Welding Engineering
Prof. Dr. D. K.Dwivedi
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 06
Design of Weld Joints
Lecture - 06
Fatigue Fracture of Weld Joints-II

So, this is the sixth lecture on the designing of the weld joints, and in this presentation mainly, we will take up the things related with thefatigue fracture of the weld jointsthis presentation will be mainly in the two parts onethe factors affecting the fatigue performance of the weld joint.

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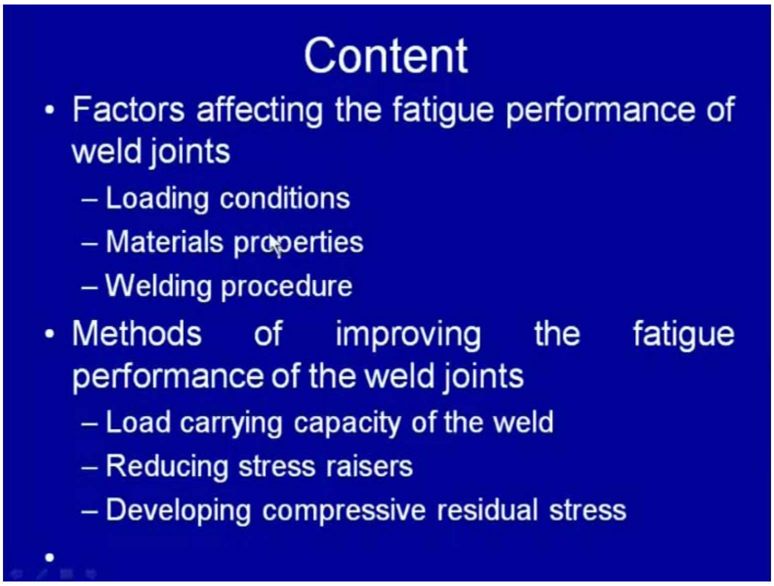

Which includes like the loading conditions,material properties,and the welding procedure,and in the second part we will take up the methods,which are usedfor improvingthe fatigue performance of the weld joint.This includes the like increasing the load carrying capacity of the weld joints. So, that it can resist effectively tothe fluctuating loads,and the reducing the stress raisers. In order to delay the initial stage ofthe crack nucleation, and developing the compressive residual stresses this approach is simply based on reducing the net tensile residual stresses acting in the weld joint.

So, that the all the stages of the fatigue fracture like crack nucleation,and the stable crack growth stage can be delayed, in order to enhance the fatigue life of the component.

So, we will be starting with theeffect of the various of loading conditionson the materialfatigue performance.We know that the loading conditions under thefatigue can be characterized in different wayslike the type of stresses, which are acting in the component the maximum stress magnitude the stress range, which is indicating the extent offluctuation in the load magnitudethen there is a stress ratio, which shows the ratio of the minimum, and the maximum loadstress amplitude,and the loading frequency like this results attainparameters related with thefatigue load.

We know that the first one like the type of the load,which is inducing the stresses in the component subjected to the fatigue. So, it is important to consider that the nucleation, and the crack growthsare important for fatigue flayer to take place, but if the material is subjected to the compressive load, then the nucleation and the growth of the crack will be delayed,and which in turnwill not be leading to the fatigue conditions. So, for fatigue fracture to take place. It is important thatthe tensile load component is present under the fatigue conditions. So, that the crack can nucleate,and then it can growunder the fluctuating load conditions.

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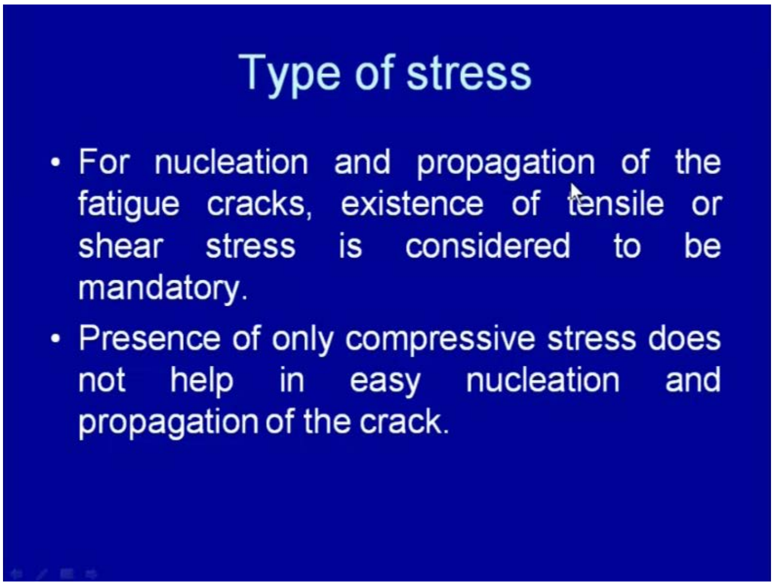

So, for nucleation and the propagation of the fatigue crack existence of tensile or the shear stresses is necessary,because only the compressive stresses does not help in nucleation, and then propagation of the of these cracks. Therefore fatigue failure tendency is reduced or almost eliminated, when the component is subjected only to the compressive type of the stresses, and as a customary the tensile and the shear stresses, which help in nucleation and growth of the crack are considered positive, whilethat compressivestress are taken as a negative,and these sign conventionshelp significantly in calculation of the stress rangeand the stress ratios.

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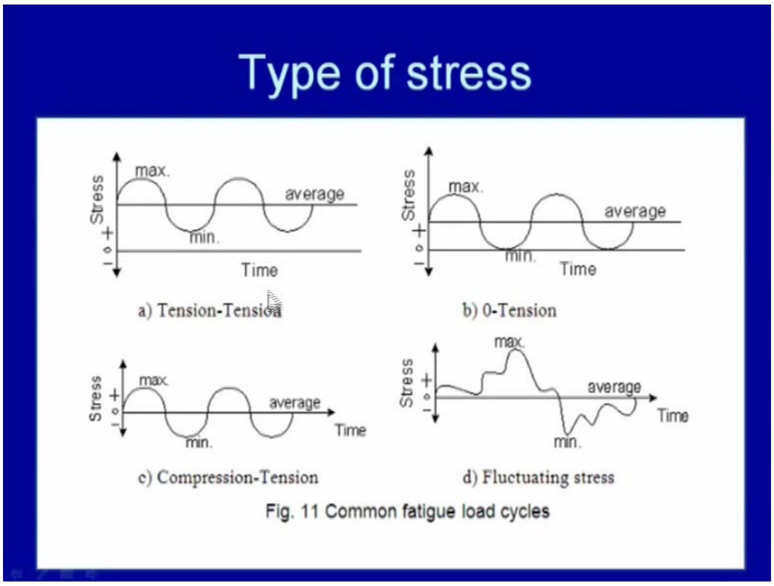

We can see thatin the time scale, if we want to see these variationsinthe stresses then the say in x axis. We have time, and then fluctuation in the stresses sayabove this scale we have the tensile stress that are positive and below this we are having negative. So, sincevariationsshowing the maximum and minimumstresses, and average stress line and. So, here in this casethe stress is varying from the minimum to the maximum level of that, and it is of the tensile in nature, while in this case it is minimum stress is zero and the maximum stress is still tensile,while in the third case the compression and the tensionstresses are being generated,where minimum stress is compressive, and the maximum stress is tensile,and the fluctuating stresses will not have any systematicthe trendof the variation in the stress has a function of time. So, the first one first type of the stress variation. We can say the tension to tension, wherethe minimum is tensile stresses and the maximum is also tensile second is zero to tension, where minimum is zero stress.

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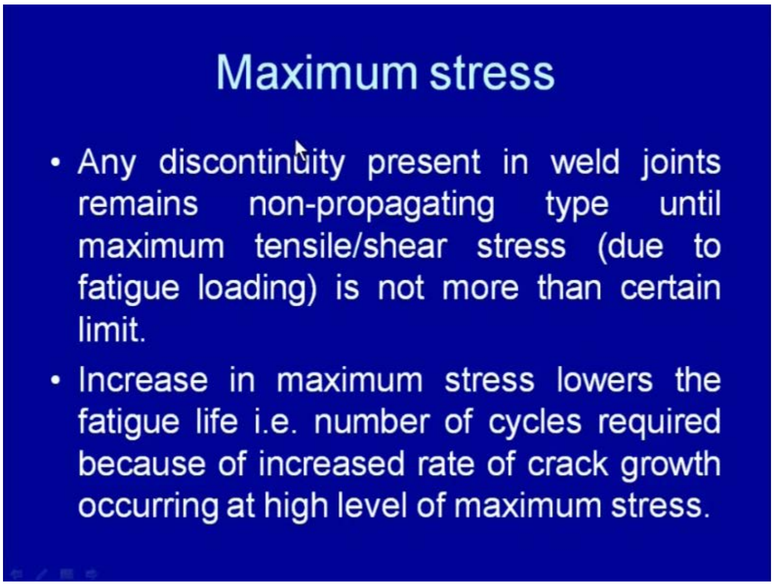

Then the another importantthe characteristic of the fatigueload is the maximum stress.We know that if themagnitude of maximum stress is very limited, then even with the presence of the crack it can be of the non propagating type. So, to have the crackinof the propagating type. It is necessary that the maximum tensile, and shear stressare more thanthe certain limit,and the increase in the maximum stress generally lowers thefatigue life, because it increasesthat a number of load cycles required for nucleation and thecompletion of the growth stage and therefore, in total that fatigue life of the componentis reducedwith the increase in maximumstresses.

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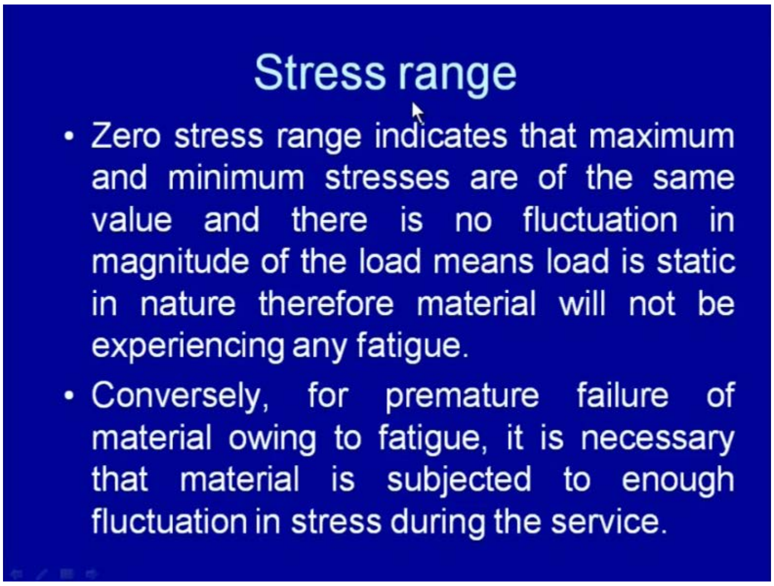

Then the anotherparameter related with the loading condition is the stress range,when the minimum and maximum stress variation is zero, then we can say thatthe load is same and there is no change as a function of time,and under these conditions the load is considered as a static in nature and material will not be experiencing any fatigue. But, when there is significant fluctuation there then onlythe material is considered to be in fatigue and therefore, for premature failure of the material by the fatigue.

It is necessary that it is subjected to have enough fluctuation in the stress level during the service in general increase in stress range lowers the fatigue life,because it decreases the number of load cycles required for each stage of the fatigue ranging from the crack nucleation to the stable crack growth rate,and the sudden fracture and the most of the weld joint designers of the.

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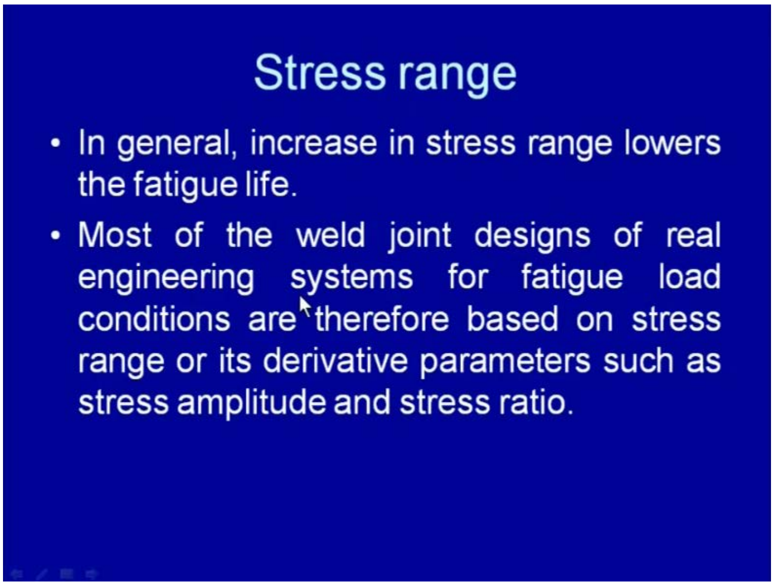

Realengineering systems, and component for the fatigue conditions.Therefore,consider the stress range in various forms, such as the stress amplitude, which is half of the stress range.

