Welding Engineering

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Module - 6
Design of weld joints
Lecture - 5
Fatigue Fracture of Weld Joints – I

This is the 5th lecture on the design of the weld joints, and this lecture will be based on the Fatigue Fracture of the Weld Joints. In the previous lecture on the design of the weld joints for static and dynamic loads, we have seen the step by step methods, which are commonly used for designing the weld joints under the static loading and the dynamic loading. Now, we say in the real life, we know that the engineering components including weld joints are frequently subjected to the fatigue loads, the loads which whose magnitude is change with the time and direction also can change. So, the loads whose magnitude changes and direction changes with the time is termed as the dynamic load or the fatigue load.

And while in case of the static loading, this the magnitude and the direction of load largely remains constant. But when an engineering component is subjected to such kind of the fluctuating loads then the life of the component is very adversely effected, because very premature failure of the such component take place during the service. So, there in this presentation we will try to explore that what is the mechanism of the fatigue fracture, which leads to the significantly reduction in the life of the component under the fatigue loading. And what are the welding related aspects and the parameters that effect the fatigue life of the weld joints. So, that is what will be focused in this presentation mainly.

So, the in it will be started means, we will be starting with the introduction of the fatigue fracture the stages of the fatigue fracture. And then factors affecting the stages of the fatigue fracture like surface characteristics, the material characteristics and the loading conditions. And thereafter, we will try to see that how the welding related parameters and welding related aspects affect the fatigue life of the component.

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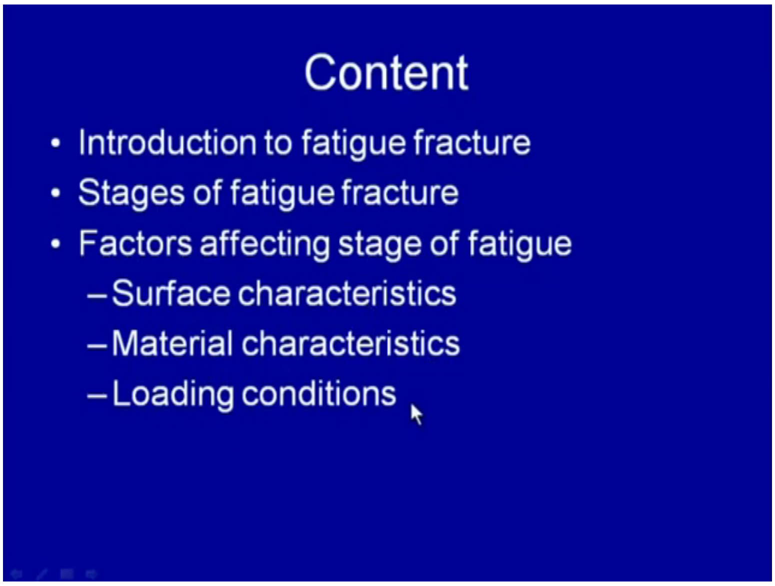

To understand this we need to see first the what is fatigue, we know that in real service the load, which act on the component mostly fluctuates in terms of the magnitude and the direction. And when such kind of loads acts on the component life, it is life is very adversely affected as compared to the performance of the component under the static load conditions.

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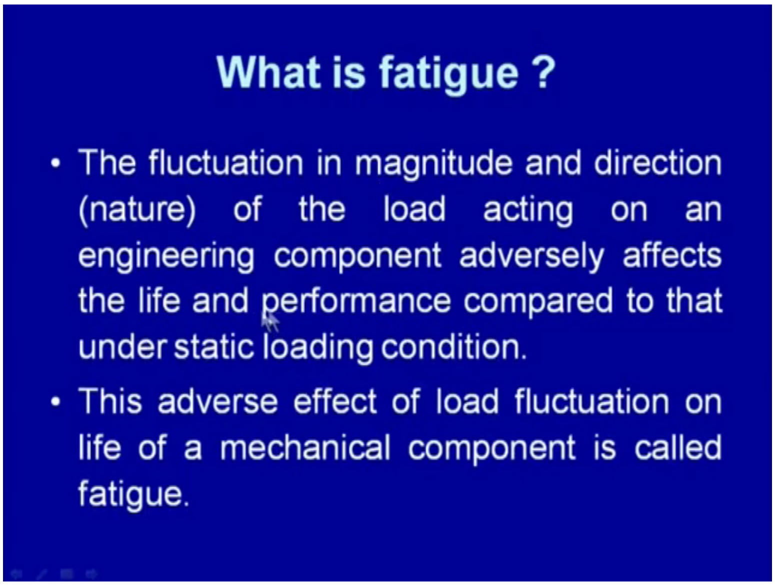

So, when an engineering component subjected to the load, which is fluctuating in magnitude and the direction suffers badly in respect of the life because very premature failure of such components takes place. So, this adverse effect of the fluctuating load fluctuation on the life of the mechanical component is called fatigue. So, basically the reduction in life of the component when it is subjected to the fluctuating loads is termed as fatigue and this life is found to be significantly lower than that is offered under the static loading conditions. So, to understand it better and we will we will try to see the schematic diagrams say whether, it is an engineering component.

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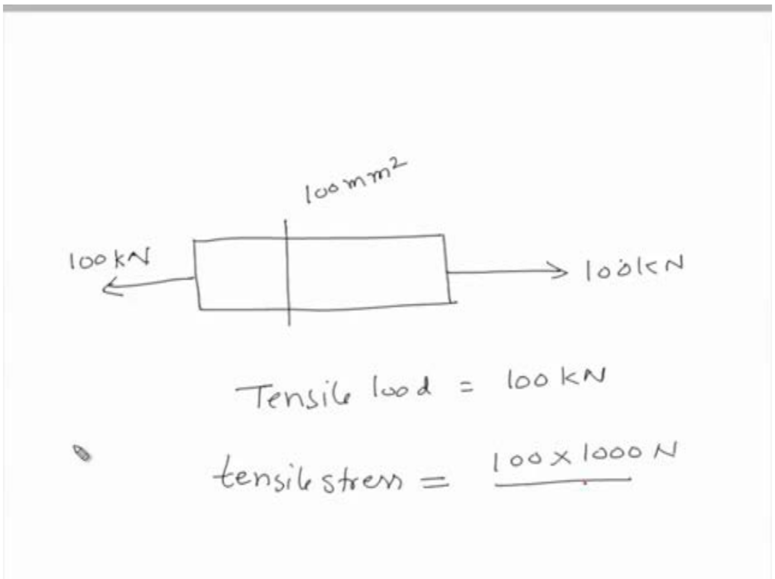

Like simple a cylindrical component subjected to a particular magnitude of the load say 100 Kilo Newton both the sides. So, the magnitude of this load is say that tensile load of 100 Kilo Newton is acting on this component. If the Load resisting cross-sectional area is of the 100 mm square, then it will result in the stress which will be uniformly distributed tensile stress, which will be uniformly distributed across the section. And that can be obtained directly from this at 100 into the, so this will be in Newton divided by the 100 mm square. So, this will be cancelled and what we will have 100 sorry, 1000 Newton per m m square. So, this is equal to the 1000 M P a, this stress is constant when a fixed load is applied, but if instead of maintaining this load, if we fluctuate it from 10 to 100 in that case the stresses will also be varying from the 100 to 1000. So, this kind of fluctuation or variation, which will remain say the minimum tensile load the F 1 minimum tensile load of that 10 Kilo Newton and the F 2, the maximum tensile load of 100 Kilo Newton.

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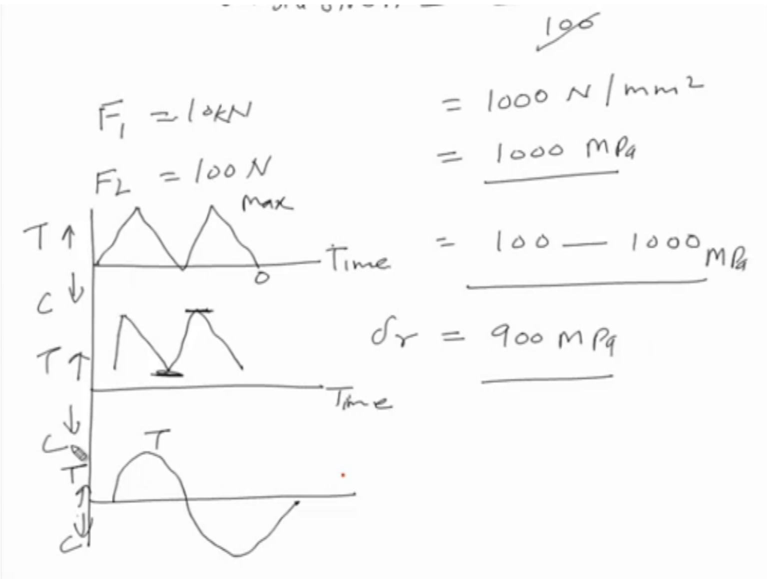

If the load is fluctuated like this, then it will result in the significant fluctuation in the stress tensile stresses, which are acting in the component from 100 to the 1000 m p a. So, this we can say the minimum stress 100 M P a, and maximum stress 1000 M P a. So, we difference of this, we can say stress range. So, the component is being subjected to a range of stresses of 900 M P a.

So, such a huge fluctuation will be existing in this component, so this is the difference in case of the static loading, the load magnitude remain fixed, but when the load magnitude fluctuates then a component is subjected to fatigue. Now, depending upon the nature of the type of the load and the variation in the magnitude of the load various types of the load patterns are available.

So, here we can say this y axis shows the load magnitude and x is shows the time. So, say the load fluctuation is simply say increasing like this increasing gradually to the peak value then coming down to the 0, then increasing to the peak value then coming to the 0. So, here load fluctuation is from 0 to some maximum value, so in this case, if the load is tensile here on the above this line and below and compressive below this line.

So, we can say that load is of the tensile in nature varying from the 0 to maximum value there may be another situation, where this is the time scale and the load is fluctuating say the top side, we have the tensile and the bottom side, we have compressive. And the fluctuation is from tension to tension say from one magnitude increasing then decreasing then increasing and then decreasing. So, the fluctuation is taking place from some low value to the high value and in this case the value of the load, when it is minimum is not 0, but it is on the higher side.

There may be another situation, where the load can fluctuate from means, the tension to the compression side. In this case say one typical kind of the load variation, which is observed is like say for one half cycle, it is tension and another half cycle, it is in compression zone. So, this kind of sinusoidal variation in the stresses, where the stresses are tensile in nature for one half of the cycle and their compressive in the another half of cycle.

So, here the load will be not just the magnitude of the load will be fluctuating, but it is nature will also be changing from the tension to compression. When any engineering component subjected to such kind of fluctuation in magnitude in terms of the nature and the magnitude the life of the component is very adversely effected. So, that reduction in life of the component when it is subjected to such kind of fluctuation is termed as fatigue. Now, this kind of fatigue failure takes place in the different stages for failure to take place.

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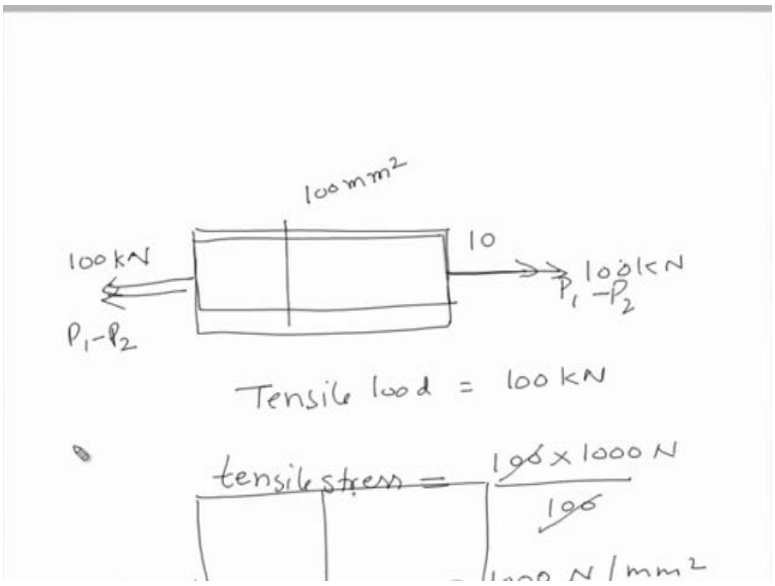

It is immaterial whether it is a welded component or any engineering simple engineering component having the uniform cross section component can fail under the in both the cases. Say this is one typical component without any discontinuity and uniform cross section and this is the, and is subjected to say load fluctuation from p 1 to p 2 in both the sides, and similarly if we take another component which is welded. So, welding is done say along this section.

