Welding Engineering
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Module - 7
Inspection and Testing of Weld Joint
Lecture - 1
Introduction

In this 40 lecture series on the Welding Engineering, this is the 7 th module, which is based on the Inspection and Testing of the Weld Joint. In the earlier 6 modules, we have talked about the introduction of Welding Engineering of x of the welding arc, power sources for the welding, welding processes or design of the weld joints and the heat flow in welding.

And all these aspects play a big role in development of the successful weld joint, but there is another important aspect which contribute significantly, in not just on the development of the sound weld joint, but also helps in taking suitable decision, that whether a particular weld joint can be used any given situation or not. So, for that purpose it is important that during the development of the weld joint proper inspection is done in at the different stages, and once the joint is developed, then it is tested to see whether the things which have been done, are perfect or not and whether the joint developed is suitable for a particular application or not.

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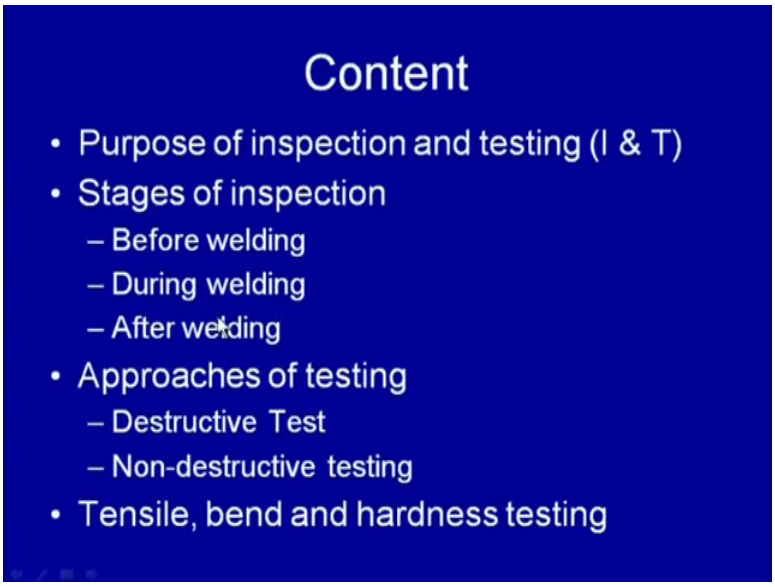

And therefore, in this chapter will be taking about first the purpose of the inspection and testing of the weld joints. And then we will see that what are the different stages? Where we should perform this kind of the inspection. These are three stages one is before welding, second during the welding and third after the welding. So, after the welding we try to assess the weld joint qualitatively and the quantitatively. So, to assess the weld joint a quantitatively, mainly the destructive tests are used, while the qualitative assessment of the weld joint is done with the help of the non destructive test.

Destructive test will be giving us, the numerical values of the different important characteristics of the weld joint, while the non destructive test will indicate whether a given weld joint, which has been developed is a sound or not and for that purpose various, the tests are used which are found to be useful for detecting the discontinuities present either at the surface or in the sub surface regions. And in this presentation under the destructive tests we will be talking about the tensile bend and the hardness tests.

So, starting with the purpose of the inspection and testing, the purpose of any inspection and testing, in the development of the weld joint is mainly related with that, taking up all the necessary inspection and testing related activities, so that a sound weld joint can be developed. So, primarily purpose objective is to ensure the development of the quality weld joint, but to assess the quality of the weld joint we need to see it is qualitatively and quantitatively.

So, qualitative assessment of the weld joint mainly, based on that whether it is sound or not, if it is not then what are the sizes and the distribution of the discontinuities present in the weld joint. And the quantitative, quality assessment of the weld joint, we try to see the different characteristics of the weld joint, like the hardness, tensile strength, ductility, toughness, fracture toughness, along percentage elongation.

So, there are various tests which are used to check the performance, mechanical performance of the weld joints quantitatively apart from these, tests there are many other tests which are performed on the weld joints depending upon the purpose for which it has been developed. These tests may be, conducted at a low temperature or at high temperature say in form of the creep test or the ductile to brittle transition test for low temperature applications.

These tests can also be in the form of corrosion test to assess the corrosion resistance of the weld joint and in the different environments. And apart from the corrosion test the quantitative assessment of the weld joints can also be done to see, whether the joint is able to understand, withstand under the a wear conditions or not. Because, the weld joints frequently subjected to the number of types of the wear during the service, these may be in form of the adhesive wear, abrasive wear, corrosive wear or solid particle erosion cavitations, fretting wear. So, there are various forms of wear for which a weld joint can be subjected.

So, to assess the suitability of the weld joints for those forms of the wear, the wear tests are also a conducted on the weld joint. So, there is a huge range of the destructive test or the tests which can be done on the weld joints to in to characterize them quantitatively and so as to assess the suitability of those joints for specific applications. So, the third objective of performing the inspection and testing is to see, the suitability of the weld joints for a specific application.