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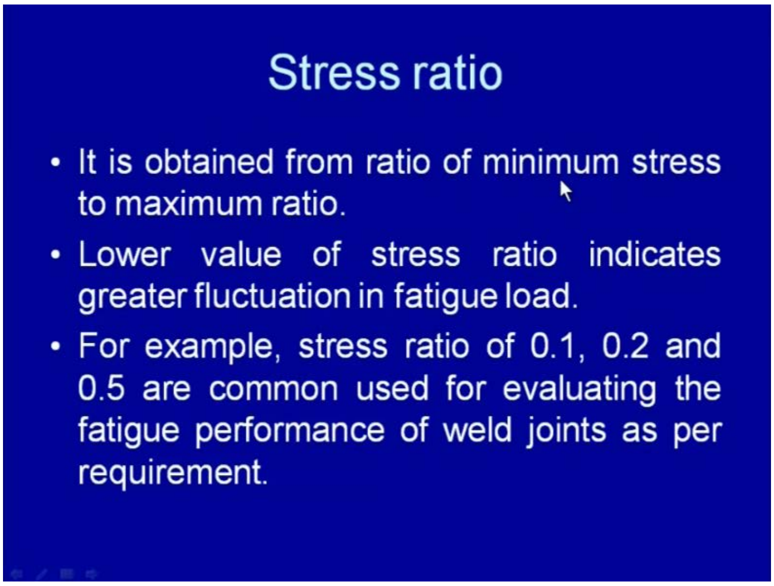

And the stress ratio, which isbasically the ratio of the minimum stress to the maximum stress. So, we know that theirstress ratio, which is obtain from the ratio of the minimum stress to the maximum stress, the lower value of the stress ratio indicates the greater fluctuation in the fatigue load.For example,the common stress ratios, which are used for the fatigue test are point, one point, two and point fivefor evaluating the fatigue performance of the weld jointaccording to the differenttest centers. So, herethe stress ratio of the point one indicate,

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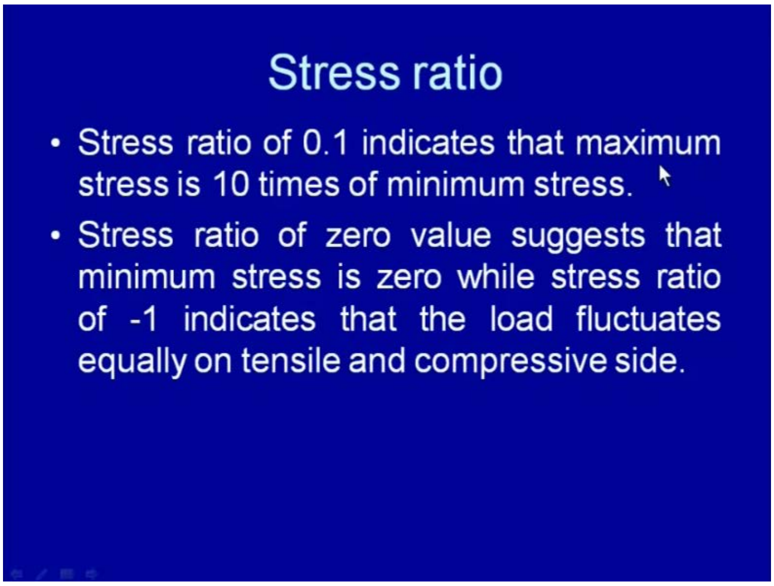

That the maximum stress is ten timeof the minimum stress, and the stress ratio zerovalue suggests that minimum stress is zero,while the stress ratio of minus one indicates that the load fluctuates equally on the tensile and on the compressive side,because the compressive stresses are taken as a negative, while the tensile stresses are taken as a positive. So, value of the both areis equal then it willyield thus minus one stress ratio.

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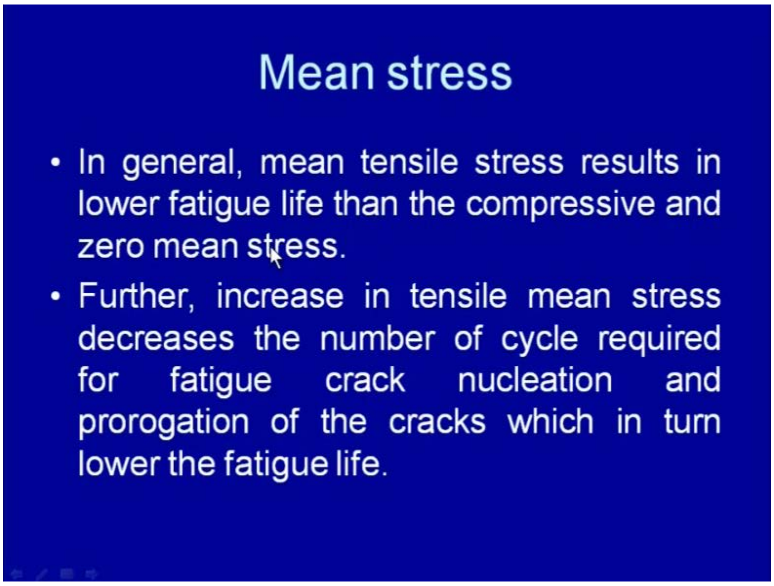

Then a another importantthe parameter that is used to characterize the fatigue load is the mean stress, when the mean stress is tensile in nature,then it adversely affects the fatigue performance as compared to the compressive and the zero mean stress. So, means having the mean stressof the tensile in nature is not good from the fatigue life point of view.As themean compressive stresses and the zero mean stresses result in the betterfatigue life further increase in the tensile mean stress decreases the number of the cycles required for fatigue crack nucleation and the propagation, which in turn decreases the fatigue life of the component this diagram can be used toschematic diagram.

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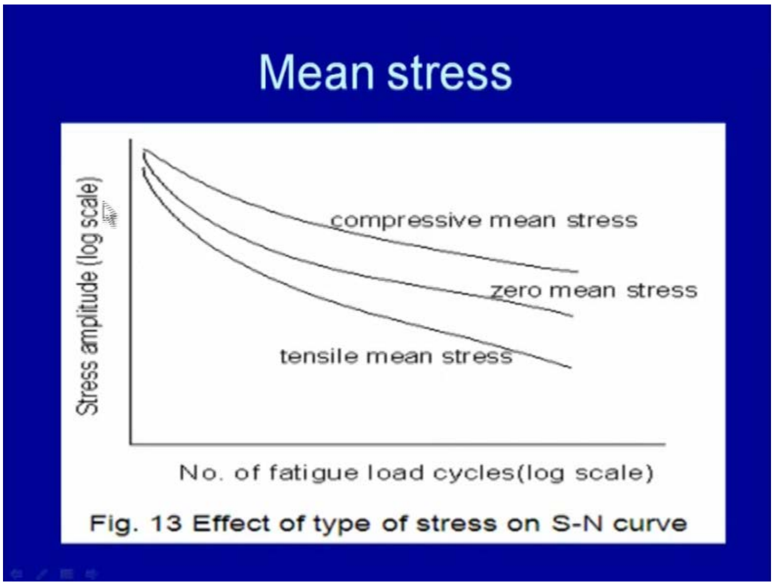

Fig. 13 Effect of type of stress on S-N curve

Showing the effect of the stress amplitude means the s n ratio for thedifferenttypes of the mean stresses.Here,the this lower one shows thethat the s n curve means the stress amplitude and the loadnumber of load cycles curve for the tensile mean stresses andfor zero and the compressive mean stresses. This curve itself suggests that for a given stress amplitudethe loadingcycle having the tensile mean stresses that will offer thelesser number of or the fewer number of theload cycles means the shorter fatigue life ascompared to that,which will behaving the zero mean stress or the compressive mean stress.

Similarly, for a given load cycles for givennumber of theload cycles of the fatigue lifethat the load fluctuating load with the tensile mean stress can sustain lower stress amplitude, while the compressivemean stress cancompressive type of mean stress can sustain the higherthe stress amplitude. So, it is. So, this figure suggests that it isfavorable to have the compressive mean stresses as compared to thetensile mean stresses, because the tensiles tresses facilitate the nucleation and the growth stages of the crack during the fatigue failure. Then,

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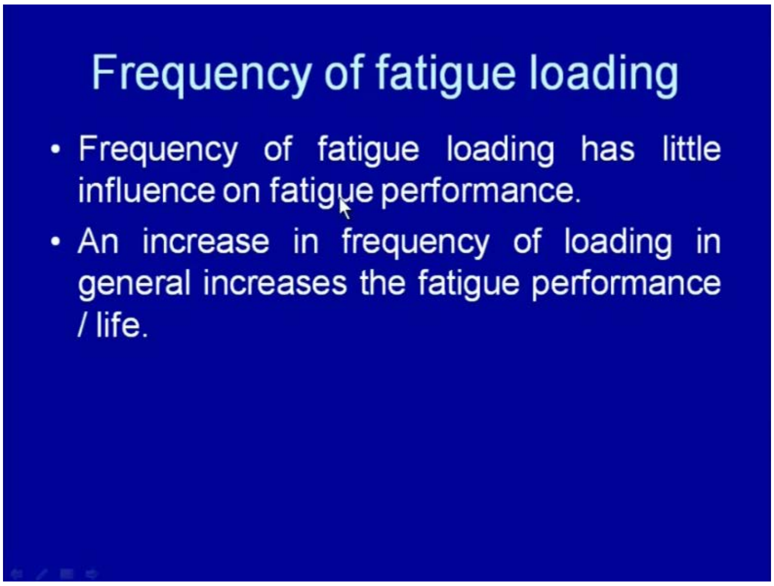

Another factor is the frequency of the fatigue loading. In general,it is felt that frequency of the fatigue loading has a very little effect on the fatigue performance, but in some of the studies it has been observed that an increase in thefrequency of loadingincreases thefatigue performance or the fatigue life of the component,then will take up the material characteristicseffect the fatigue life of the component.

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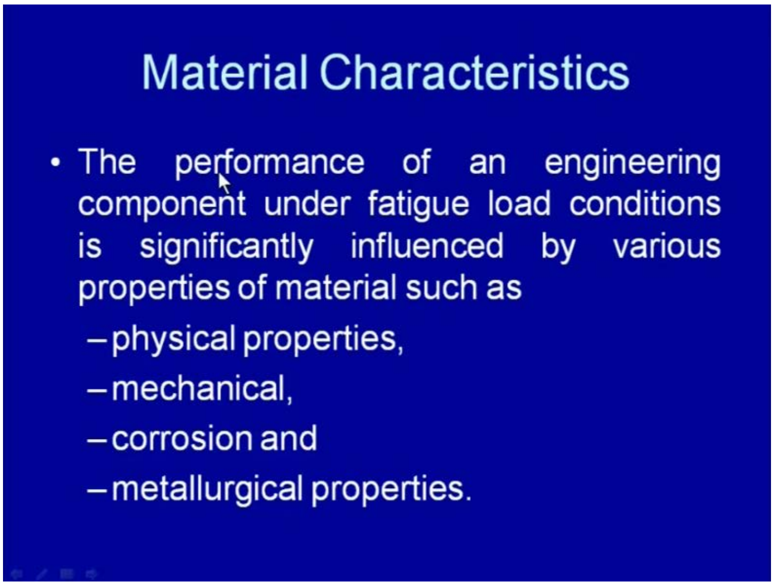

Now, that the performance of the engineering component under the fatigue loading conditions is significantly influenced by the various properties, such as physical properties, mechanical properties, corrosion and metallurgical behavior. So, one by one we will be taking up these properties physical properties including,

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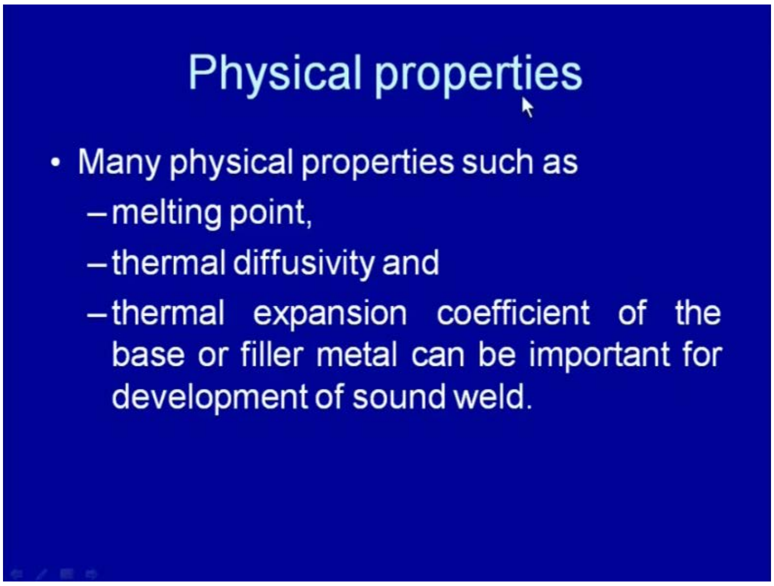

The melting point, thermal diffusivity, and thermal expansion coefficient of the base material and filler material are importantfrom these,we cansaythat if the thermal diffusivity is high, thenthe weld joint will be subjected to the uniformity in the temperature gradient,temperature gradient will be lower,and the differential expansion and contraction will be lower and, which in turn will be resulting in the better combination of themechanical properties and microstructure as compared to the case, when the thermal diffusivity is less.