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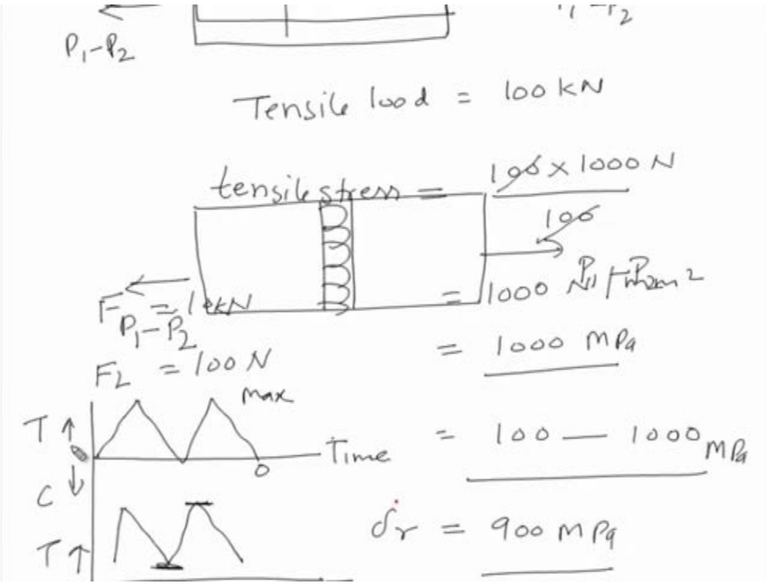

This is the line of the weld and again, it is subjected to the same the kind of fluctuation in load from p 1 to p 2. So, in both the cases fatigue fracture can occur in both the cases. So, and for that what is required requisite for fatigue fracture to take place in the second case in both the cases is that, the failure of is that it should pass through the three stages.

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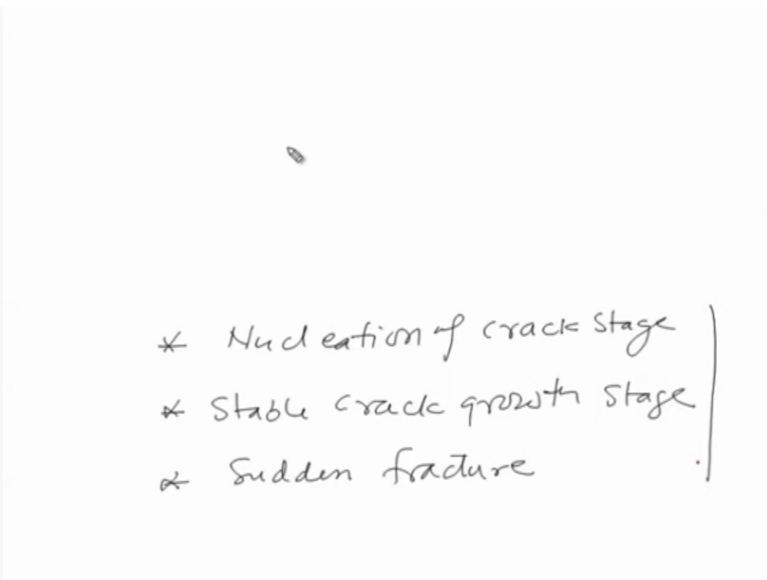

So, the stages which are required for fatigue failure to take place are the nucleation of crack stage where first the crack will nucleate. The second is stable crack growth stage and third the sudden fracture stage. So, whether the component is very smooth and of the uniform cross section or it is having the discontinuities and sudden change is there in cross section. Both the components can fail under the fatigue loading, but the number of cycles, which will be required number of the loads cycle, which will be required for failure to take place that can vary significantly so.

But, in any case for fatigue fracture be passing through these 3 stages. So, for the stage in case of the smooth component, some sort of the crack will nucleate at any point, where stress results are present. Either in form of defect or in form of surface regularity like the greater roughness, while in other cases, where already some sort of discontinuity is present those discontinuities and the sudden variation in the cross section will be acting as the stress razors and they will be facilitating the easy nucleation and growth of crack.

So, what is the difference in how the fatigue life will be affected in the 2 cases, when one is having the discontinuities and the sudden changes in the cross sections. And another is having very uniform cross sectional area and smooth finish surface. So, how the fatigue life will be effected in the 2 cases, when it is subjected to the fatigue loading that will be same through these presentation. So, here what is the reason behind why the fatigue life is reduces.

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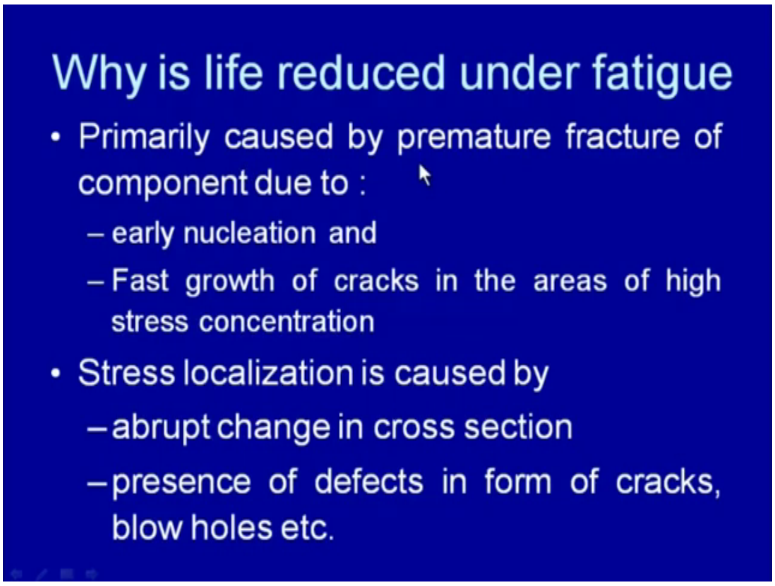

The fatigue life under the fatigue loading is reduced, because under the fatigue load conditions very premature failure of the component takes place and this premature failure occurs. Because, of the easy nucleation of the crack and the fast growth of crack especially, in the areas where stress razors are present and these this is stress results may be present in form of the abrupt change in cross section or some sort of discontinuities are present in the component or in the weld joint. And these discontinuities may be in form of the cracks and the hole.

So, important thing is that when the component is subjected to the fatigue loading very premature failure takes place. Because, in these under these conditions cracks nucleate easily and they grow at a faster rate, especially in the areas of the high stress concentration and these are the preferred areas, where stress concentration can exist.

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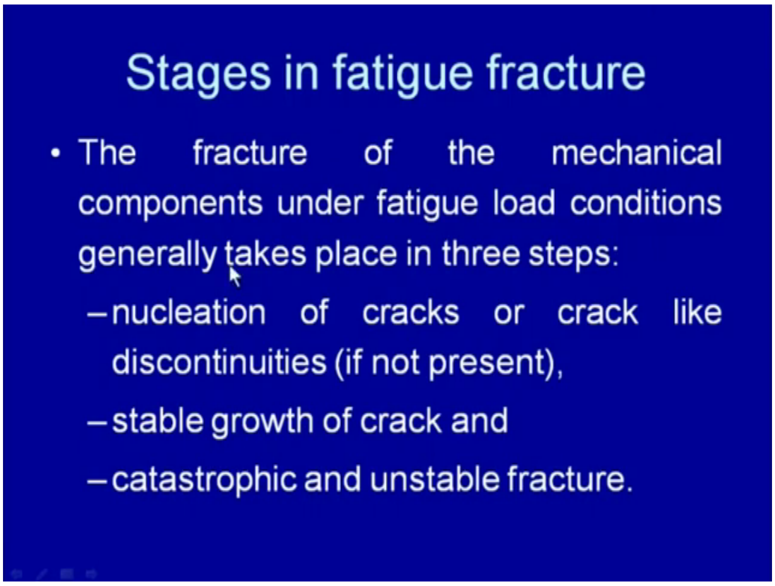

So, as I said for fatigue failure to take place certain stages are there and these stages will be occurring in sequence 1 by 1 then these 3 stage, there are 3 stages for fatigue failure to take place of the mechanical component. One the nucleation stage of the crack where crack, if it is not present then it will be nucleated first or if some sort of discontinuities are present, they are acting as a the acting like a crack then the crack. Their growth will start directly, the 2nd stage is the stage stable crack growth zone, where crack will be growing in very stable manner slowly and this is the most useful part of the fatigue life. And this stage will be offering the most useful part of the fatigue life of the component.

And in the 3rd stage, when the cross sectional area of the component is reduced to the greater extent catastrophic failure takes place. So, to understand this, we will be going through one very systematic approach, we know that when any component is subjected to the fatigue loading, first the areas of the high stress concentration cracks nucleate. So, it will require first a few number of the load cycles for nucleation of the crack then few number of cycles required for stable of the for stable crack growth. And thereafter some number of cycles will be required for computation of the 3rd stage, that is the catastrophic failure.

So, that algebraic sum of the number of load cycles required for completing, each of the stages will determine the number of cycles required for fatigue failure and that will indicate the fatigue life of the component. So, all the factors that affect that can delay the number of cycles required for completion of the any stage that will help in improving, the fatigue life of the component. For example, if the certain factors can delay the nucleation stage, then they will be helping in improving the fatigue life. Similarly the factors that delay the completion of the 2nd stage, they will also be helping in increasing the fatigue life and likewise the 3rd stage.

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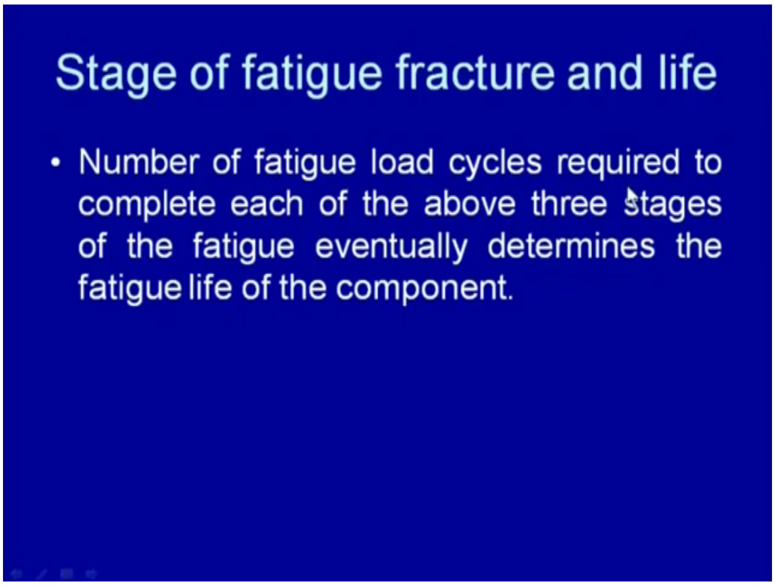

So, the number of load cycles required for completing the each of the above 3 stages of the fatigue, eventually will determine the fatigue life of the components.