So, a specific application say if particular criteria has been established that weld joint should have this much load carrying capacity or this much corrosion resistance or at least this much the ductility. Then the weld joint should qualify for those requirements, before using the weld joints for those specific applications.

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So, basically the inspection and testing's are performed to first to ensure that the quality welds are developed, then to check whether the developed joint is fit or means it is a quality weld or not which can be done. Qualitatively and quantitatively and thereafter to assess the suitability of the weld for specific application. So, as far as inspection of the weld joint is concerned in the development stage, in it is development stage there are three different stages in which inspection can be performed. One is the before welding where we try to check whether, the things which are to be used in a proper form and the proper condition or not.

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So, to produce a quality weld joint it is necessary that an eye is kept on what is being done, at the three different stages of the welding. Before welding, we try to see the cleanliness whether the faying surfaces have been perfectly, cleaned using the recommended method or not whether the method of mechanical cleaning or the chemical cleaning has been used for cleaning the faying surfaces.

Then whether the edges have been prepared using the recommended method like the mechanical method, which involving the machining or the thermal method, depending upon the type of the steels or the suitable kind of the edge has been prepared or some other kind of the edge has been prepared, like these may be in form of the v groove u groove j groove double v double j double bevel etcetera.

So, whether the right kind of the edge has been prepared with the required dimensions are not. And thereafter, we also try to see whatever consumables are being used for development of the weld, joint there of the right kind and the recommended ones or not these may be, in form of whether the baking of the electrode has been done, up to in the right conditions.

In order to drive off the moisture from the electrode coatings or the correct kind of the electrode is being used the suitable gas, of the suitable correct grade of the shielding gas is being used for development of which will be used for developing the weld joint. So, whatever the welding consumables are to be used, they are according to the recommendations or not or if there is any deviation, then the suitable quality of those consumables should be brought in for development of the weld joint

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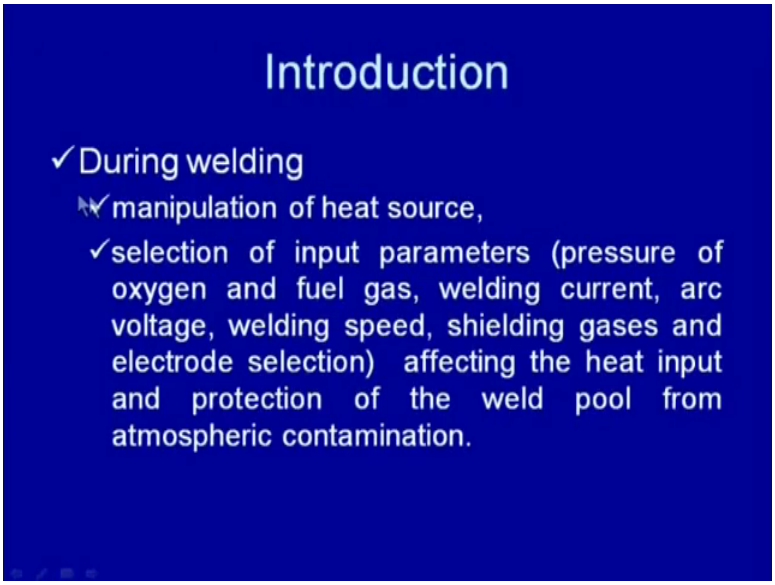

Then during the inspection, it is very important to see that whatever edges have been prepared according to the recommendations and the welding consumables have been arranged for development of the weld joint. They are used properly as per the requirement and for that purpose, first is that the whatever heat source, whatever type of heat source is being used for melting the faying surfaces and the filler material. That should be manipulated, that is manipulated properly as per requirement.

So, that suitable heat input can be given, to the faying surfaces for achieving the desired degree of the penetration and fusion of the faying surfaces, in order to develop the sound

weld joint, and the second the welding parameters, which are to be used for developing the weld joints. For example, the pressure of the oxygen and fuel gas in case of the gas, welding, the selection of the welding current and the arc voltage and welding speed, shielding gas and the electrodes.

And the type of the electrode, say in case of the tungsten electrode or s m a w suitable kind of the electrode has been selected and the same is being used or not. So, whatever the input parameters have been selected, they are being properly used or not that is checked during the welding stage. And these things will basically, all these parameters, which will be effecting the heat input and protection of the weld pool.

So, since the development of the weld joint is predominantly governed by the kind of heat input, which is being given and the how the weld pool being formed is protected from the atmospheric contamination. So, based on these two the quality of the weld is determined significantly. So, if whatever, the recommended input parameters are there they are actually, being used during the welding or not that should be checked properly in the inspection stage.