Similarly, when the expansion coefficient of the material base material and the filler material is low, then it will be resulting in the lesser expansion and contraction during the heating and cooling cycle of the welding, and this in turn will be leading to have the fewer residual stress and distortion related problems and the lesseris the magnitude of the residual stresses being developed during the welding,then it will have the lesser effect on the fatigue performance of the weld joint.

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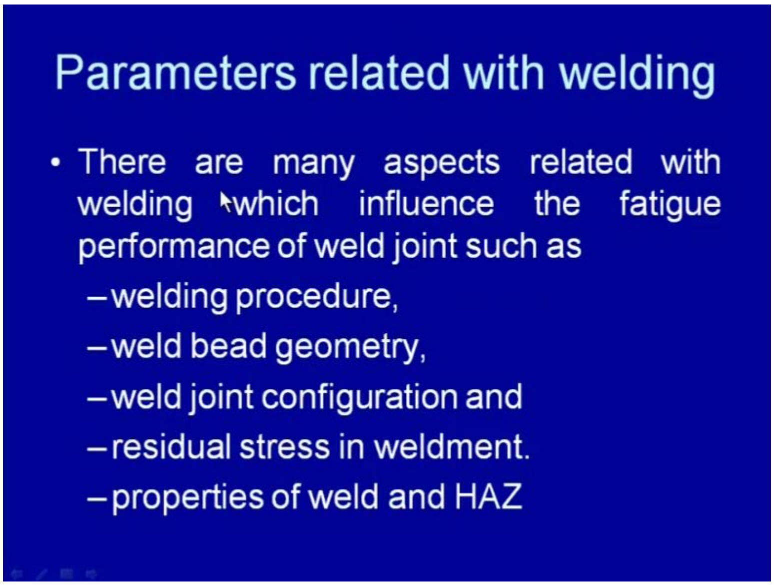

Then,thensay there are the manyaspects related withrelatedwith specific to the welding and, which influence the fatigue performance of the weld joint there are many factors,which are very specific to the welding they have the significant effect on the performance of the weldjoint,and out of these one of the most important factor that affect the fatigue performance of the weld joint is the welding procedure.Welding procedure includes all the steps, which are used for the development ofthe weld joint ranging from the edge preparation to the welding process welding process parameters,then after thereaftercleaning during the inter pass welding preheating and the post weld heat treatment or any other special treatment,which is done for enhancing the performance of the weld joint.

So, the various aspectsalmost all steps,which arethere induring the development of the weld jointwill bewill be forming the part of thewelding procedure. So, welding procedure becomes very important a factors or the parameters that will be affecting to the fatigue performance of the weld joint,and thendepending upon the kind of welding procedure, which is being used we can have the variety of the weld bead geometries. It is always desired to have the low bead angle and theandunnecessary highweld bead reinforcement is avoided and proper fusionis obtained with the proper penetrationis achieved, while developing the weld joint. So, theweld bead parameterespeciallythe sharp transition in cross section near the two of the weld is avoided,and the low bead angle is obtainedfurther unnecessaryregularities on the weld bead.

A surface is also avoided in order to have any adverse effect ofthe weldingfrom the weld bridge geometry point of viewon the fatigue performance of the weld joint. So, these are the important things,which are to be kept in mind as far as the weld bead geometry is concerned,then the weld joint configuration in, which way for a given procedure what kind of the weld joint is being developed that significantly affect the fatigue performance.

For example,butt weld buttgroove weldjoint offers the higher fatigue performance as compared to the fillet weld,because fillet weld inherently suffers with theproblem of the stress raisers and, which help in easy nucleation and growth of the crack and that is, why the fatigue performance of the fillet weld joints is found lower than thebutt groove weld joints,then the residual stresses welding procedure significantly affect the kind of residual stresses and there magnitudegenerally the weld jointsis subjectedmeans weld joint develops the tensile residual stresses,while the heat affected zonegenerally comprises the compressive residual stresses.

So, if the presence of the tensile residual stresses in the weld jointencourages the crack nucleation, and growthcrack growth tendencyunder the fatigue load conditions especially in the weld region and, which in turn adversely affects the fatigue performance. So, it is always desirable to have the compressive residual stresses in the weld region. So, that these can reduce the effectiveexternal tensile stresses acting in the weld joint in order to enhance the fatigue performance, then the properties of the weld and the heat affected zonethe properties like the bettersurface hardness, and the goodyield strength, and good fracture toughnessdiscouragethe crack nucleation andresist the failure of the component by the fatigueprovided that it is having the good a fracture toughness.

So, properties of the weld joint are controlled in, such a way that it is havingthe reasonably good surface finish andat the same time unnecessarily embrittlementof theweld region and the heat affected zone is avoided. So, thethese properties are achieved through thesuitablecontrol of the welding parameters andweld composition and the post weld heat treatment,these aspects will be taken up one by one in detail. The subsequent slides so, as described above there are certain parameters, which are very specific to the welding and they effect the weld performancefatigue performance of the weld significantly, but the how far andhowwhat will be the extent of effect of those parameters on the fatigue performance.

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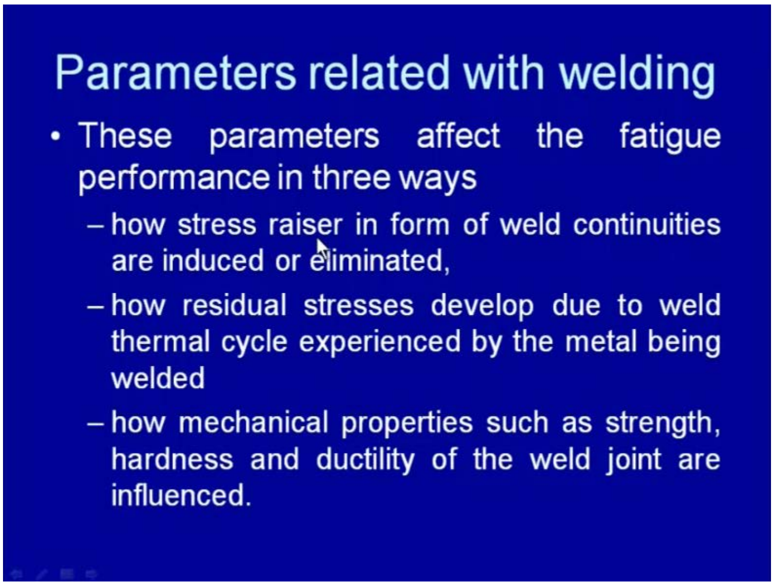

That will be governed by the above parameters in three ways means the parameters, which have been described in the previous slide that how these parameters affect thefatigue performance that will be governed in the three ways one is that how the aboveparameters like the welding procedure or the weld bead geometryandaffect the stress raisers in theaffect the development of the stress raiser in thein the form of the weld discontinuities and ,whether the welding procedure and weld bead geometry are helping inreducing these stress raisersand or they are encouraging the development of the stress raisers in form weld discontinuities or how the welding procedure and the related parametersof the filler material, and the base metalaffect the development of residual stresses in the weld.

Due to the weld thermal cycle, which is being experienced by the base material during the welding. So, depending up on the kind of residual stresses, which are induced and theirand the type of the residual stresses, which are induced and their magnitude that will be affecting to the fatigue life,and then how the welding procedureis effecting to the mechanical properties of the weld metal,and the heat affected zonein form of the tensile strength hardness and ductility that will decide that what will be the effect of the parameters related with the welding procedure and weld bead geometry on the fatigue performance on theof the weld joint.

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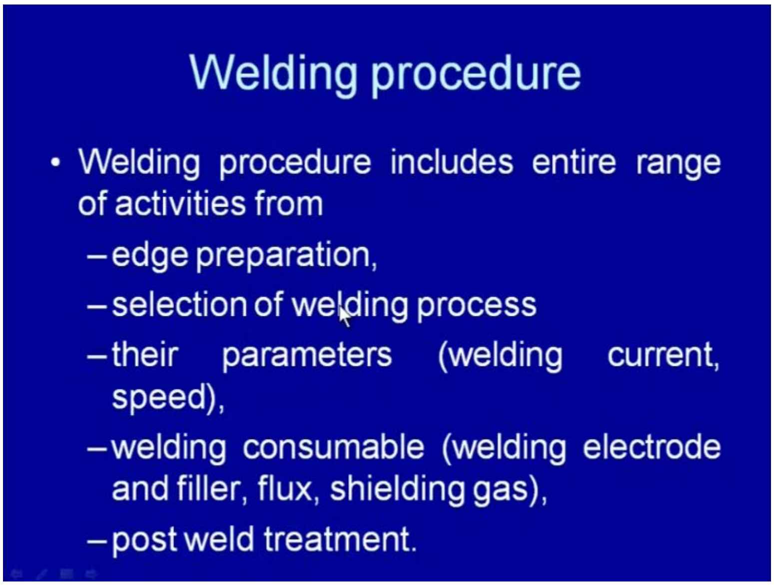

Then the various since the welding procedure is one of the most importantaspect that will be effectingthe fatigue performance of the weld joints. So, we will be looking into the greater detail of the each parameterrelated with the welding procedure that and try to see that how, it can affect the fatigue performance of the weld joint. So, the welding procedure includes the entire range of the activities, which are used for the development of the weld joint ranging from the edge preparation,the selection of the welding process, which welding process is being used whether it is low or high energy density process, how the edge is being prepared it is being is it being prepared by the mechanical cutting or by thermal methods, which method of cleaning is being used its mechanical cleaning or the chemical cleaning

So, based on that the affect will be different on the fatigue performance what kind of the parameters are being used especially the weldingcurrent and the welding speed, because these two parameters significantly dictate the net heat input to the weld joint,andthen the welding consumables like theelectrode diameterthe fluxand the coating on the electrode material this kind of shielding gas,which is being used and the filler material.

So, these parameters will be affectingthe characteristics of the weld metal and the tendency of the residual stresses being developed in the weld region, and then the post weld treatment what the kind of the post weld treatment are being tried like the shot peeningor the stress leaving treatment or any other especial post weld heat treatment in form of the normalizing or tempering is being done.

So, all those things will be affecting the residual stresses state the metallurgical structure of the material in the weld region, and the heat affected zone and the mechanical properties of the weld joint and, because of all these variation the fatigue performance of the weld joint will be significantly affected by the post weld treatment the welding consumables the parameters, which are being used for development of the weld joint the welding processes itself and the edge preparationmethod ,which is being used.