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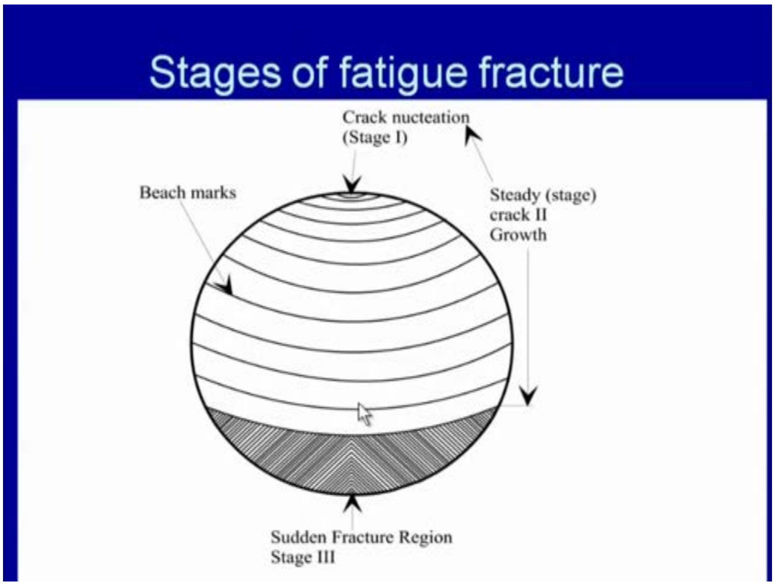

Say 1 component cross section of cross section of 1 component having very smooth surface will be come under the fatigue load conditions will be coming across, these 3 stages. In stage 1 for very fine smooth at the very smooth surface, first the crack will be nucleated in the stage 1 and thereafter that crack will be growing step by step, through the number of load cycles and will be getting. These concentric circle marks, where centre will be the crack nucleation the location of the crack has nucleated.

And these marks are termed as the beach marks and these marks are the typical feature of the fatigue fracture and these beaches and the stable crack growth rate will be occurring in the 2nd stage. And this portion of the life is the number of the load cycles that will be required for completing, the 2nd stage that will be contributing to the most portion of the fatigue life. While when the due to the growth of the crack in this 2nd stage, where the load resisting cross sectional area is reduced to the greater extent than the sudden fracture, it takes place in the 3rd stage.

So, this is the shaded portion indicates, the sudden fracture zone of the third stage. So, the sum means load few load cycles about 10 to 20 percent of the fatigue life load cycles are required for completing the nucleation stage and about 60 to 70 percent of the load fatigue life goes in this stable crack growth. And lastly about 10 to 5 to 10 percent of the load cycles will be required for completing the 3rd stage. So, it will be important to see that how the load cycles required for completing the each stage can be achieved.

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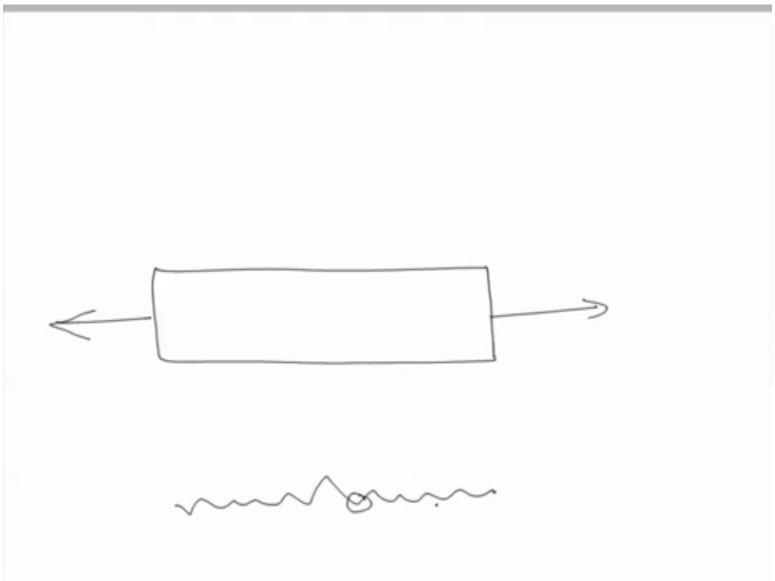

Say thus is very smooth and the finished component subjected to the load fluctuation. So, under the load fluctuation say a the each surface even, if it is smooth will have some sort of the irregularities. These regularities may be at the micro level. So, wherever the deep valleys are present, those areas under the load fluctuation will be showing, some minor stress localization.

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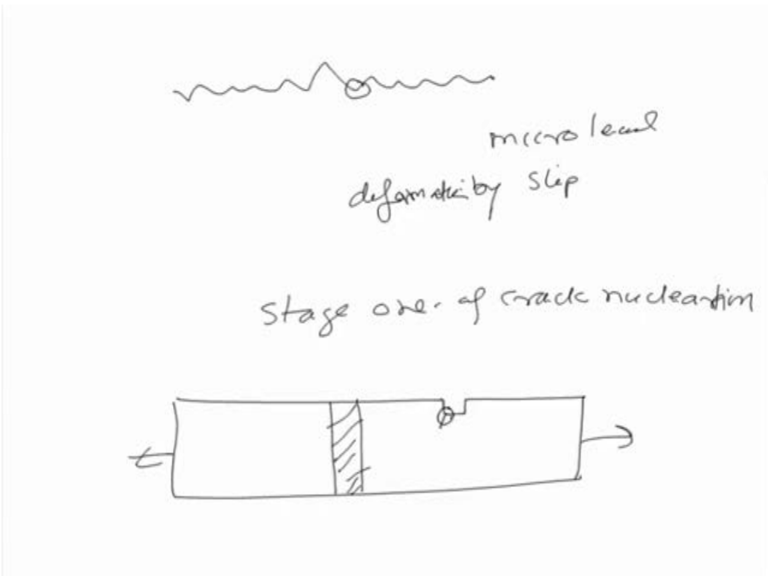

And at these locations very micro level deformation will be occurring by slip. So, micro level deformation occurring at the surface by slip, this will be facilitating the development of the crack after the large number of the cycles a large number of the load cycles. So, the important thing, when the load fluctuates by the micro level deformation occurring by the slip near the surface layers will be leading to the development of the crack.

So, number of loads cycles required for development of this crack will constitute to the stage 1 of crack nucleation. So, all those factors that help in reducing the deformation micro level deformation by slip at the surface, they will be delaying the stage 1, if the surface is smooth. So, this is the situation or this is the case, when the surface is very smooth the 2nd stage is 1, when the engineering component is having either some sort of the geometric discontinuity or it is made it is having the weld joint, which are bound to which are usually have 1 or other kind of the discontinuity.

So, these areas where either geometric discontinuity is present due to the design requirements, so these areas will be acting as a areas of the high stresses. So, in these areas of the high stresses, where stress localization is taking place crack will be able to nucleate easily and thereafter their growth will start. So, the nucleation stage is achieved earlier and easily in case of those components, where either weld joints are present or they are having some sort of the geometric means, the variation in cross section due to the design requirement in the component in form of the key slots holes or some other variation in cross section of the components.

So, these areas will be very sensitive for easy nucleation and growth of the cracks. So, the weld joints and the other and the components having some sort of the variation in cross section due to the design requirements, they will be subjected to the easy nucleation of the crack in the stage 1. So, if we consider this the nucleation stage then what are the factors that affect the nucleation stage of the fatigue fracture.

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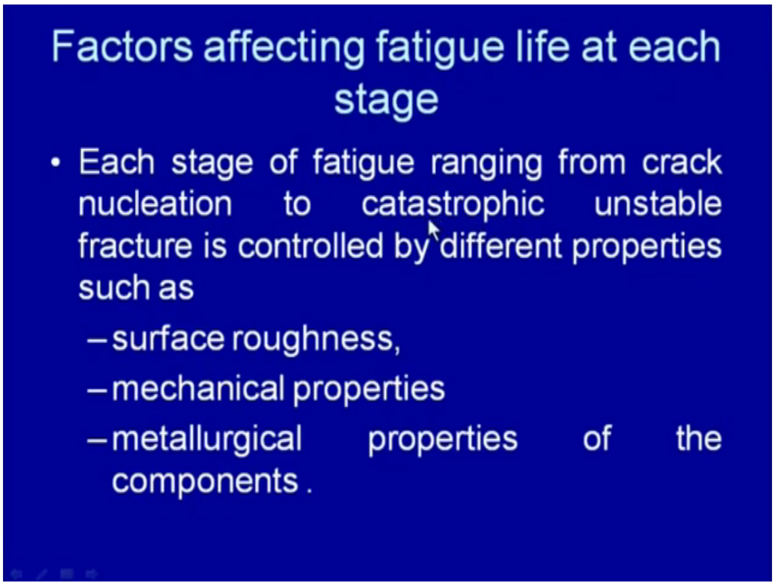

So, the factors affecting the fatigue life at the each stage like the each stage of the fatigue ranging from the crack nucleation to the 3rd stage that is of the catastrophic unstable fracture is controlled by the different properties. So, properties that predominantly affect the each stage of the fatigue fracture include the surface roughness mechanical properties and the metallurgical properties of the component. So, the surface nucleation stage of the fatigue fracture is governed by the following.

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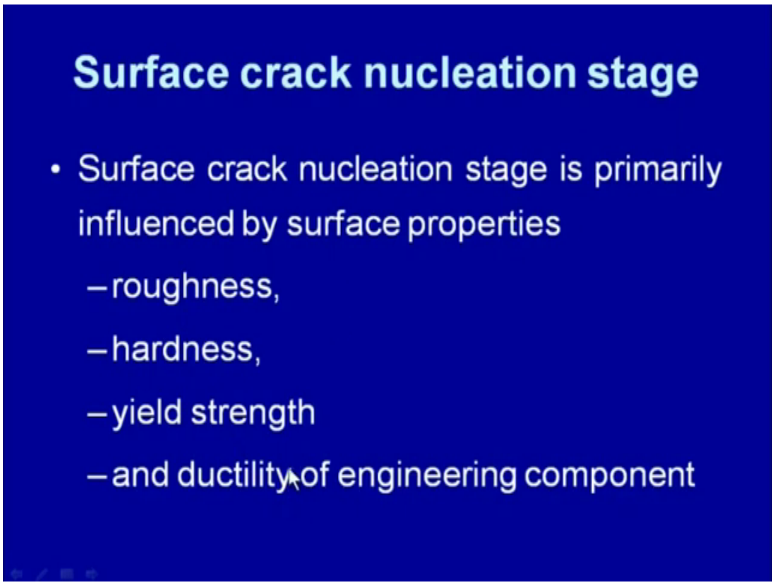

Surface properties like the surface roughness in general surface, if the surface roughness is more than due to the presence of the deeper peaks and higher peaks and the deeper weld is the nucleation of the crack will be easier as compared to the situation, when the surface is smooth. The surface hardness higher surface hardness higher yield strength will reduce the micro level deformation by the slip, which will be facilitating the easy nucleation of the crack in the stage 1.

Similarly, the low ductility high ductility will be promoting the micro level deformation by the slip and thus it will be facilitating the nucleation stage. But, if we smoothen the surface increase the hardness, increase yield strength and reduce the ductility of the material present at the surface layer then these things will be discouraging the nucleation of the crack by the micro level a deformation through the slip mechanisms. So, if it is required to improve the fatigue life by delaying the crack depletion stage then surface is finished and the hardness yield strength are improved and ductility is reduced.

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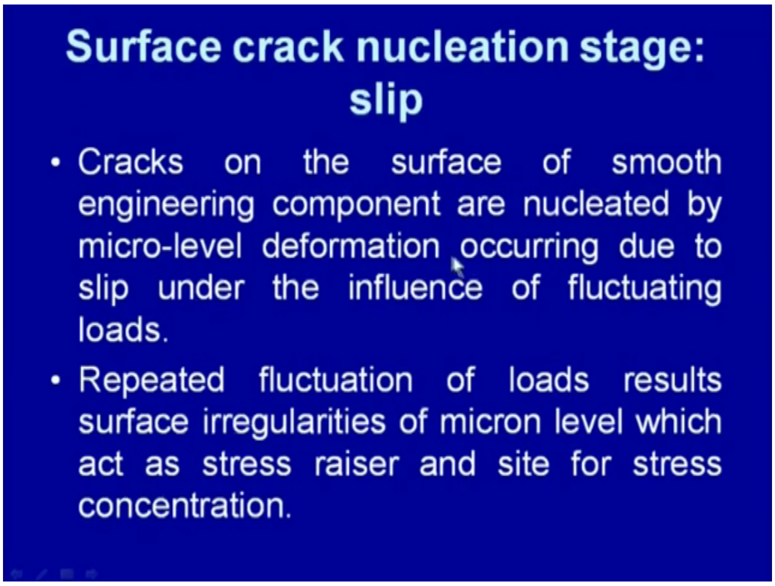

So, as far as the surface nucleation stage by the slip, we know that the cracks on the surface of the smooth engineering component are nucleated by the micro level deformation. Occurring due to the slip under the influence of the external loads and repeated fluctuation of loads results in the surface irregularities of the micro level, which act as a stress raiser and the site for the stress concentration.

