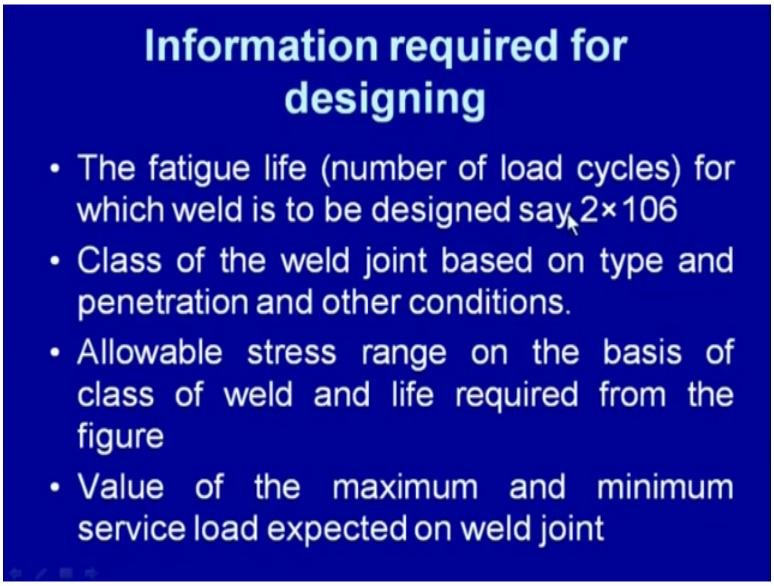

We need to identify the life for, which weld joint is to be designed say it is 2 into 10 to the power 6. Then the class of the weld joint based on the type and the penetration and other conditions allowable stress range on the basis of the class of the weld and the life required. And the value of the maximum and the minimum service load, which is expected on the weld joint.

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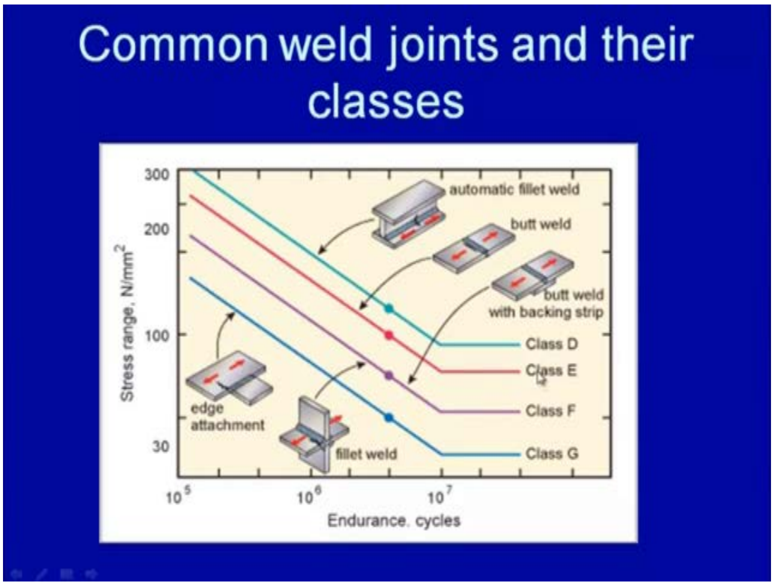

For developing the weld joints for applications, where fatigue loading takes place on the weld joint, it is desired to classify the weld joints under the different classes, which indicates the severity for which a weld joint will be subjected. So, higher is the class greater will be the severity of the stress conditions and lower will be the fatigue life of the component.

So, for the design purpose basically, the different types of the weld joints are classified or categorized first into the different classes and based on that, we decide the allowable stress range for a given butt joint. So, that the weld joint design can be obtained and the safe weld can be made.

Say for example, here the this the sky color line shows the d class allowable stress range versus the endurance cycle or the fatigue life relationship for the D class weld D class weld. Indicates that the loading, it is the fillet weld along the length of and the loading it is subjected to the length of along in the length of the weld. And this has been made using the automatic fillet automatic process to develop the fillet joint.

So, here for and they how it is used say for 10 to the power 5 number of the life cycles, the allowable stress range is 300 ampere and that for 10 to the power 6, it is about say 200 or 250 ampere. So, higher is the allowable stress lower will be the endurance cycle or the fatigue life of the component. Similarly, if we talk of the other classes of the weld joint say this one shows, the butt weld joint made and the loading load is applied in the direction perpendicular to the direction of the weld.

So, this kind of the weld falls in category of the E class and A F class weld, where the weld joint is made. Using again the butt weld, butt with the backing strip weld is made and the loading is applied again the in direction perpendicular to that of the weld joint. It falls in category of f and the cruciform and the edge joints or the cruciform of the weld joints fall in g category.

And if we see these relationships then the these are the most severely stressed or the joints subjected to the higher stress concentration and that is why, they lead to the lower allowable stress range as compare to the lower class weld joints like the D class. And the E class for the given life of 10 to the power 6 number of cycles, the stress allowable stress range for the G class weld joint is found to be bit lower then the 100 M P a, while that for the D and E classes, it is more than 200M P a. So, that shows that the lower is the class of the weld higher will be the allowable stresses for a given endurance cycle or the given fatigue life.