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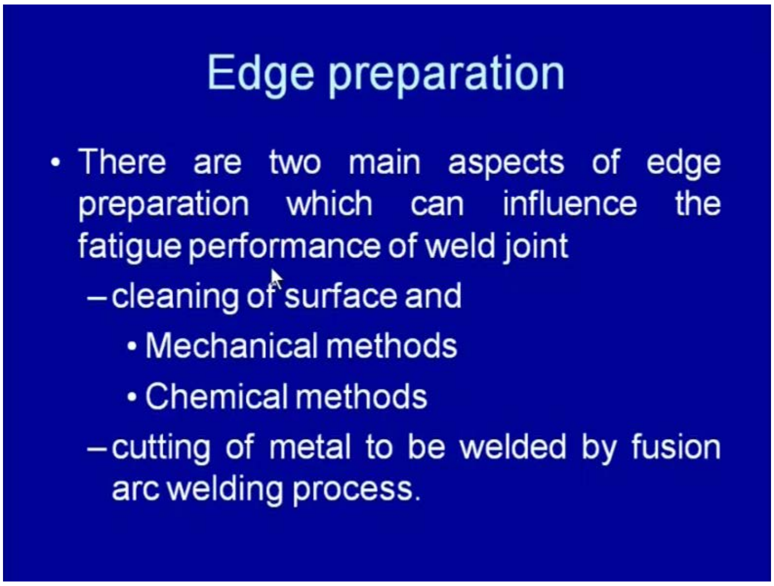

So, these will be taken up one by one,we know that for the edge preparation thereedge preparation is important to haveto remove the impurities present on the faying surfaces ofthe base material to be welded and to have the required edges. So, that these can be brought to the molten statesometimes the bevelling is required in order to ensure the true thick penetration. So, for that bevelingwe purpose we can use the mechanical or the thermal methods.

So, basically for the cleaning purpose in order to remove the impurities and theother things, whichunwanted things present on the faying surfaces basically two methods are used mechanical methodandcleaning method.Mechanical method is considered to be favorable, because in cleaning method when we use the hydrogen based chemicals like h t s c l h two s o four etceterathere this hydrogen getsdiffused into theregion closed to the faying surfaces, and this hydrogen gas sometimes leads to thehydrogen induced cracking tendency in theweld heat affected zone and,which in turn decreases the fatigue performance of the weld joint.

Similarly, the cutting of the weld metal is being done either by mechanical methods like machining or it is being done by the fusion method. So, when the cutting is done by the mechanical methods. It does not affect the fatigue performance appreciably, but the cutting offthe faying surface cutting of the plates to be weldedby the thermal methods especially in case of the hardenble steels adversely affect the fatigue performance, because the thermal methods frequentlycausethe development of the residual stresses and hardening of the cut surfaces and,which will be increasing the cracking tendency of the base material itselffrom the heat affected zone portion, whichwas produced earlier during the thermal cutting method. So, it is notadvisable to use the thermal cutting method especially in case of the hardenble steels.

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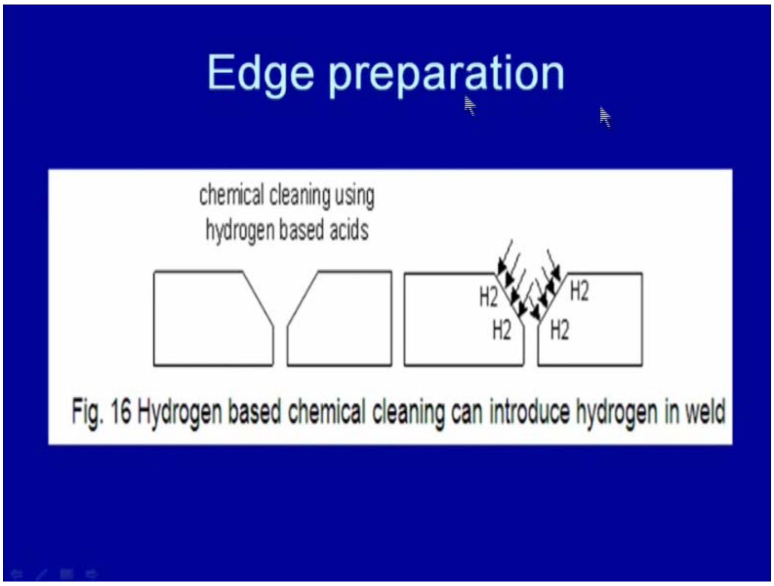

Now, we can see that if the hydrogen based acids are being used on theto clean the surface of the faying surface of the component, then the hydrogen can gets diffuse into the region close to the faying surfaces, during the welding it can createthe problem of theinduced cracking or just after the welding. We can see that excessive presence of the hydrogen has led to the cracking of the heat affected zone.

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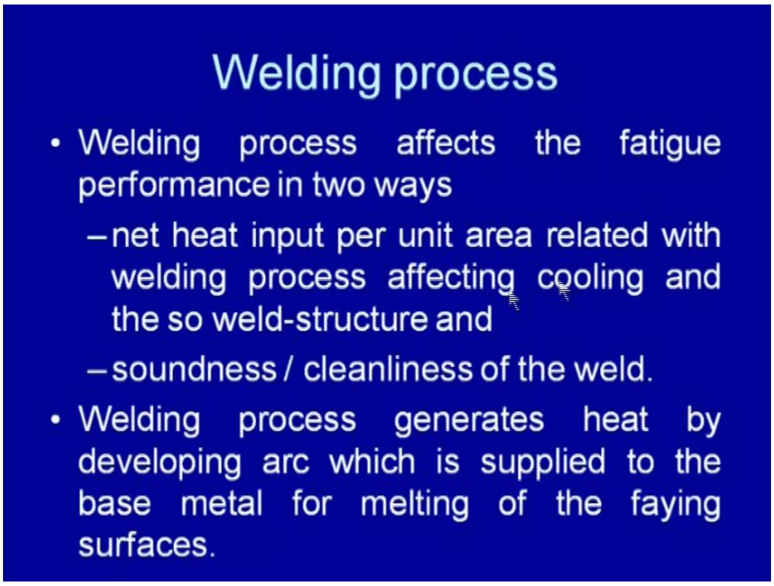

Then there are otheranother important aspect is the welding process, which is being used for the development of the weld joints. So, as i said itimportant aspect related with the selection of the welding process is the energy density. The welding process of the low energy density will be supplying the greater amount of the heat for developingthe weld joint as compared to those of the high energy density processes. So, greater is the heat input by the low energy density process like gas welding or theshielded metal arc welding process.

So, they will be supplying more amount of the heat. So, more amount of the heat will be resulting in the slowlow cooling rate and low cooling rate will be deteriorating the mechanical performance ofthe heat affected zone,and the weld region will be reducing the mechanicalproperties in terms of the hardness and tensile strength and the poor mechanical properties can lead to the reduced fatigue performance of the component.

And another important thing related with the welding process apart from the energy density related aspect is that, how clean weld can be produced using a particular process. So, the two important things are related with the selection of the particular process and its effect on the fatigue performance one is that what kind of the heat inputnet heat input is required for developing a weld joint through a particular process, because it effects the cooling rate and. So, the weld structure and heataffected zone properties,and another aspect is that how the welding process affects the soundness of the weld joint especially in respect of the cleanliness, because the different process offers the different kind of protection of the weld pool from the atmospheric gases.

So, thelike the process is like the g t a w will be offering the cleaner weldas compared to the other process like s m a w. So, the and the weld if the weld is not clean it is having the impurities in form of the gases and, which are leading toinclusions and the porositythen present of these defectwill be leading to theweld joint of the poor soundness, if the weld joint is not sound then it thesediscontinuities will be providing the easy site for nucleation and growth of crack and, which in turn will be adversely affecting the fatigue performance of the weld joint. So, the welding processes, whichwelding processes generates the heat by developing the arc, which is suppliedto the base metal for melting of the faying surfaces.

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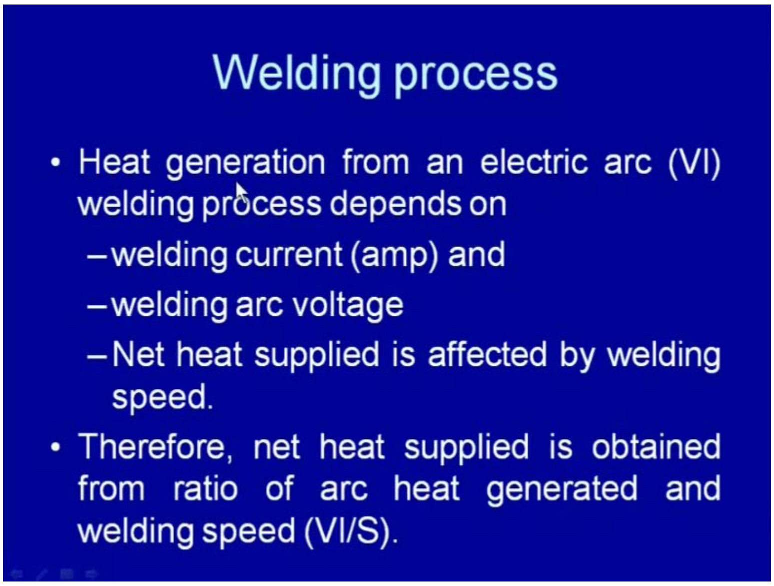

And the from the heat generation point of view heat generation froman electric arc welding process depends up on the welding current and the arc voltage,while the net heat supplied is affected by the welding speed. So, the net heat supplied is obtained from the ratio of the arc heat generated divided by the welding speed. So, we have seen that the welding process can affectthe fatigue performance of the weld joint in two ways one is that how does it affect the heat generation, and the second is how does it affect the cleanliness of the weld as far as the heat generation is concerned. So, those welding process which offer the high energy density.

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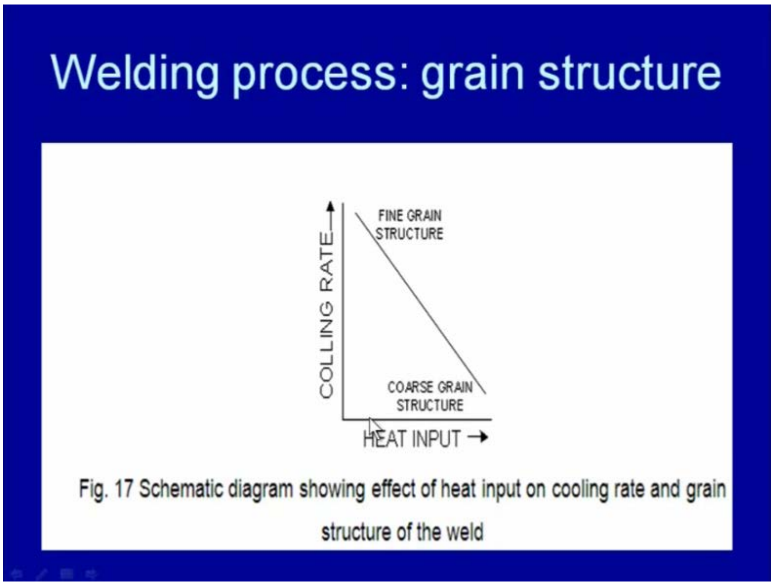

They supply the less heat for developing the weld joint and the low heat input results in the finer grain structure, fine grain structureleads to a better mechanical properties and the better fatigue performanceas compared to the case, whenthe high heat input is used in case of the low energy density process like gas welding andthe shielded metal arc welding processes. So, the low heathigh heat input will beproducing the low cooling rate in the weld region and in the heat affected zone and the low cooling rate will be producing the coarse grain structure, and coarse grain structure will be resulting in the poor mechanical properties and. So, the poor fatigue performance.

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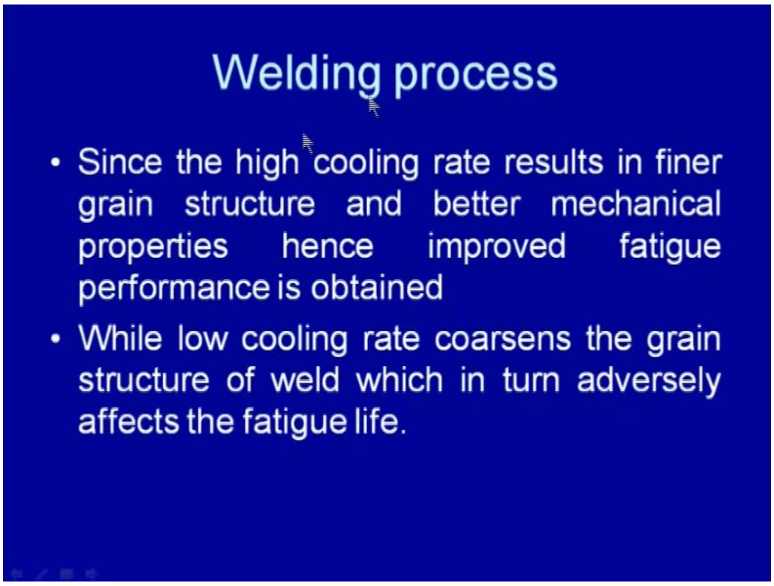

So, there’s a logic as far as the welding process and it affects on the fatigue performance is concerned that the since the high cooling rate results in finer grain structure and better mechanical properties.Hence, the improved the fatigue performance is obtain especially with the a low energyhigh energy density processes, which supply low heat input while the low cooling ratecoarsens the grain structureof the weld, which in turn adversely affects the fatigue life and this is the kind of behavior mainly observed,when low heat inputlowhigh heat input processesare used which are having the low energy density.