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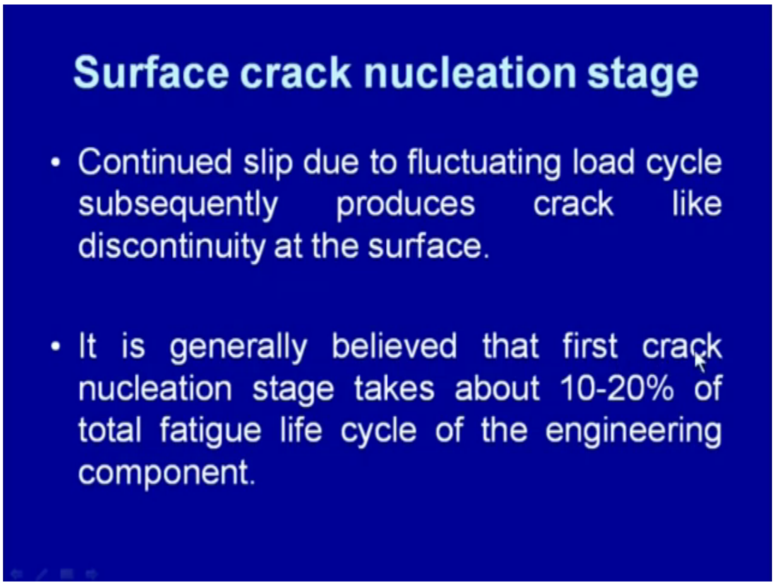

Continued slip under the fluctuating load cycles subsequently produces crack like discontinuities at the surface and it is believed that the first crack nucleation stage takes about 10 to 20 percent of the total fatigue life cycles of the engineering component. So, the factors that can be used to reduce nucleation stage, crack nucleation stage from the mechanism of the fatigue crack nucleation.

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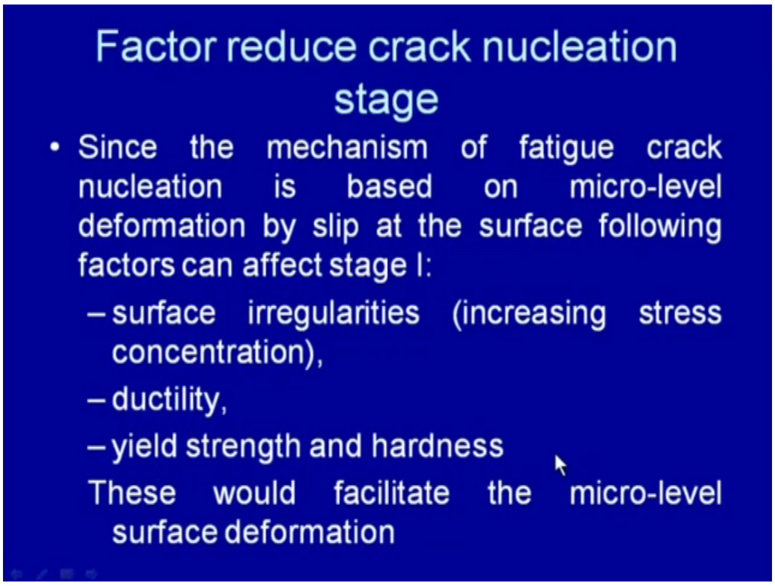

We know that, it is based on the micro level deformation by the slip. So, all the factors that can reduce this micro level deformation by slip, they will be helping in reducing the crack nucleation and delaying the crack nucleation stage. So, like the surface irregularities increasing the stress concentration. So, reducing surface irregularities will help in they will help in delaying the surface nucleation stage. And the reducing ductility and increasing the yield strength and hardness, these will be helping to delay the nucleation stage.

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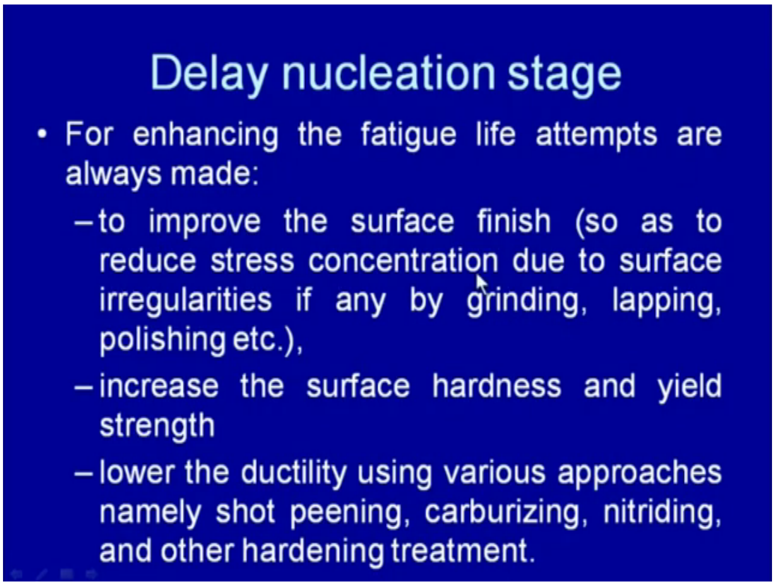

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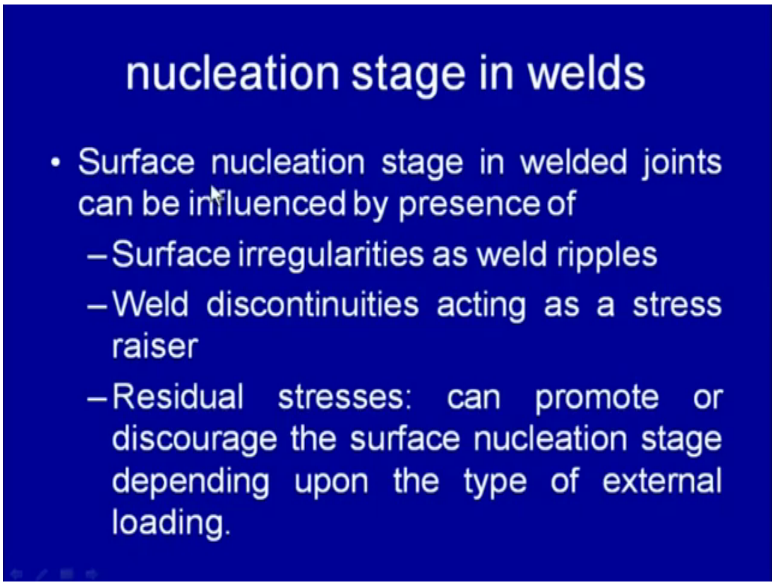

So, for enhancing the fatigue life attempts are made to improve the surface finish. So, as to reduce the stress concentration due to the surface irregularities and this can be done by the grinding lapping and the polishing of to the surface of the component and increasing the surface hardness and the yield strength. So, that the micro level deformation by the slip can be reduced and reducing the ductility. Using approaches like the shot peening, carburizing and nitriding and other treatment. So, the surface hardness and yield strength and reduction in ductility can be achieved, through these approaches. In the nucleation stage in case of the weld nucleation stage, in the welded joints can be influenced by the presence of surface irregularities, which are usually present. In the weld in form of the weld repels and weld discontinuities also usually present in form of the crater, the cracks and the inclusions porosities etcetera. And these act as a stress raisers and apart from these the weld joints most of the time have the residual stresses, which can promote or discourage the crack nucleation stage, depending upon the kind of the external loading is there.

For example the tensile residual stresses will be facilitating the crack nucleation stage, if the external loading is a of the tensile in nature, while the compressive residual stresses will be discouraging, the crack nucleation stage under the identical conditions.

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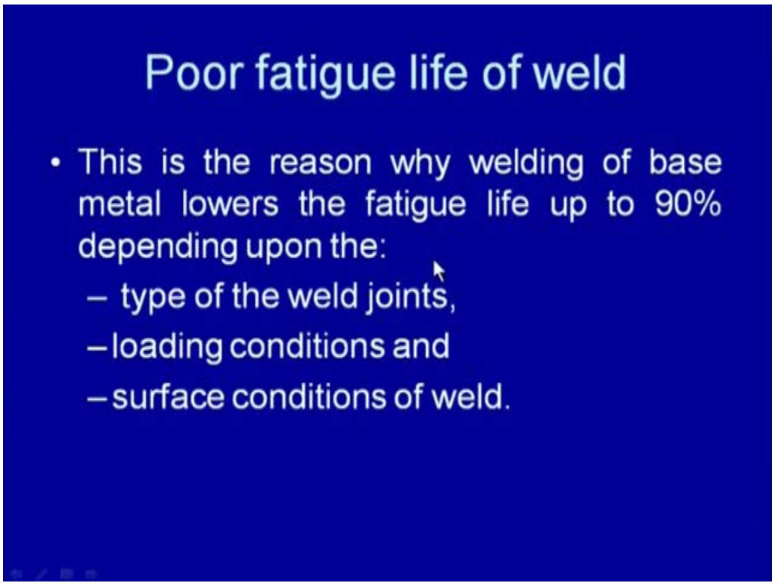

And because of the above reasons like the presence of the, because surface is rough as the and the weld joints in as welded conditions have the lot of surface irregularities. They have discontinuities, which as act as a stress raiser and further these also have the residual stresses. So, all these factors facilitate the easy nucleation of the crack under the fatigue conditions and therefore, the fatigue joints frequently, offer the poor fatigue life as compared to that of the respective base metals.

And this is the reason why the welding of the base metal lowers the fatigue life of the component as high as the 90 percent of their base metal means, the reduction in life can be up to the 90 percent of the life of the components.

So, and this the extent of the reduction in the life of the component is governed by the type of weld joint, which is being used like the butt joints offer better fatigue life than the fillet joints. The loading conditions, whether it is tensile or compressive and the surface conditions of the weld like the presence of ripples discontinuities, and the other form and the residual stresses at the surface of the weld. So, due to these typical features related with the weld joints the fatigue life of the weld joint is found to be significantly, lower than their base metals.

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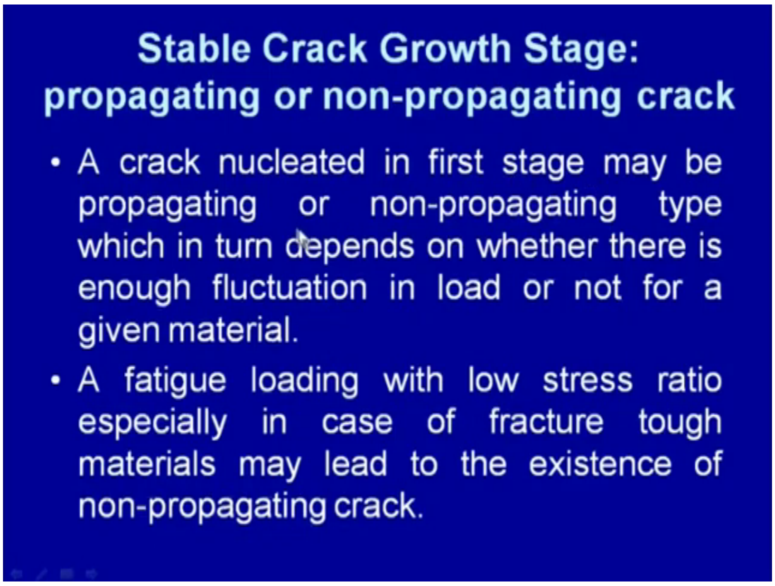

Then the nucleus the stable crack growth stage, we know that the cracks, which either have been developed in the nucleation stage or these were present right from the beginning in form of the weld discontinuities or other form of discontinuities. These cracks in the initial stages may be of the propagating type or non propagating type depending upon the loading conditions.