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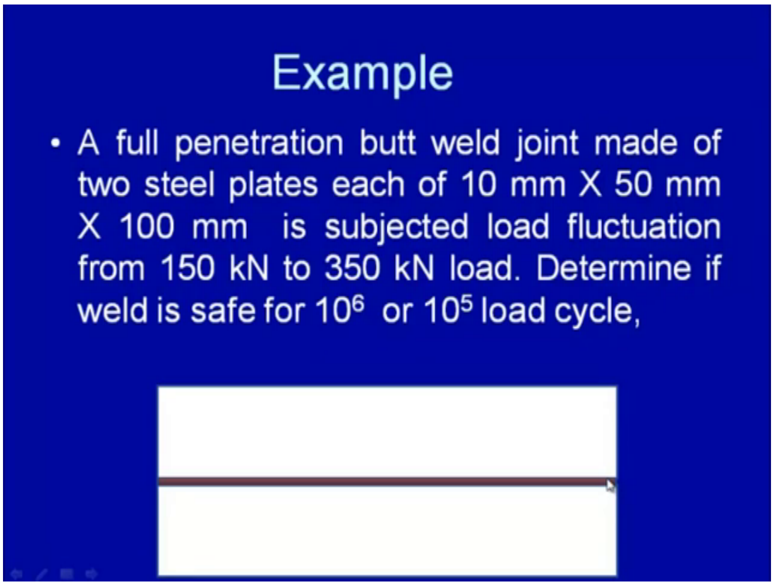

So, we will see one example to show that, the how the weld joint can be designed for the fatigue loading. Say for example, a full penetration butt weld joint made of the 2 steel plates, each of the 10 mm thickness 50 mm width and 100 mm length is subjected to the load fluctuation from 150 Kilo Newton to the 350 Kilo Newton. Then determine, if the weld is say for 310 to the power 6 or 10 to the power 10 to the power 5 load cycles. So, in this case say this is the length of the plate is a 100 mm and the full penetration weld is made butt weld is made along the length of the weld. So, in this situation if the transverse loading is carried out is in loading is in the direction perpendicular to that of the weld line.

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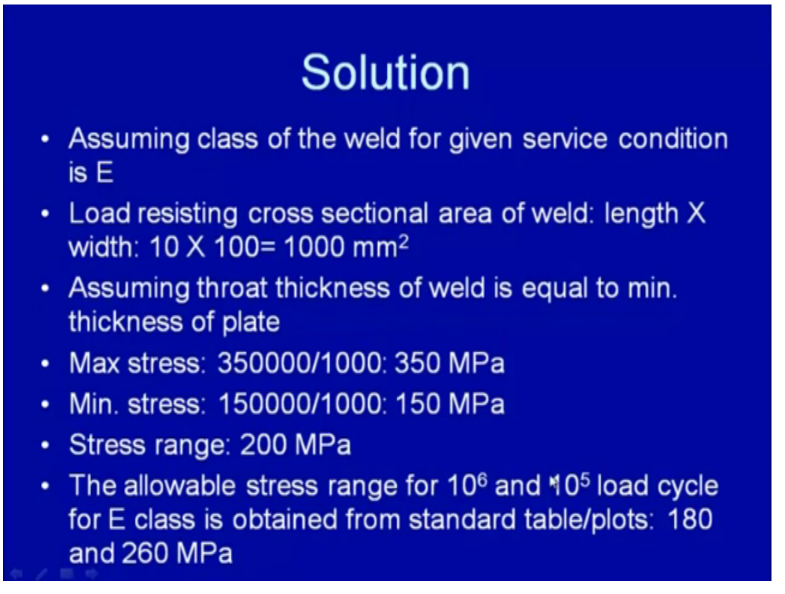

Then for this situation, we can determine whether the weld will be safe or not. Assuming the class of the weld for a given service condition is a e and load resisting cross sectional area of the weld is length of the weld multiplied by the thickness of the plate. That is corresponding to the width of the thickness of the plate corresponding to throat thickness of the weld basically.

So, 10 multiplied by 100 gives us the 1000 mm square and assuming throat thickness of the weld is equal to the minimum thickness of the plate. So, the maximum stress corresponding to the maximum load is obtained from 350 Kilo Newton that is the 3 lakhs 50000 Newton divided by 1000.

So, it gives us 350 M P a and the minimum stress is corresponding to the 150 M P a and the allowable stress range for the e class of the weld can be obtained. Allowable stress range comes out to be the 200 M P a then the allowable stress range for. So, here stress range corresponding to these conditions is 200 M P a. So, if the allowable stress range for 10 to the power 6, 10 to the power 6 and 10 to the power 5 load cycle for e class weld is obtained from the standard tables and plots then it comes out to be 180 and the 260 amperes. So, here we see the allowable stress range is obtained from the difference of the maximum stress to the minimum stress. So, 350 minus 150 gives us the stress range, which is acting under the given set of the loading conditions and allowable stress range for 10 to the power 5, 6 load cycles. It comes out to be 180 M P a and that for 10 to the power 5 load cycles, comes out to be of 260 M P a.

So, this suggests that the weld will be safe for the 10 to the power 5 load cycles, but it will not be safe for ten to the power six load cycles. Now we know that the fatigue failure of the component, it takes place very prematurely, if the design of the weld joint is not done properly. And this kind of fatigue is very fatigue failure is commonly encountered, especially in the weld joint because of the presence of the stress risers.

So, the we will be talking the mechanisms of the fatigue mechanisms that contribute towards, the failure of the component by the fatigue. And what are the factors related with the welding that affect the performance of the component, under the fatigue conditions. And what are the methods, which can be used for improving the fatigue performance of the weld joint during the service that, we will be taking up in the coming lecture.

But, as far as the summary of this present lecture is concerned in this presentation I have talked about the basic approaches, which are used for designing the weld joints for static and dynamic loading. And we have observed that the approach for designing, the weld joint for fatigue loading is different from the conventional design of the weld designs for the fatigue loading.

This the first the class of the weld is identified and based on the class of the weld and for a given life of the joint. We identify this allowable service allowable stress range and this allowable stress range is used for identifying the load resisting cross sectional area. So, other aspects related with the fatigue performance of the weld joint and various factors affecting, the fatigue performance of weld joint, we will be taking up in the coming presentation.

Thank you for your attention.