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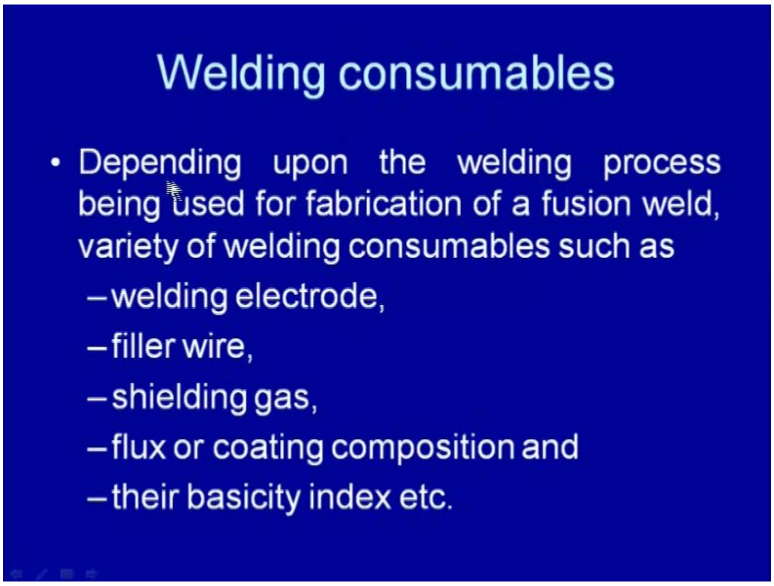

The depending then anotherimportant factor related with the welding procedure is the welding consumable use of the welding consumable significantly dictate the fatigue performance, because it affectsthe mechanical properties of the weld metal that development of the residual stresses, andthe kind of the heat input which will be generated during the welding and. So, the related cooling effect and the cleanliness of the weld.

So, these are the various factors related with the welding consumables that one is welding electrode what size of the welding electrode is being used,and what is its composition that effects grain structure and the heat, which will be generated during the welding then the filler material the expansion coefficient of thefiller material,which is being used for development of the weld joint.

And it its yield strength will be effecting to the residual stress development and the shielding gas howthe depending upon the kind of shielding gas, which being used it will be affecting the eitherheat generation and at the same time. It will be effecting the protection to the weld pool from the atmosphericgases then the flux and the coating composition flux and coating composition affects the cleanliness of the weld as well as the heat being generateddue to the presence of the low ionization potential elements,and the basicity of the flux is effects the cleanliness of the weld as well as the weld metal composition. One by one these factors related with the welding consumable will be taken up.

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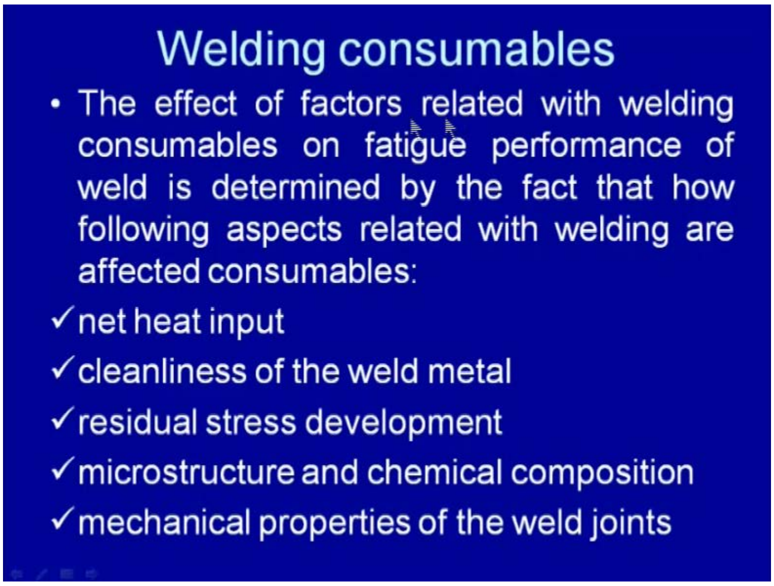

The effect of the factors related with the welding consumables on the fatigue performance is primarily determined by the fact that how the following aspectswith the welding are affected by the use of particular kind of consumablewelding consumableaffect the net heat input depending upon the kind of the electrode diameter,which is being used or what kind ofelectrode coating material is being used then it effects the cleanliness of the weld, because the shielding gas and the flux, which is being usedeffects the cleanliness of theweld then it effects the residual stress development also,because theexpansion thermal expansion coefficient of the filler material anditsthe yield strengthdecides the what magnitude of the residual stresses will bedeveloped after the welding.

Then the microstructure and chemical compositionwill be dictated by the composition of the filler material, which is being used and since if the if the filler material is having the grain refiners then it will leading to have the finer grain structure,which will result in the better mechanical properties as compared to the coarse grain structure material having nograinrefiners. So, the mechanical properties of the weld joints is. So, depending up on the kind of the properties like yield strength, hardness, and the fracture toughness of theconsumable, which is being used for development of the joint will be dictating the properties of the weld jointthen accordingly its fatigue performance will be affectedas far as thefirst parameter means firstthe welding consumables are concernedthe size of the electrode, which is being used affects the fatigue performance in big way and the main approach for explanation of this is that.

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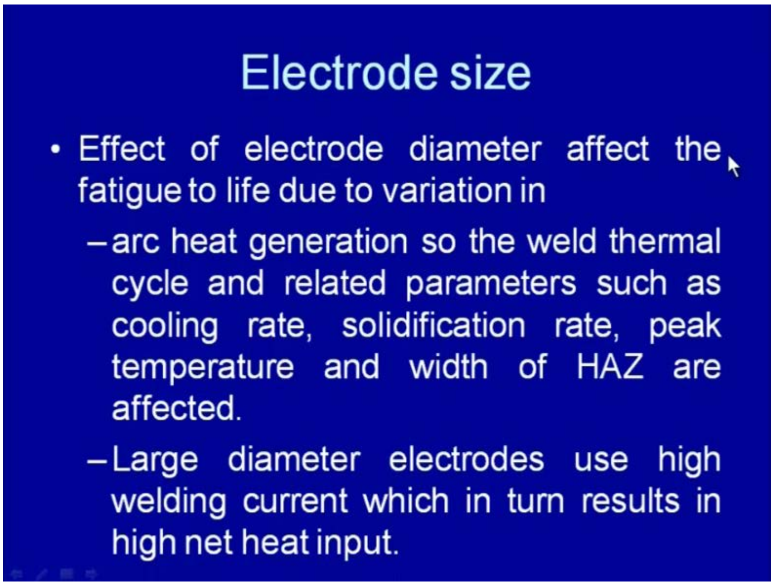

The electrode diameter affect the fatigue performancedue to the variation in the arc heat generation. So, that the weld thermal cycle associated with the heat generation is affected, which in turn will be governing the cooling rate solidification rate peak temperature and width of heat affected zone. Because, if we go with the larger diameter electrode then we will have to use a higher current, and high current results means supplies the more heat input, and high heat input results in the lower cooling rate and,which will be deterioratingthe mechanical propertiesand the fatigue performance of the weld joint as compared to the case,when the small diameter electrodes are being used provided in both the cases sound weld joint is developed.

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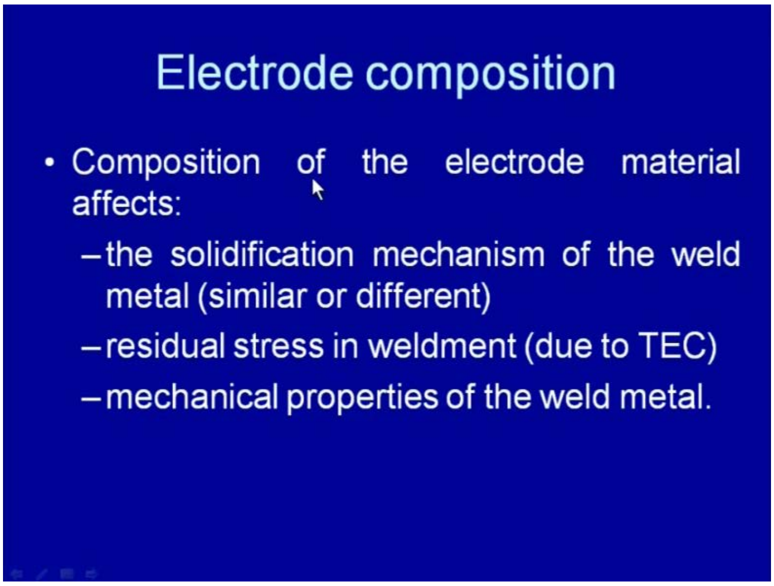

Thenthe composition of the electrodeaffects the fatigue performance of the weld joint. In the following ways one is that,whetherthe composition of the electrode material facilitates the heterogeneous nucleation or homogenize in case of the heterogeneous nucleation very fine grain structure is obtainedand at the same timesolidification mechanism is also affected by the electrode material say for the electrode material, which is similar to that of the base material will be resulting in theepitaxial solidification, while in case when the filler material composition is significantly different from the base material. It will be leading to havethenon epitaxial solidification where first nucleation and thengrowth will be taking place.

While for the similarfiller material similar to that of the base material will besolidifying directly with the growth mechanism as it does not require the nucleation stage.Thefiller material composition also affects theresidual stress development, because the difference in composition leads to the different thermal expansion coefficient and, which in turn results in thehuge difference in the residual stresses, which are being developed in the weld region and the difference in composition affects the microstructure of the weld metal and accordingly it affects the mechanical properties of the weld metal,and variation in mechanical properties directly affect the fatigue performance of the weld joint.

As has been explained earlier that hardness yield strength and fracture toughness of the material directly dictate the different stagesof the fatigue failure. So, all those mechanical properties that can delaythe different stages of the fatigue failure. They will be helping in improving the fatigue life of theweld joint.

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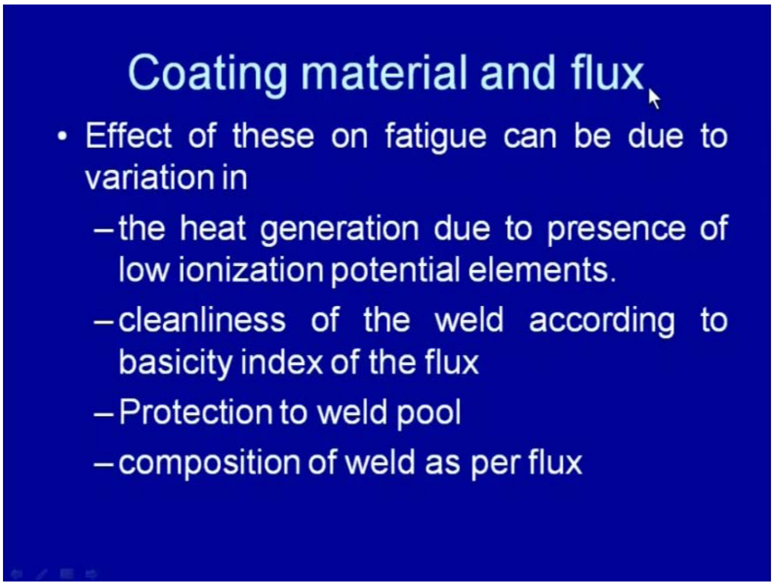

Then the coating material and the flux these factors effect of these factors on the fatigue life can be explainedthat willmeans can be explained in in the following ways like that the, how thecoating material and the flux effects the heat generation. So, that will beaffecting the cooling rate during the solidification stage,and depending up on the cooling rate being experienced by the weld metal mechanical properties will be effected due to thevariation in the grain structure.