We know that, the crack can be there for longer duration without any propagation, if the fluctuation in load is limited. So, for to have the crack of the propagating type, it is necessary that whatever crack is present, there must be sufficient fluctuation in the load magnitude, otherwise crack can become a non propagating kind also. So, a crack nucleated in the stage 1 may be propagating or non propagating type, which in turn depends, whether there is enough load fluctuation or not in a given material.

So, the is the fluctuation is very limited despite of having the crack present or nucleated in the initial stage, it can become non propagating type, if the fluctuation in the load is limited then a fatigue loading with the low stress ratio. Especially, in case of the fracture tough material may lead to the existence of the non propagating crack. So, when the load fluctuation is very limited that is shown by the low stress, that is shown by the high stress ratio and if the material is also very fracture tough then the crack present may be of the non propagating type.

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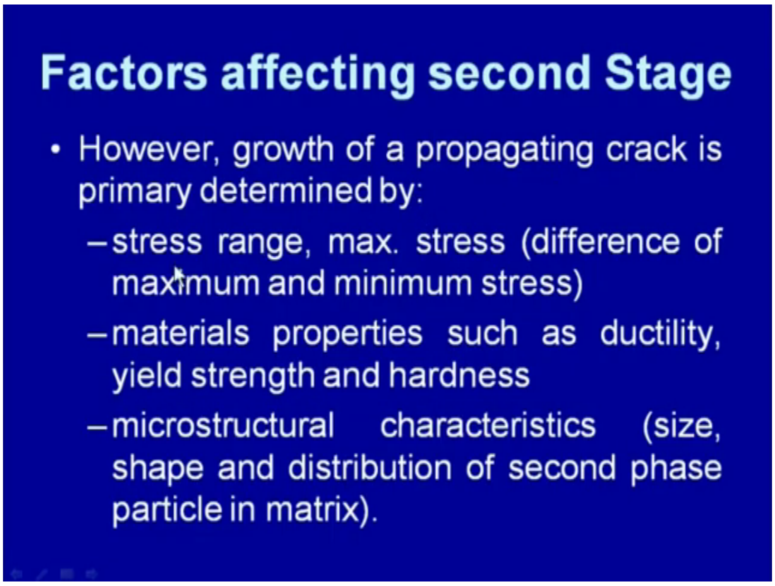

So however, the growth of the propagating crack is primarily determined by. So, if the crack is propagating type then it is growth rate will be effected by the stress range, the maximum stresses. So, we know that a higher is the fluctuation greater will be the stress range. So, the greater will be the crack growth rate maximum stresses higher is the maximum stress, greater will be the crack growth rate and material properties like ductility yield strength and hardness.

If the crack is propagating in the much better system, if it is ductile then it will be discouraging the crack growth. Because, crack tip will be blunting with the ductile materials while low ductility materials promotes the crack growth rate.

Similarly, the yield strength a high yield strength materials, promote the crack growth rate and high hardness materials also promote the crack growth rate. So, the material properties significantly affect the crack growth stage to reduce the crack growth rate it is necessary that or to delay the crack growth stage, it is necessary that ductility is high yield strength is low and material hardness is low.

So, at the same time stress range is also low and the maximum stresses are on the lower side especially, when the load is of the tensile type. Then micro structural characteristics also affect the crack growth stage in respect, if the micro structural features like the size of the grains their shape and distribution.

The large size means the course grains and then of the needle shape or for the higher crack growth as compared to the finer grains and the spherical or the equiaxed grain structures resist the crack growth and. Thereby they delay the crack growth stage and thus they help in improving the fatigue life of the component.

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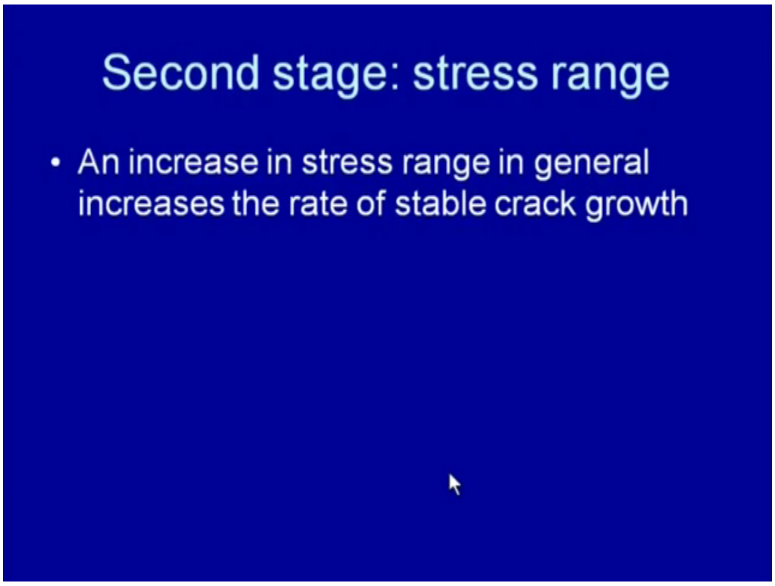

So, as far as the effect of the above parameters on the fatigue life is concerned and. So, that is what we will be seeing here in the as far as, the stress range is concerned an increase in stress range in general increases, the rate of the stable crack growth and increase in rate of the stable crack growth will be decreasing the fatigue life of the component. Because, it will be decreasing the number of load cycles required for the completing, the second stage of the fatigue failure and then metal properties.

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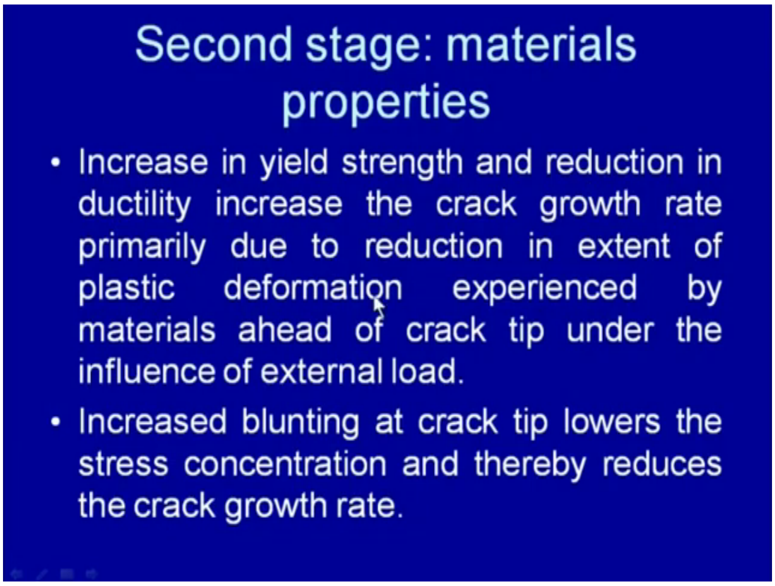

Like increase in yield strength and the reduction in ductility increases the crack growth rate due to the reduction in the extent of the plastic deformation, that will be experienced by the material ahead of the crack tip under the influence or external load. So, because of the limited deformation of the crack tip stresses will be more localized and stresses will be more concentrated at the tip of crack and that they will be facilitating the growth of the crack easily. And that is why the material of high yield strength and low ductility offer the higher crack growth rate as compared to the low yield strength and the high ductility material. So, the increased deformation and blunting of the crack tip lowers, the stress concentration thereby they reduce the crack growth rate.

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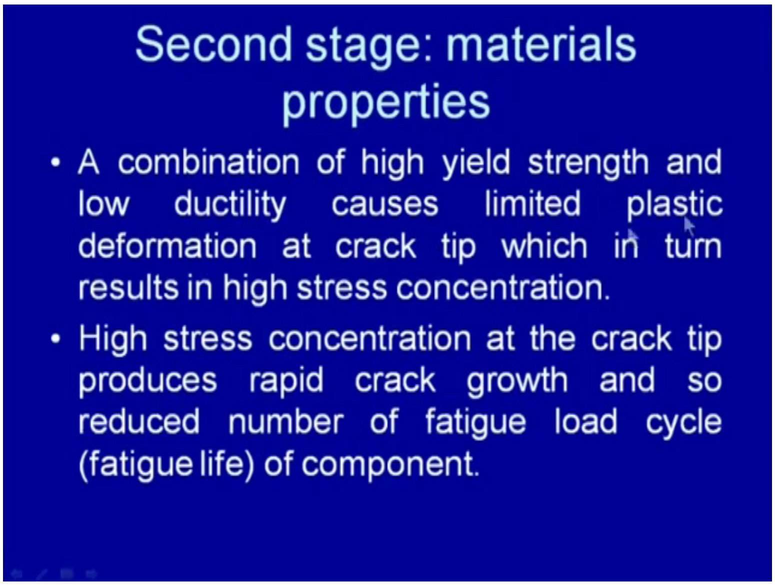

So, a combination of the high yield strength and low ductility causes the limited plastic deformation at the at the crack tip, which in turn results in the higher stress concentration and the higher stress concentration inside the crack tip produces, the rapid crack growth and. So, the reduced number of loads cycles required for computing the 2nd stage.

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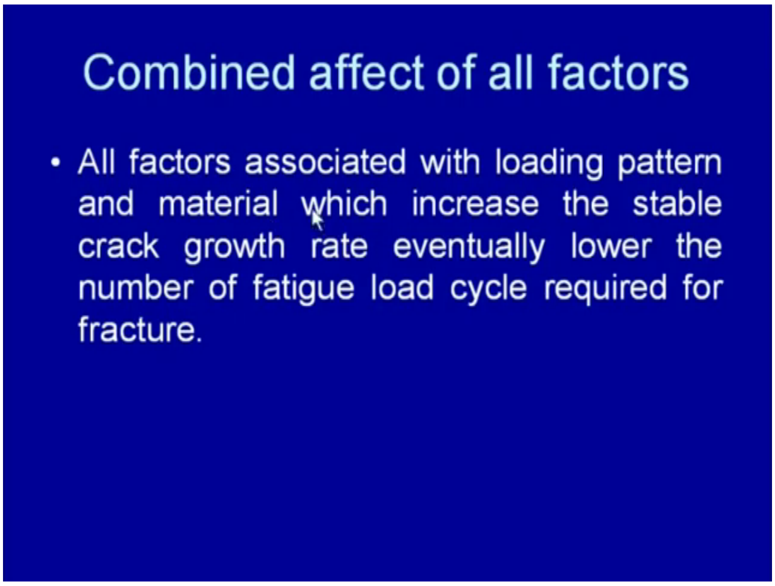

All the factors that is, if you want to see the combined effect of all the factors. So, all the factors associated with the loading pattern and the material, which increase the stable crack growth rate, eventually will be lowering the number of cycles required for fatigue fracture of the components. So, whatever loading characteristics of the load and the material characteristics, which are affecting the either nucleation stage or the stable crack growth or the crack growth stage, they will be affecting the fatigue life. So, if all those factors related with the low pattern and the material, which increase this stable crack growth rate, they will be decreasing the life of the component under the fatigue conditions. Then the 3rd stage the in which very unstable crack growth takes place.

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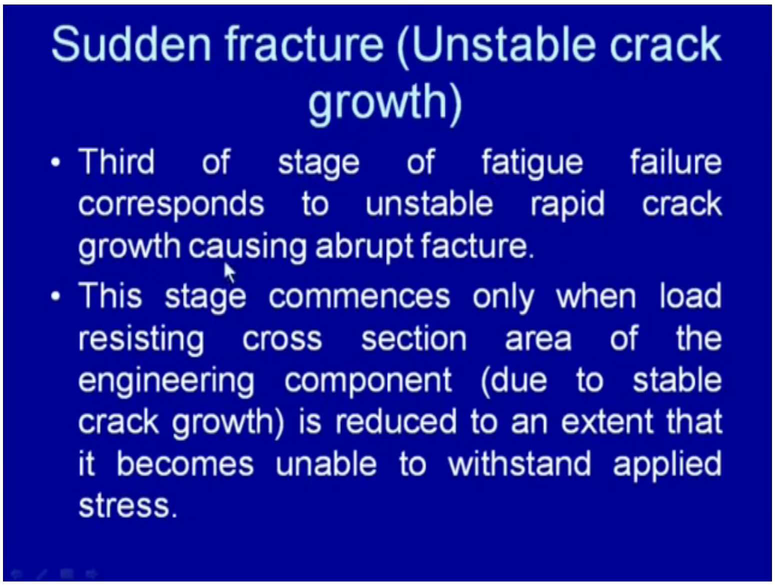

The 3rd stage of the fatigue failure corresponds to the unstable rapid crack growth causing the abrupt fracture and this stage commences only, when the load resistance load resisting cross sectional area of the engineering component is reduced to the great extent. And due to the stable crack growth and this reduction in cross sectional area occur due to the growth of the crack in the 2nd stage. And when this reduction in cross sectional area takes place to such an extent, that it becomes unable to with stand under the external load the sudden fracture takes place. So, to understand this we can schematically, say another diagram.

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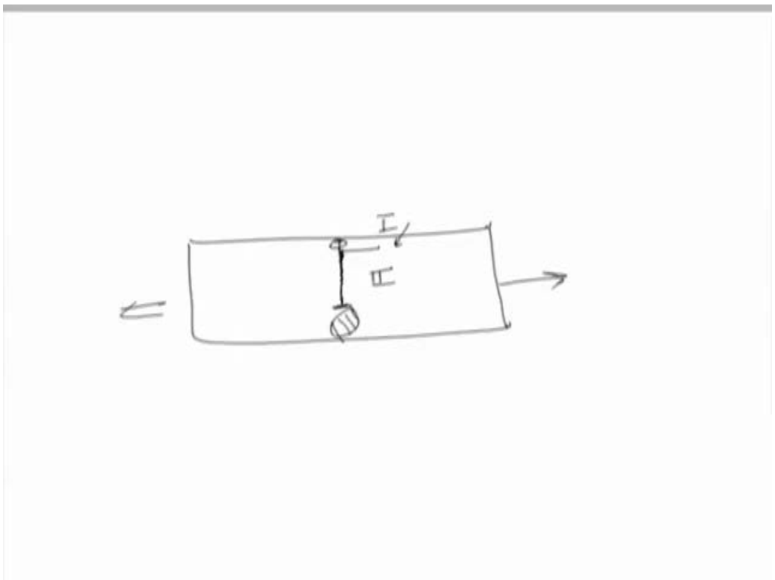

Here, we can see that under the fatigue load conditions say in this component due to the load fluctuation in the initial stage crack as nucleated and then it will be growing gradually. So, gradually as a crack will grow, there in this was the stage 1 is very limited of z 10 to power 15 20 percent of the load fatigue life cycles.

And then the stage this is very stable and slowly, the crack will be growing with the growth of this crack, there will be reduction in load resisting cross sectional area. So, say this is the stage 2, in which stable crack growth rate has taken place. And this growth of crack in this stage 2 will continue until this load resisting cross sectional area is reduced to such an extent that, this area is unable to take up the external load, which is acting on the component. And this stage certain fracture takes place. So, those metal systems, which are very fractured tough and very then those fractured tough material will allow the growth of the crack to the greater extent.

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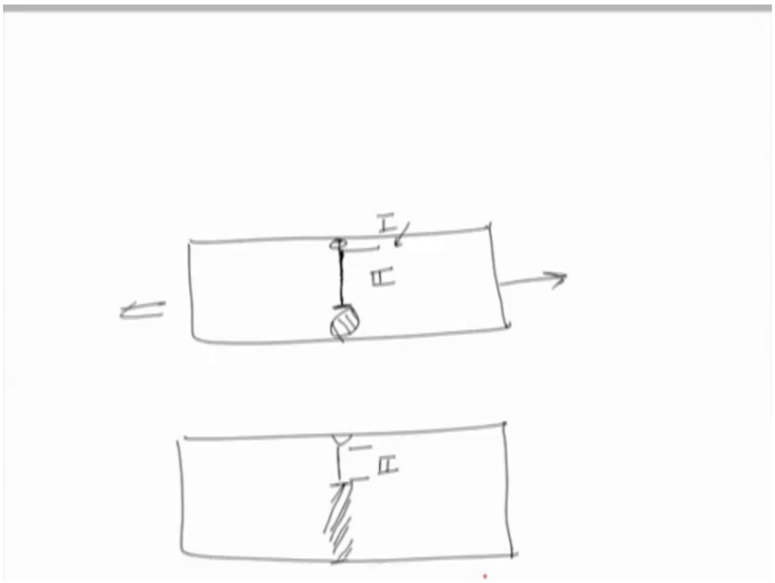

While the materials, which are not very fractured tough after the nucleation stage and the propagation of crack to the limited extent, the sudden fracture can take place, so even when they will lot of load resisting cross sectional area is left for the stage 3 very the for the certain fracture can take place earlier. So, in that case the growth of crack in the 2nd stage will be very limited as compared to the first case, when the fracture toughness of the material was high. So, depending upon the capability of the material to with stand, under the growing crack that will dictate how far crack will grow. In the 2nd stage, before the premature failure and abrupt failure takes place corresponding to the stage 3, this is what we can see in the cross section.

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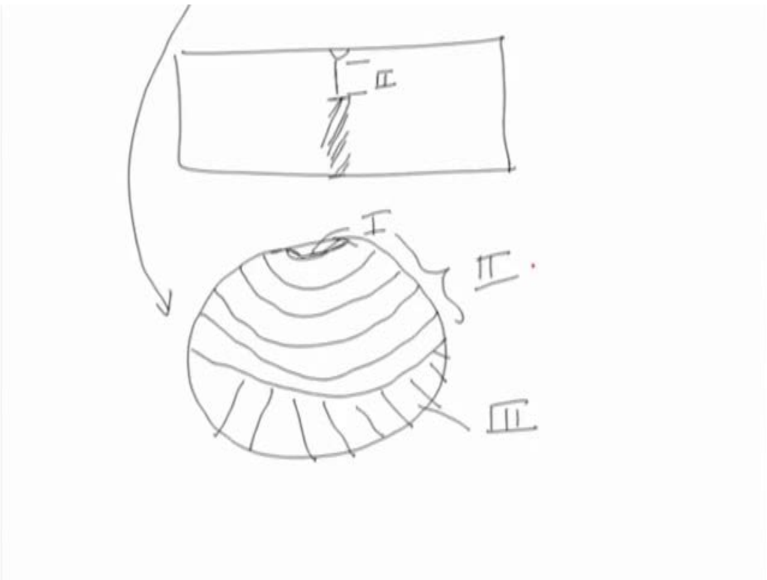

Point of view, if we try to see say this is the cross section. So, in the initial stage say crack is nucleating in the stage 1, then it will be growing gradually like this, if this is what is seen from the side view then we will be able to see that the crack is growing in a very stable manner. And when this load resisting cross sectional area is reduced to such an extent that, it is unable to take up the external load sudden fracture takes place. So, this corresponds to the 3rd stage and this corresponds to the 2nd stage.

So, this is how we can say and distinguish the different stages, in case of the weld joint the stage 1 does not contribute much towards the failure of the component. Because, most of the time discontinuities and the rough and high due to the high roughness of the weld surfaces. The very few number of cycles required for having the sizeable crack or sizeable propagating crack in case of the weld joint, that is why few number of cycles required for the weld joints to complete the nucleation stage, crack nucleation stage in case of the weld joints.

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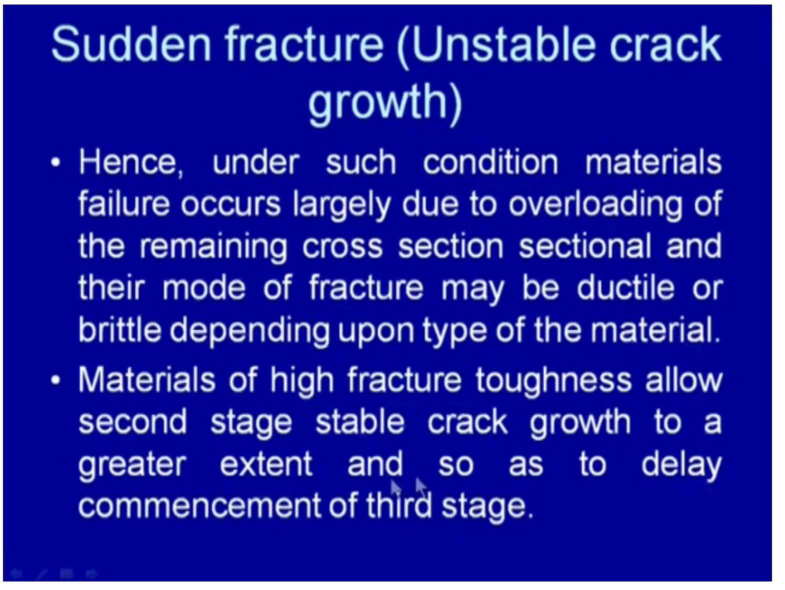

So, a sudden fracture continuing with the sudden fracture zone, under the such conditions the material failure occurs largely due to the overloading. So, means in the 3rd stage the failure of the material of failure of the material will be occurring and due to the overloading and this kind of this failure may be ductile and the brittle depending upon the type of the material. So, means the 3rd stage sudden fracture can occur by through the nucleation of the voids and their collisions mechanism that is the dimple fracture or it can be a brittle fracture depending upon the nature of the material.

While the in the 2nd stage, we will be able to see the typical beach marks or the striations corresponding to the growth of the crack in each load cycle. So, material of the high fracture toughness allow the 2nd stage stable crack growth to occur to greater extent, so that. So, as to delay the commencement of the 3rd stage means, the fracture tough materials will delay the completion of the 2nd stage and which in turn will help us in improving the fatigue life of the component.

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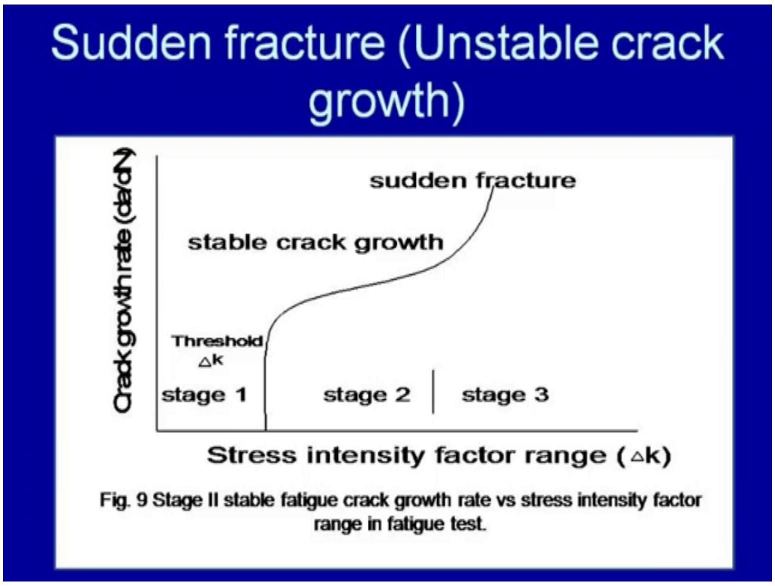

So, if we see in this respect of that, if the crack is present in the component and the load is fluctuating. So, there are the 2 factors are combined like the stress the fluctuation and the presence of the crack in terms of the stress intensity factor, which is composed of the sigma pi C, pi C is the half crack length for the internal cracks and C is the and for open cracks C is the crack length.

And so if we relate the stress range the combined effect of the stress fluctuation in form of a stress range and the crack size, which is present in the component in form of the stress intensity factor range and it is effect on the crack growth rate. Then we can see that for a certain very narrow fluctuation in the stresses in form of your stress intensity factor range for a given crack size, there would not be any the mean any growth of crack means, the crack will remain non propagating for this range of the stress intensity factor.

This stress intensity factor is nothing but it indicates the combined effect of the stress fluctuation in form of a stress range and the presence of the crack. So, and the crack size, which is present in the component, and which is normally presented by the sigma r, under root pi C. So, sigma r indicates the stress range and the pi C is corresponding to the pi is coefficient and C is the crack length means half crack length for internal crack and the full crack length for the open crack, which is present at the surface.