And So, the flux material means the heat generation due to the presence of the low ionization potential elementis affected, if the large amount of the low ionization potential elements are present then the heat generation is reduced, because of the high conductivity of the arc gap, and the reduced heatgeneration leads to the higher cooling rate during the solidification,which in turn will bedeveloping the fine grain structure in the weld region and the better mechanical properties at the same time, when the flux and the coating material will be effecting the cleanliness of the weld, becausethe these fluxes under the influence of the arc heatprovide the protective atmosphere to the weld pool and ifthe protectionof to the of the weld pool is not proper, then it will be effecting to theeffecting to the cleanliness of the weld grater poorer is the protection to the weld pool.

And that this will be leading to themore amount of the impurities in the weld metalin form of the gases, theoxides, and nitridesof the metal, which is there in the weld pool. So, the inclusions and porosities are basicallyencouraged with thepoor protection of the weld pool, and that will depend upon the type of the flux and the its amount being used with the electrode material.

Similarly,thebasicity index of the flux also affects the cleanliness of the weld, because the basicity index greater than one point two in generally in generalresults in the cleaner weld as compared to the flux is having the basicity index less than one and, which will be governed by means the basicity index is governed by the composition of the flux material, which is being usedeither in form of the electrode coating or to cover the weld pool.Incase of the submerged arc welding and protection to the weld pool is effectedby the coating material and the flux material, because it decides that how much amount of the inactive and protective gases.

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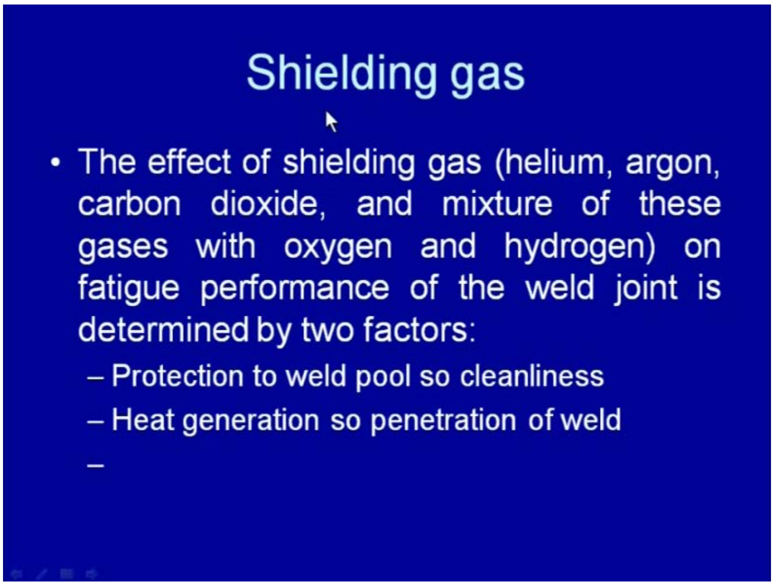

Inactive and the protective gases will be generated by the effect of the heat of the welding arc to protect the weld pool. And the composition of the weld metalis effected by the composition of the flux, which is being used to protect the weld pool and sometimes the flux is intentionally modified to change the composition of the weld metal as per the requirement in order to induce the specific set of the properties.

And the another consumable likeshielding gas variety of shielding gases are used to protect the weld pool like the helium, argon, carbon dioxide or mixture of these gases with the oxygen and hydrogen and performance of these shielding gases on the fatigue performance of the weld joint is basically determined by the two factors one is the,how the protection is effected with the change of the shielding gasto the weld pool.

So, the cleanliness of the weld is affected all those gases like helium and argon, which protects the weld pool effectivelyresults in the cleaner weld and the better fatigue performance of theweld joint, becausethe absence of the discontinuitiesin form of the inclusions and porosityresults in thelonger fatigue life. Due to thedelayedthe initially stage of the crack nucleation and the crack growth and then the heat generationis also affected by the shielding gas, becausethe presence of the gaseslike the use of the heliumresults in the higher heat generation during the welding results in the deeper penetration in the weld as compared to that of argon and this difference is, because of the low ionization potential offered by the helium.

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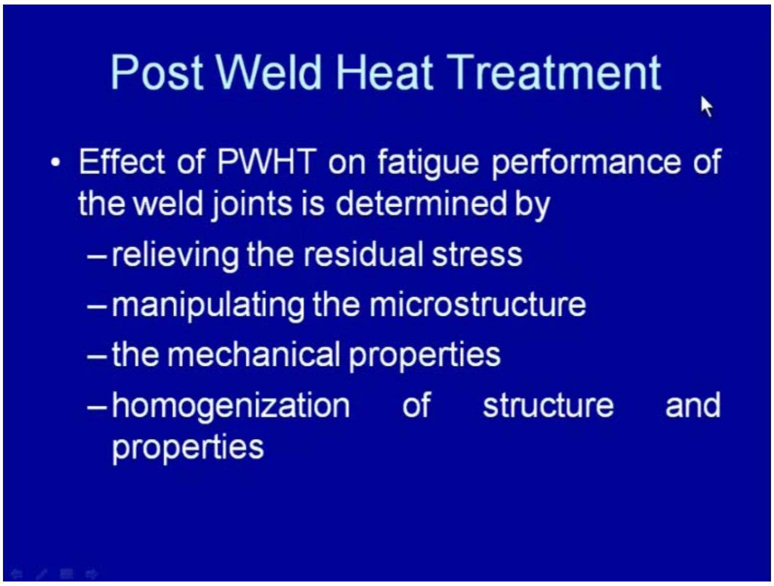

Whilesometimes the addition of the oxygen and hydrogen in the argon and the carbon dioxide also helps in increasing the heat generation by reducing,and that increased heat generation helps inhelps inimproving the penetration, and the improved penetration results in the perfect sound weld joint,which in turnimproves the fatigue performance of the weld joint.

Then the post weld heat treatment post weld heat treatmentof the weld joint is performed for variety of the purposes the one is the relieving the residual stresses. So, that whether there is tensile or thecompressive residual stresses. They will be relieved and theand accordingly thechanges forany distortion out or out of the safe tendency will be reduced. Further the effect of adverse effect of the tensile residual stresses on the fatigue performance is alsoreduced after relieving the residual stresses by the postweld heat treatment, and thepost weld heat treatmentalso helps in manipulating the microstructuresay the crack sensitive microstructure in form of martensiteis transformed into the soft phases like bainite and pearlite.

So, these soft phases discourage the cracking tendency and there by these helps in improvingthe fatigue performanceand the mechanical properties. The variety of the heat treatmentslike normalizing andquenching followed by the tempering help in improving the mechanical properties of the weld joint, which will be delaying thecrack nucleation stage,and the crack propagation stage of the fatigue fracture and there by these will help in improvingthe fatigue performance of the weld joint.

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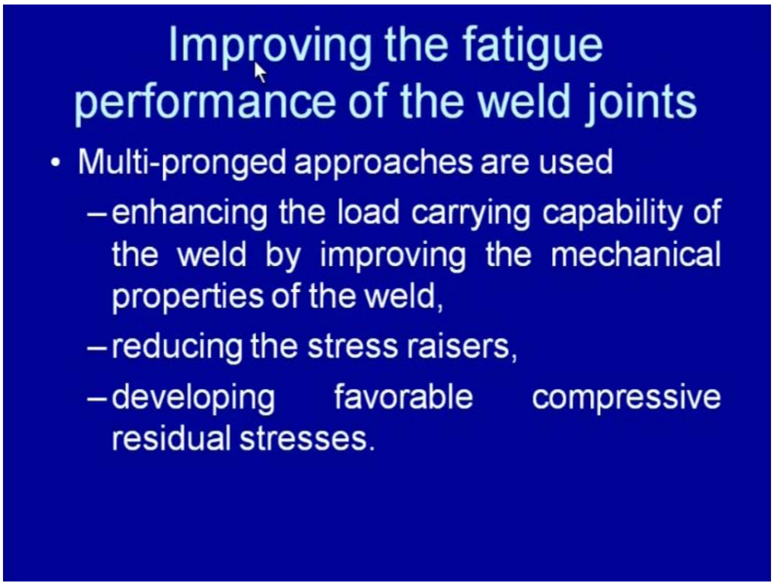

And the post weld heat treatment alsoimproves the structure, and leads to the homogenization of the properties in the weld region and in the heat affected zone. So, homogenization of the structure and the properties after the post weld heat treatment in the different zones of the weld joint leads to the reduced crack nucleation, and the crack propagation tendency and that in turn helps in improving the fatigue performancethen now will we will talk about the different approaches, which are used.

For improving the fatigue performance of the weld joint, we know that the weld joint primarily suffer from the fatigue performance of the weld joint primarily suffers from the presence of the discontinuities in the weld region,because it is found very difficult to produce the weld joint, which are free from thefrom these discontinuities in all weld jointsone or other form of the discontinuity will be present. Thus however, their size may vary significantly from very fine to the large sizes.

Henceat the same timerevealedthe fatigue performance of the weld joint is also adversely affected by the presence of these stress reaisers in form of discontinuities,and the presence of the residual tensile stresses in the weld region. So, in order toin view of these the variety of the aspects that will be affecting theadversely affecting the fatigue performance of weld joint.Multi pronge approach is usedfor enhancing the fatigue performance of the weld,and this approach involves like enhancing the loading carrying capability of the weld join by improving the mechanical properties. So, the properties of the heat affected zone and the weld in this approach the properties of the weld region and the heat affected zone are improved.

So, that it can resist the external loading during the service and delay the nucleation, and the crack growthstagesto avoidthe fatigue fracture or to delay the fatigue fracture. So, that the fatigue life can be improved.We know that the initial stage of the crack propagation is significantly governed by the presence of the stress raisers. So, if the weld joint is free from the stress raisers, then the nucleation stage crack nucleation stage will be delayed,and the delay in crack nucleation stage due to the absence of these stress raisers will help in enhancing the fatigue performance of the weld joint, and the third and an another important aspect another approach, which is used for enhancing the fatigue performance is that (( )) the weld jointis produced with the tensile residual stresses,wherethese stresses will be present along the weld line.

And therefore, the fatigue performance of the weld joint with the tensile residual stressesdecreases significantly especially, when that external loading is tensile in nature.

So, if somehow we can develop the compressiveresidual stresses, which can reduce the affect of theexternal tensile loading then that will help in delaying the nucleation stage of the crack and the crack growth stage will also be delayed. So, basically this the third approach works on the effect of works on the concept of reducing theeffectivetensile stress magnitude acting in the weld region. So, that all the stages of the fatigue fracture can be delayed in order to improve the fatigue life. So, these approaches will be discussed oneby one.

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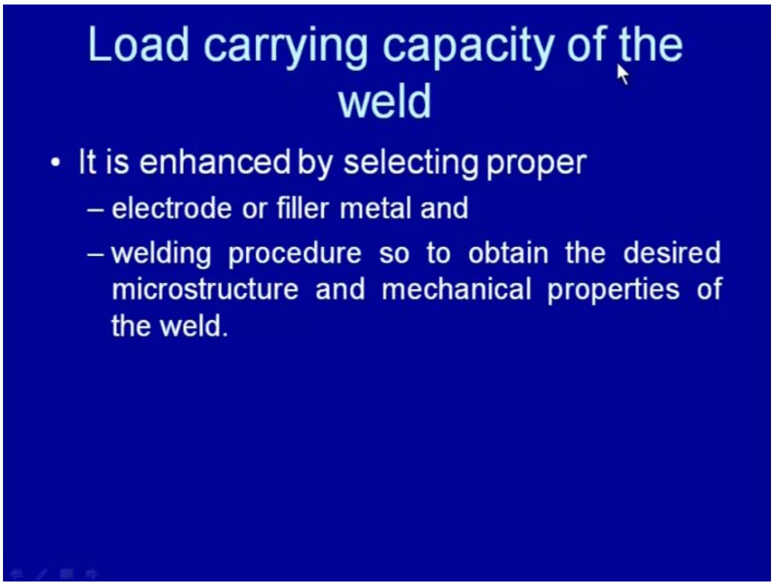

In the first approach, where loading carrying capacity of the weld is enhanced to enhance the fatigue performance of the weld joint. In this approach basically the weld metal is selected in, such way that it is it is having the desired hardness yield strength and the fracture toughness. So, that all the stages of the cracknucleationcrack growth rate,and thesudden fracturerelated with fatigue fracture can be delayed, and thewelding procedure is developed in, such way that the weld propertiesmicrostructure and mechanical properties of the weld can be improved.