So, for this stage 1 the crack is non, if we see the crack growth rate versus the stress intensity factor plot, then in this plot in the stage 1, the crack 1 will be and crack will be non propagating and then this stage 2, the crack will be growing at the very stable manner and the stage 3 crack growth rate will be accruing at the increasing rate.

So, in the first stage, if there is if the crack represent it will remain non propagating type and then it will be growing in a very stable manner. So, this mainly the fatigue life of the component is dictated by this rate, at which the crack growth occurs in the 2nd stage and higher is the crack growth rate lower is the life of the component under the fatigue conditions.

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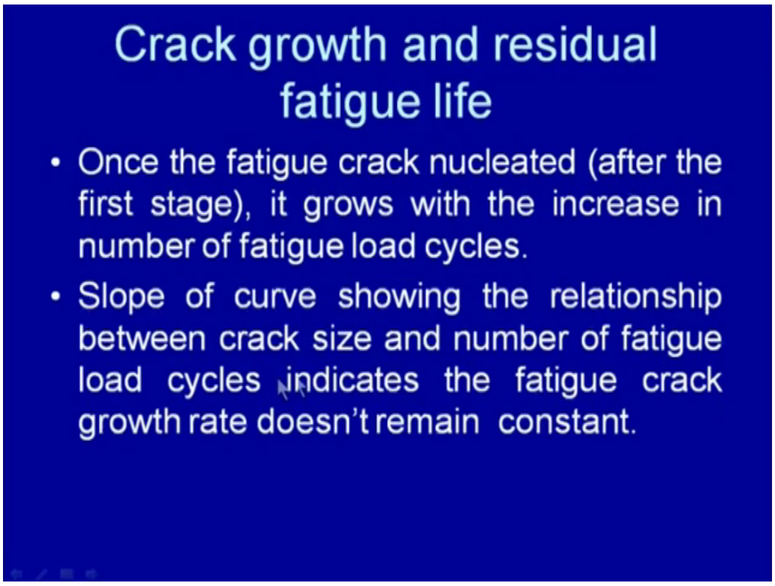

Then how we can identify the residual life residual fatigue life, when the crack is growing, we know that once the fatigue crack nucleated after the first stage, it grows with the increase in with the increase in number of the load cycles. And slope of the curve showing the relationship between the crack size and the number of the fatigue load cycles indicates the fatigue crack growth rate and it does not remain constant.

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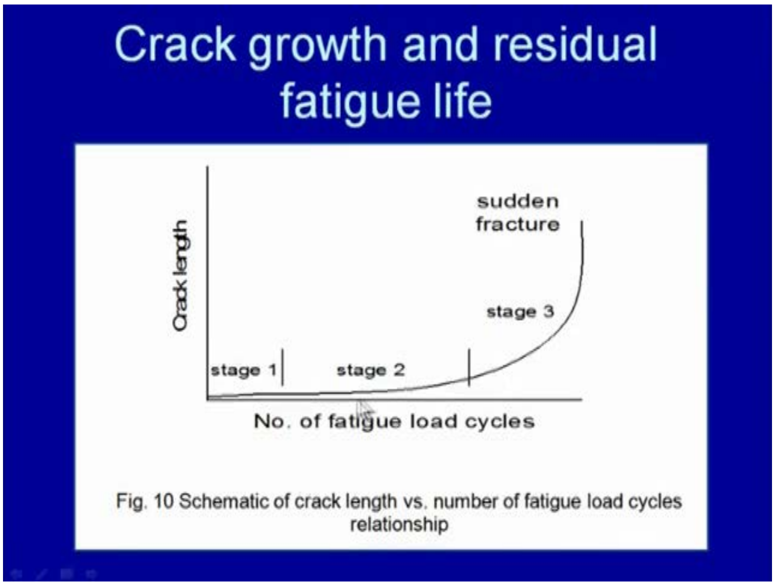

So, if we see here this plot showing the relationship between the number of load cycles and the crack length. So, if you can see the crack length is increasing with the increase in the load number of increasing the number of load cycles and this slope is continuously changing, which is suggesting that the crack growth rate is continuously changing.

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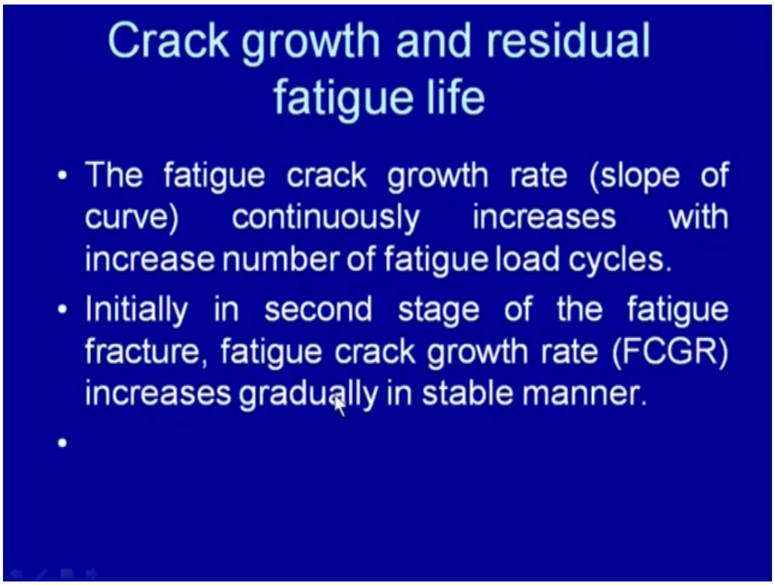

The crack growth rate, which can be observed from this slope of the curve continuously increases with the increasing number of load cycles, initially in the 2nd stage of the fatigue fracture crack growth rate increases, gradually in stable manner.

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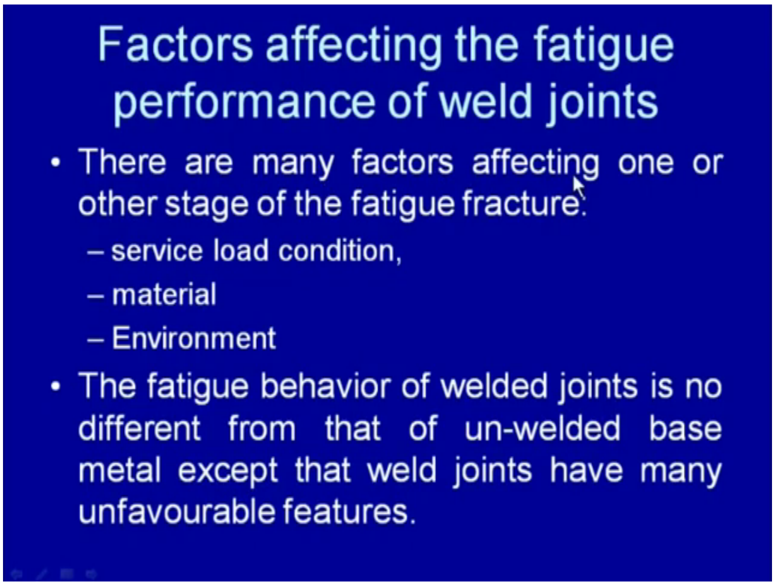

Now, the factors affecting the fatigue life or the fatigue performance of the weld joint. So, if we try to see that the specific factor related with the welding that are affecting to the life of the component under the fatigue conditions. We need to see that, there are many factors affecting the 1 or other stage of the fatigue fracture as far as the weld joint is concerned. These are the service load the material related parameters and the environment.

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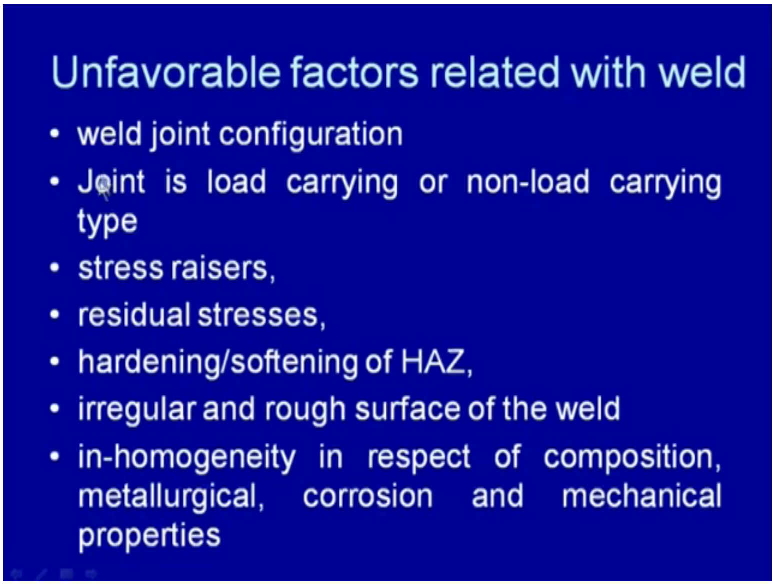

So, the fatigue behavior of the weld joint is no different from the un-welded base material except, that weld joints have the many unfavorable features. And these unfavorable features, which are adversely affecting the performance of fatigue of the performance of the weld joint, under the fatigue conditions include.

The weld joint configuration for example, the fillet welds offer very poor fatigue life as compared to e groove butt welds, that type of and the whether the joint is carrying load or it is non load carrying type. For example, if we can take up a particular case to understand this.

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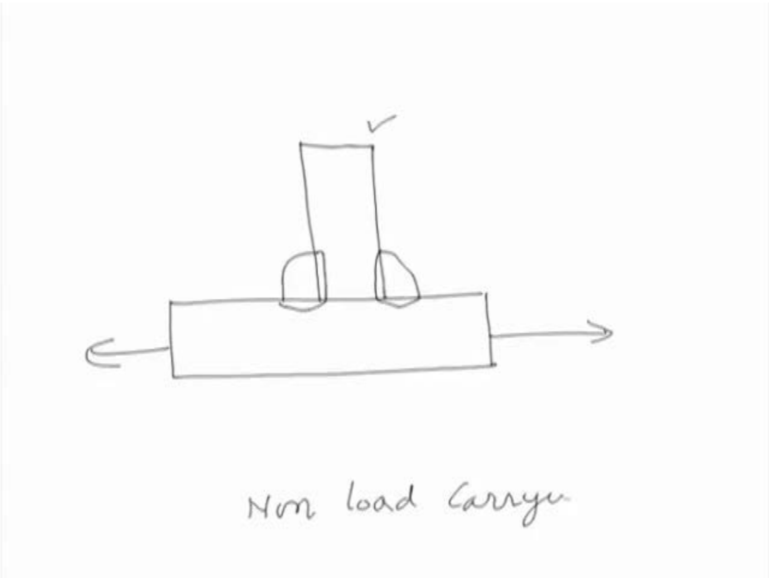

Here say this is the plate and having the t joint, in which weld has been made like this using the fillet. So, if the load is acting on this member only and load is not acting on this member then this will be then the weld joint will be the non load carrying type. So, effect of effect on the fatigue performance of this weld joint due to the development of weld will be very limited, but if the load is if the weld joint is the load carrying kind.

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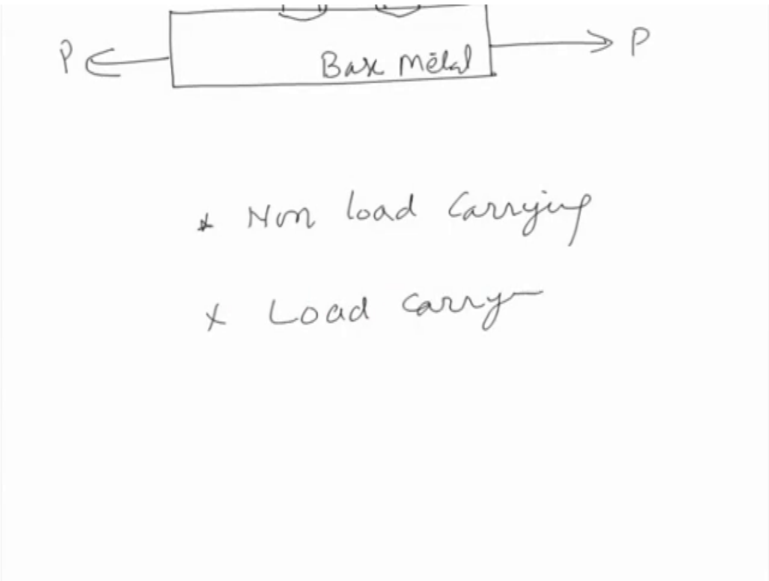

So, here in the load is in this case load is acting only, in case of only on the base material, but if the situation is different. And the 2nd case, if the component is subjected to the load like this say another load x is acting in this another member then this load will be taken by the weld joint. So, in that situation the weld joint is expected to the carry the load. So, load carrying weld. So, the fatigue the performance of the weld joint, which is expected to carry the load will be very adversely affected as compared to the situation, when the weld joint is just developed. But, it is not expected to carry the service load, so depending upon the case the effect of the weld joint.

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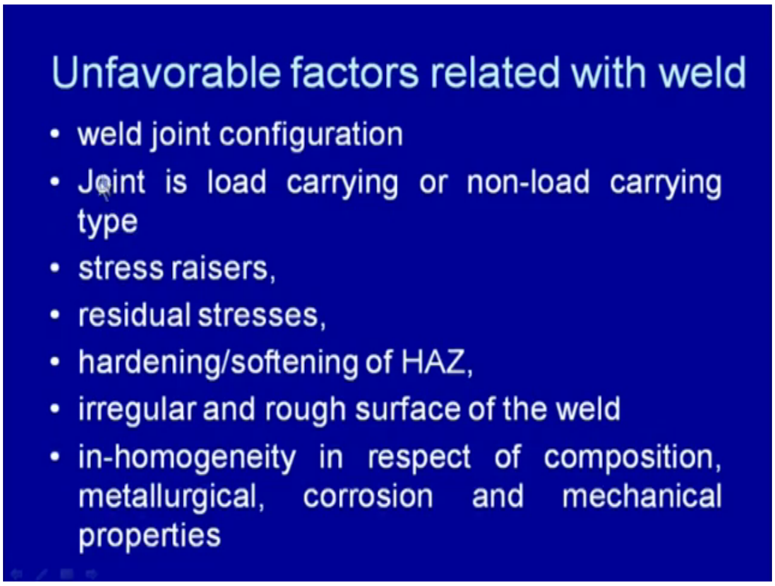

On the performance of the assembly will be different and depending upon the case, whether the joint is the load carrying kind or the non load carrying type. Then stress raisers weld joints frequently have the stress raisers in form of the ripples present on the weld surface in as welded condition. Presence of cutter at the end of the weld zone or the weld toe and the sometimes, the cracks in the heat affected zone discontinuities in the form of the porosity and inclusions are commonly present.

And these frequently act as a the stress raiser and presence of these discontinuities in the form of the stress raisers facilitate, the easy nucleation of the crack in the stage 1 and thereby they significantly reduce the fatigue life of the component.

Similarly, the presence of residual stresses weld joint, we know that because of the differential heating and cooling tensile and the comprehensive kind of residual stresses are developed in the weld joints. And the presence of these stresses depending upon the nature of the external load encourage or the discourage, the nucleation and the fatigue fracture.

For example, the similar kind of the residual stresses, similar to that of the external loading will be adversely affecting the fatigue performance of the component. For example, if the weld joint is having the tensile residual stresses then weld joint it will be performing very badly, under the tensile external loading. But the opposite kind of the residual stresses from the external loading will be helping to improve the fatigue performance.

For example the development of the compressive residual stresses in the weld joint will be increasing the fatigue performance, under the tensile loading then the surface hardening and the softening of the heat effected zone. So, the surface hardening like increase in the hardness of the surface will be decreasing, the nucleation of the crack. Especially in the heat effected zone and in the weld region, because of the increase in number of cycles required for nucleation of the crack. But, if the softening is taking place either in the heat effected zone, and in the weld zone.

Then it will be facilitating the crack nucleation stage, because of the easy micro level deformation by the slip. Similarly the regular and the rough surfaces will be facilitating the crack growth in the initial stage and thus they will be adversely affecting to the fatigue life. And in homogeneity, which is invariably present in the weld joint in respect of the composition metallurgical characteristics corrosion and mechanical behavior. Further facilitate the nucleation stage and the crack growth stage and thereby these adversely affect the fatigue performance. So, because of these unfavorable factors related with the weld joint.

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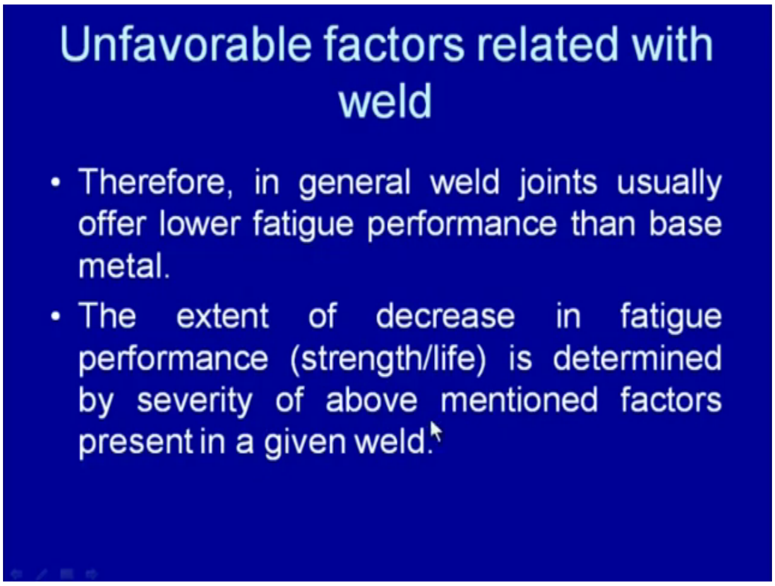

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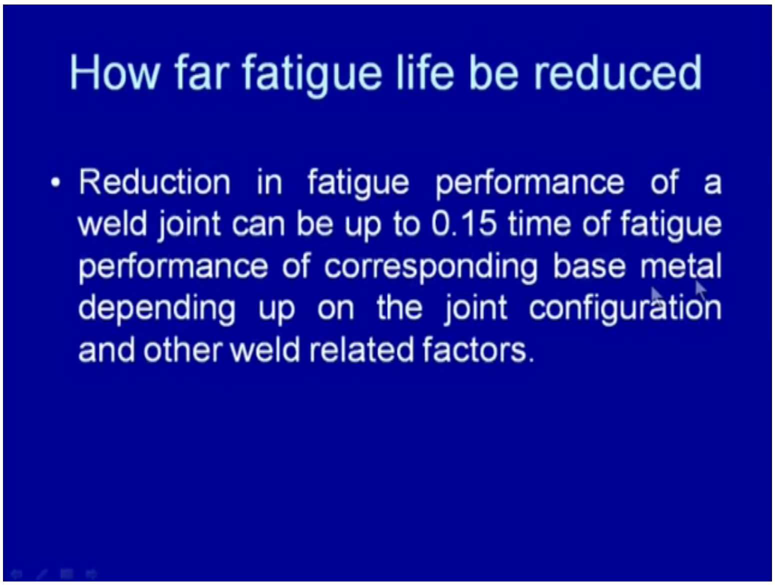

In general weld joints usually, offer the lower fatigue performance than the base metal and the extent of the decrease in the fatigue performance is determined by the severity of the above factors, which are present in a given weld. So, how far there will be reduction in the fatigue life of the component due to the welding.

That can be up to 0.1.5 times of the fatigue performance of the base metal of the corresponding, base metal depending upon the joint configuration and the other weld related factors.

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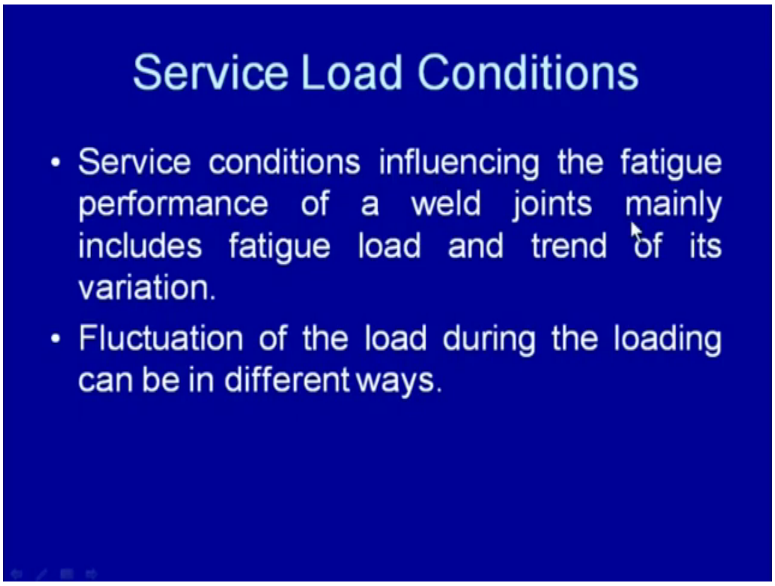

So, as far as service related factors are concerned service conditions influence the fatigue performance of the weld joint, mainly including load and the trend of the variation the fluctuation in load.

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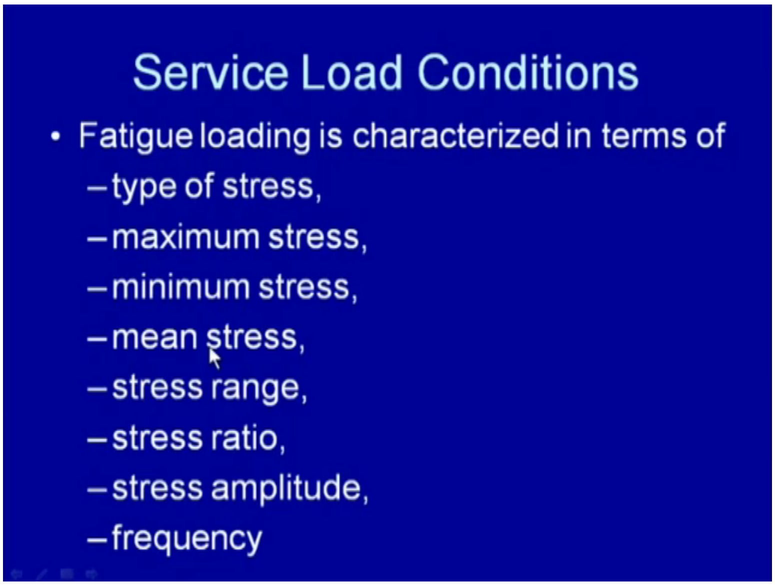

During the loading can be in different ways and this fluctuation is observed in respect of the type of stresses maximum stresses, minimum stresses, mean stresses, stress range, stress ratio, stress amplitude and the frequency. The tensile stress is adversely affect the fatigue performance as compared to the compressive. The compressive stresses sometimes even decrease the fatigue fracture tendency and improve the fatigue life. Similarly, the increase in maximum stresses and the minimum stresses, which will be increasing the stress range will be adversely affecting to the fatigue life.

The mean stresses of the tensile can increase in value of the mean stress of the tensile kind will be facilitating the crack growth and thus reducing the fatigue life. Increase in a stress range will be increasing the fatigue will be reducing the fatigue life and increasing, decreasing the stress ratio will also be reducing the fatigue life.

The stress amplitude lower will be fatigue life of the component effect of the load frequency is found to be less on the fatigue performance. However, increasing the fatigue in general the fatigue increase in fatigue frequency decreases the fatigue life of the component. So, these are the some of the load related or the service load related factors, which affect the fatigue performance of the weld joint. There are many other factors related to the weld joint like the welding procedure and the material related aspects that effect the fatigue life significantly.

So, the those things will be presented in the next presentation and we will also try to talk about that, how the fatigue life of the weld joint can be improved. So, what are the various approaches for improving the fatigue life of the weld joints will be taken up. Now to summarize this presentation mainly, we have talked about the fundamentals related with the fatigue fracture. The stages of the fatigue facture and the various the service load related parameters that effect the fatigue performance of the engineering component.

So, thank you for your attention.