And for this purpose for example, proper preheating is donesuitable welding procedure welding process is selected welding procedure process parameterslike welding current, and the speed is selected in, such a waythat the fine grain structure can be developed, and thereafter post weld heat treatment is also designed in, such a way that the fine structure fine grain structure in the weld region heat affected zone and improved mechanical properties can be obtained.

So, basically we try to set the welding procedure in, such a way that themicrostructure and mechanical properties of the weld region and in the heat affected zone can be improved in order to enhance the load carrying capacity of the weld joint. So, in orderfor this purpose various approaches are used like to achieve the desiredgrain structure in the weld region and in the heat affected zone.

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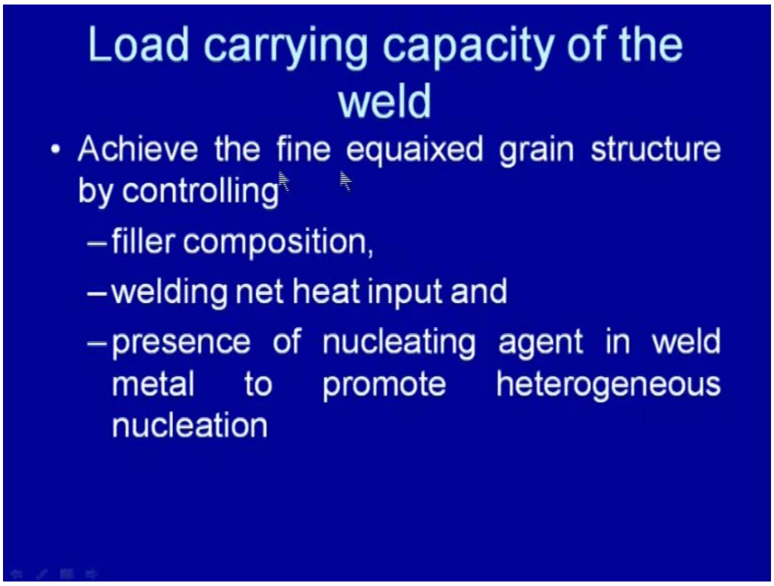

One is to achieve the fine equaixed grain structure in the weld region. So, that the improved mechanical properties can be obtained. In order to enhance the load carrying capacity of the weld one is the select the suitable filler materials compositions. So, that it offers the desired structure and properties reduce the net heat input in order to have the fine grain structure in the weld region orincrease the heterogeneous nucleation by adding suitable refiners in the weld region. So, that the fine equaixed grain structure can be developed. So, these are the three approaches, which can be used for developing the fine grain structure in the weld region in order to enhance the loading carrying capacity of the weld. Another approach for enhancing the load carrying capacity of the weld is that use of the post weld heat treatment.

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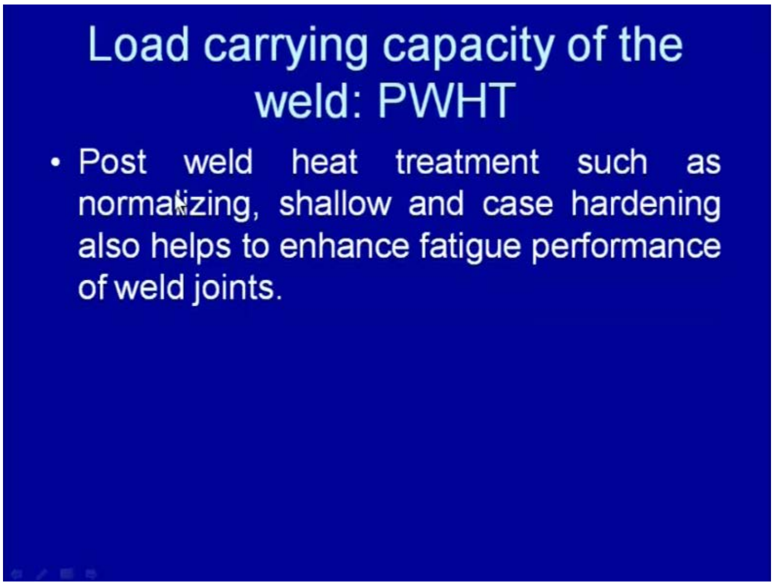

We know the post weld heat treatment such as normalizing shallow hardening and the case hardening helps to enhance the fatigue performance, because they will be helping in enhancing the servicesurface hardness and the, while maintaining the toughness of the core regionand. So, at the same time these also help in developing the residual compressive stressesin the surface region.

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So, the surface hardening treatments like carburizing nitriding help to increasethe fatigue performance of the weld joint in two ways that surface hardness is increase up to certain depth. So, that the crack nucleation stagesis delayed, because of the high hardness of the surfaceat the same timeresidual compressive stresses are induced.After the case hardening and thelike the shallow hardening treatments and this will help inreducing the effect of reducing the effective tensile stresses acting in the component, and there by these will be helping to improve the fatigue performance of weldjoint.

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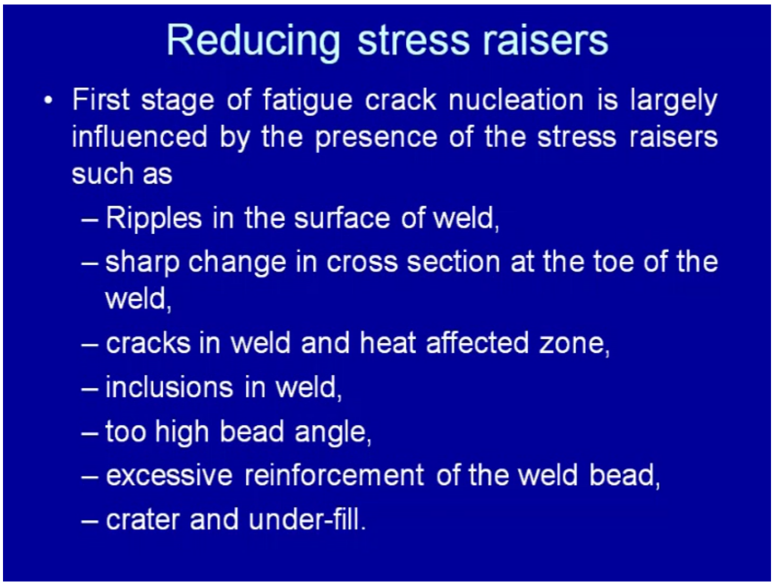

Then thesecond approach is of reducing the stress results in the weld joint. And these approach basically will helpin delayingthe crack nucleation stage due to the absence of the stress results and, if these are present in then the crack nucleation stages facilitated,and the number of load cycles required for completion of the first stage is decreased significantly. So, the first stage of the crack nucleation is largely influenced by the presence of the crackstress raisers, such as ripples present on the surface of the weld.

These can be avoided by themachining and grinding of the welded zone from the top surface.The weld beadmeans weld bead can be machined and the grounded off to get the desired degree of finish means change sudden change in cross section is avoided especially at the toe of the weld,and for this purposea slight machining and the grindingnear the toe of the weld can be done or the weldmanipulation of the arc during the welding can be done.

In such a way that very gradual transition from the base material to the weld zone takesplace in order to avoid the sharp change in cross section,and then avoiding the cracks in the weld and the heat affected zone avoiding reducing the inclusion in the weld or avoiding the too high bead angle.In order to avoid the stress concentrationthe junction of the base metal, and the weld bead and avoiding the excessive bead reinforcement and avoiding the crater and under fill.

These are the common types of the stress raisers, which are found in the weld region and to avoid these stress raisers basicallythe proper welding procedure is developed welding arc is manipulated suitably. So, that the proper weld bead geometry can be developed and the sound weld joint, which is free from the discontinuities like inclusions cracks and porositycan be developed. So, one of the approaches of the reducing the stress raisers in the weld joint.

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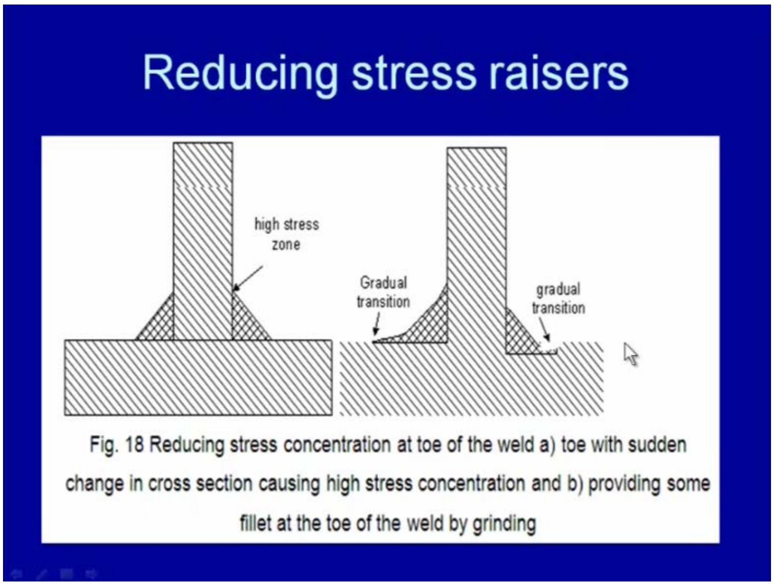

Like say the fillet weld, which hasbeen developed using this kind of the geometry will be having the sharp stress concentration at the toe of the weld. In order to avoid the stress concentration.In these areas grinding of thegrinding using the grinder slightchamfering or you see contouring can be done.In order to have the gradual transition from the base material to the weld zone cross section. In order to have the gradual transitionespecially at the junction of the base metal and the weld metal. So, for this purpose basically grinding and the machining is done. So, that some sort of radius at the junction between the weld metal base metal can be given.In order to reduce the stress concentration at the toe of the weld.

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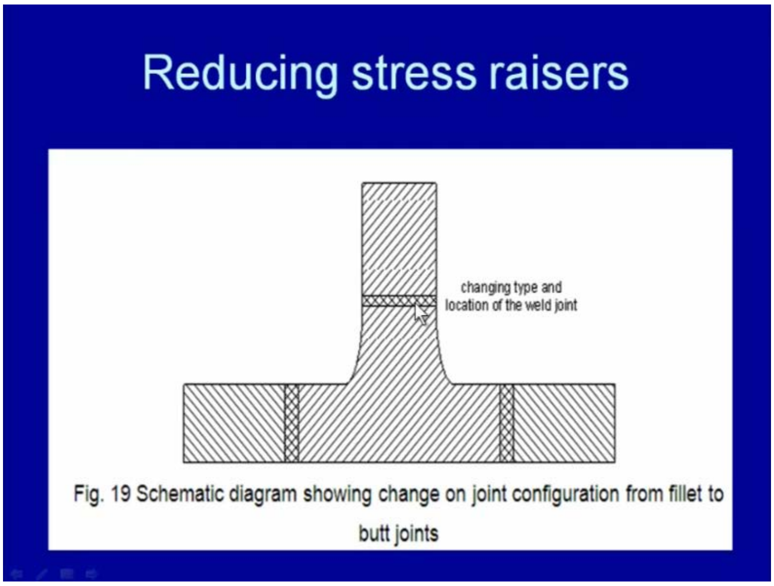

Another approach is to shift the location of the weld region in the previous case. We have seen that to have the t joint we had these two welds, but if the location of the weld jointcan be shifted to some other location where instead of the fillet weld.We have the butt weld then this will help in improving the performancein the previous case. We had the fillet welds, which are known to have the poor fatigue performance.

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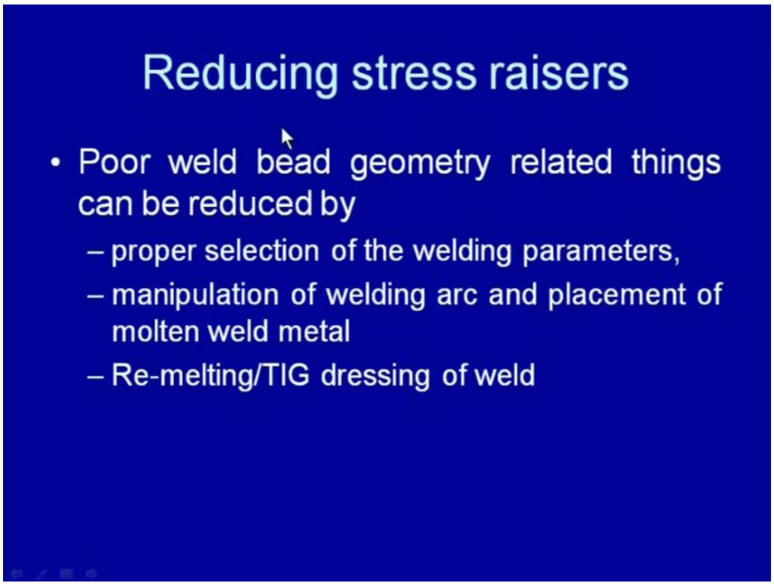

So, if this kind of fillet weldscan bereduced or eliminated and they can bethe design can be modified in, such a way thatinstead of fillet weld. We can use the butt grooveweld joint then that will help in improving the fatigue performance like. In this case the designed has been modified and the fillet two fillet welds replaced with the help of these three butt groove joint. In order to avoidthe adverse effect of the fillet welds on the fatigue performance of the weld joint.

The thirdapproach ismeans the another approach of the reducing thestress raisers in the weld region, that lead tothe poorfatigue lifeto and that will be in form of that poor weld bead geometry related things can be reduced by proper selection of the welding parameters like the welding current and the welding speed. So, that unnecessaryhigh bead angle andbead reinforcement can be avoided, and this can be replaced with the means the parameters can be selected in, such a way that the bead angle is low and unnecessary high weld bead reinforcement is avoided at the same time arc manipulation is also done.In order to have the proper weld bead geometry and the tig dressingor the remelting of the weld bead can be done to eliminate the presence of the defects, if they are present in the weld region and this tig dressingconcept is very simple here.

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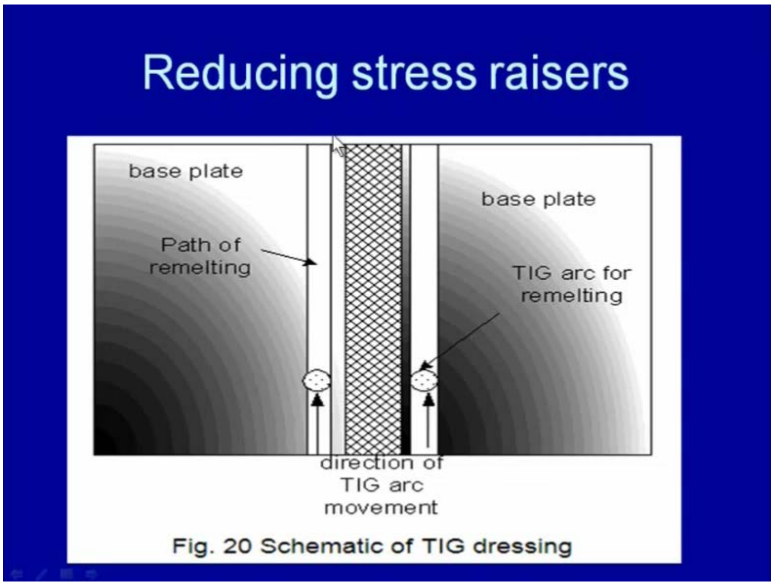

Fig. 20 Schematic of TIG dressing

See this is the weld,which has been deposited on to theto join these two plates. So, the regionclose to the weld will be heatedabout two three to four m m distance from the weld region is heated using the tig arc and. So, that the melting takes place especially the toe area of the weld. So, when the remelting of the toeof the region close to thetoe of the weldis brought to the molten state and on the solidification. It helps to eliminate all the defects orthe inclusionsporosities, which were present they are eliminated. So, that helps in enhancing the soundness of the weld joint andthis in turn helps in improving the fatigue performance of the weld joint.

So, tig dressing is one of the commonly used approach,whereit istig arc is used to remelt the weld metal region especially in the area closed to the toe of the weld. So, that on solidification it results in the weldespecially in the areas near the toe of the weld that is free from the defect, and this reduction in the amount ofdiscontinuities and the number of the discontinuities.In these areasand reducing the stress concentration especially near thetoe of the weld helps in improving the fatigue performance of the weld joint.

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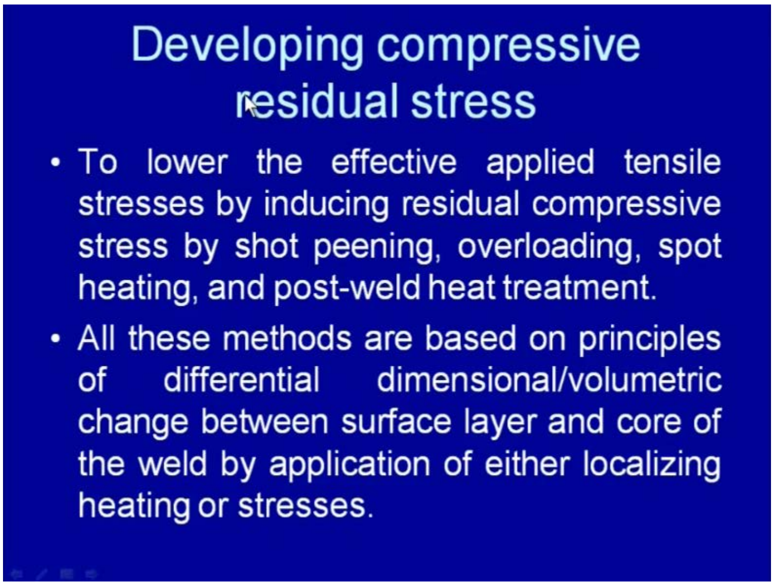

This is third approach, which basicallyinvolves the development of the compressive residual stresses. In order to reduce theeffective applied tensile stresses by inducing thecompressive residual stresses and the compressive residual stresses are inducedusingthe these can be induced by using shot peening ,over loading, spot heating, and the post weld heat treatment.

So, these are the four approaches,which can be used to induce the residual compressive stresses in the weld region. So, that the effective applied tensile stresses magnitude can be reduced, which in turn will help in improving the fatigue performance, because the external tensile stresses basicallyfacilities the crack nucleation and the growth stage that adversely effects the fatigue life.

So, all these methods are based on all these methods like shot peening, overloading post heating,and post weld heat treatment.These methods are based on the simple principle of the intentionally having the differential volumetric change near the surface layersas compare to that of the core. So, that thelocalized compressive residual stresses can be developed and for thisthelocalized differential change in the volume is achieved. Either by applying the heat in very localized manner or by applying the stresses in localized.

So, theshot peening overloadingthese two methods are based on the application of the very localized stresses. In order to have the differential change in the volume near the surface layers, while incase ofthe spot heating and the post weld heat treatment very localized heating is heating followed by the cooling is done in order to develop theresidual compressive stresses.

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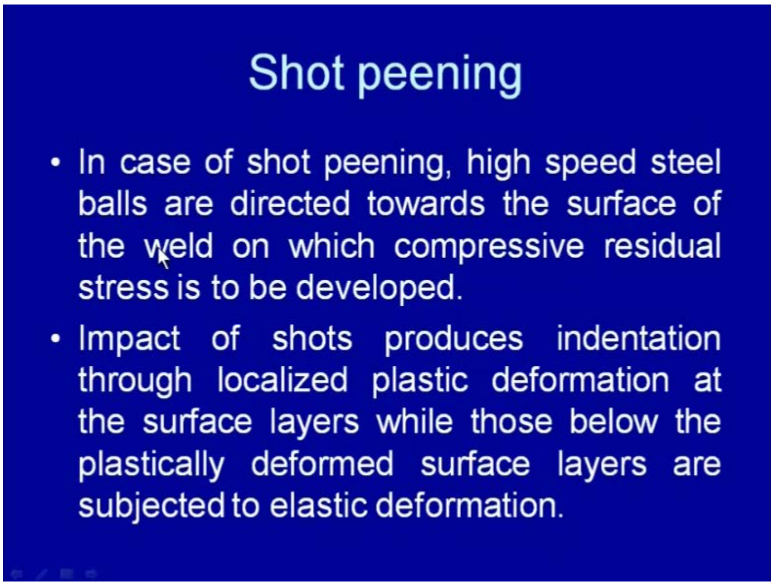

So, in the shot peeningthe high speed steel balls are directed towards thesurface of the weld on, which compressive stresses to be developed and impact of these shots produces the indentation through the localized plastic deformation at the surface layers.While the sub surface region is subjected to theand the, while those below the plastically deform region surface layers are subjected to the elastic deformation. So, when the ballballs are extract on to the surface of the component.The surface layers are deformed plastically, while the region below the surfacethat is deformed elastically. So, after the impact the elastic deformation zone tends to comeback, but thatcomeback is restricted by the plastically deformed zone, and that leads the development of the compressive residual stressesat the surface.

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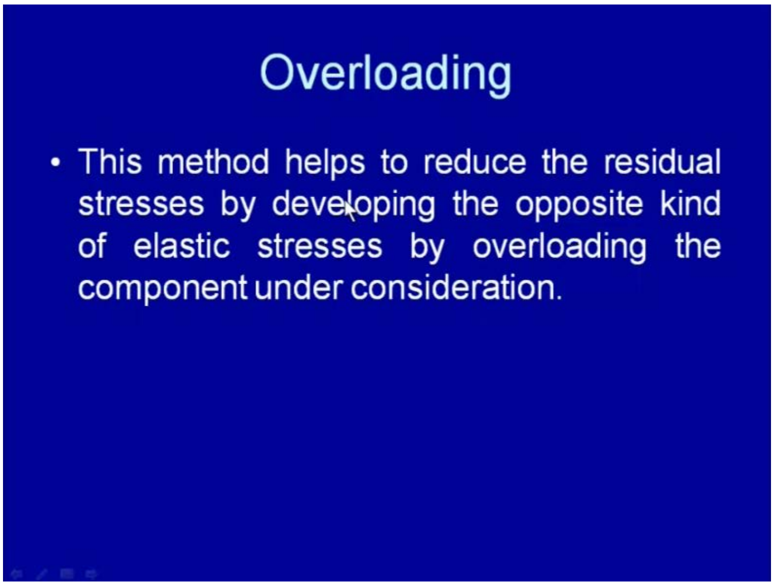

Anotherapproach is the over loading. In thismethod helps to reduce the residual stresses bydeveloping the opposite kind of the elasticstresses by overloading of the component,which is under consideration while the shallow hardening improves the fatigue performers in the two ways.

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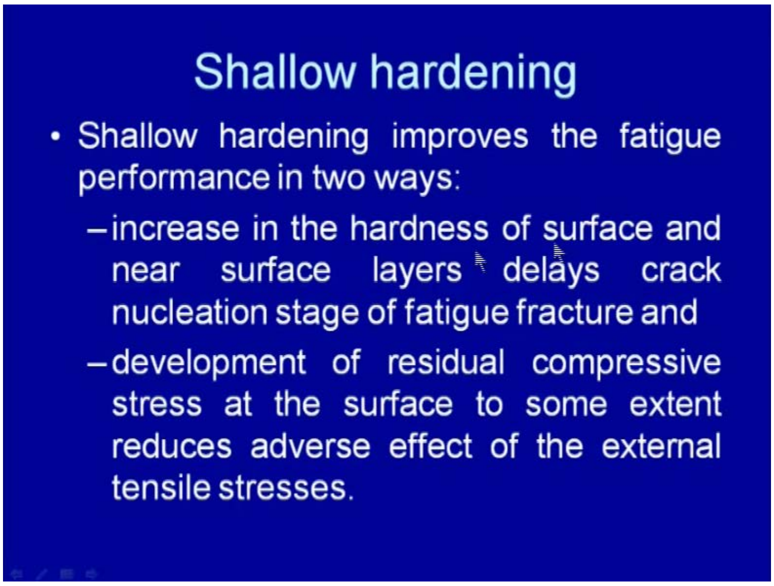

By one is increasing the hardness of the surface and near surface layers, which helps in delaying the initial crack growth stage and the second one shallow hardening also helps in developing the residual compressive stresses at the surface to some extents. So, that adverse effect of the external tensile stresses can be reduced. So, now, these were the methods,which are commonly used for improving the fatigue performance of the weld joint. So, to summarize this presentation in this presentation mainly we have talked aboutthe factors that affectthe fatigue life of the component and apart from that. We have also talked about the methods, which can be used for improving the fatigue performance of the weld joint.

Thank you for your attention.