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Then after the welding how the slag is being removed, after the welding or during the intern passes whether slag is being removed properly or not. Otherwise this will the left out slag between the weld beads especially, in the toe region will be leading to the

development of the inclusions. And the preening is being done in systematic manner and using the proper kind of conditions or not.

And whatever post weld heat treatment is being recommended is being done under the correct conditions and at the correct stage or not, many times it is recommended that the post weld heat treatment is done immediately after the welding, before the weld joint comes down to the room temperature. So, whether that is being followed or not it is also, checked that whatever clamps and frictions have been used for during the development of weld joint there are, being removed the right stage after relieving the residual stresses or not.

So, different important things that effect the quality, of the weld and that can affect the performance of the weld after at the development, all that is checked that whether all those things are being performed systematically and properly or not. So, this is what is done as far as inspection is concerned in different stages.

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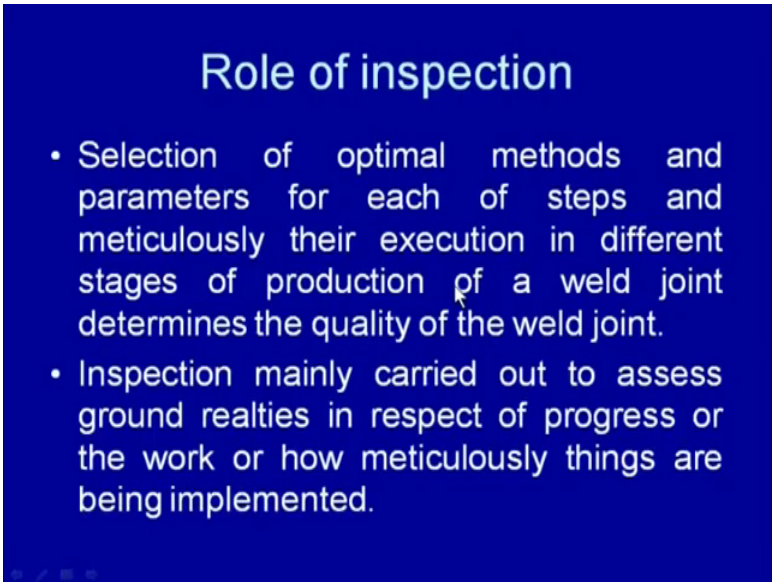

We know that the selection of the optimal method and the optimum set of the parameters, for each step of which are to be used for development of the weld joint, must be meticulously followed in the execution stage of the production of the weld, because all these factors like the suitable method, which have been used and the various parameters associated with that particular method. These are whatever has been selected

these are being actually used in the development stage of the weld joint, will be determining the quality of the weld joint.

So, in the inspection stage inspection mainly is carried out to assess the ground realties in respect of the progress of the work or how meticulously things are being implemented in the shop floor on the paper. All the things may be, from the cleaning of the surfaces, edge preparation to the selection of the welding process and welding parameters. And thereafter post weld heat treatment steps like removal of the slag or the post weld heat treatment, all those things may be perfect, but at the execution stage what is being actually done to have a check on that the inspection plays a very important role, because this will be deciding whether the desired quality of the weld will be obtained or not after development of the weld joint. So, inspection is mainly performed to assess the ground realties in respect of the progress or the work or how meticulously the things are being implemented, during the welding, during the development of the stage.

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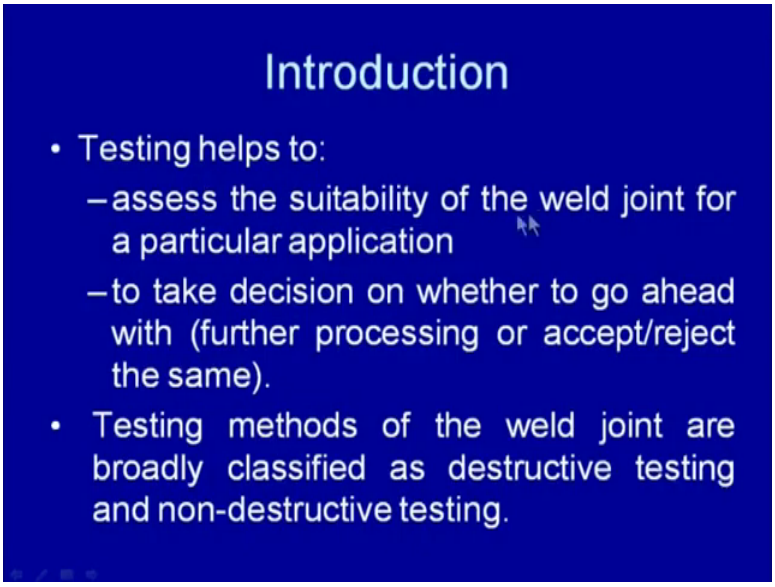

Once the joint has been developed it becomes important to see, what is the quality of the weld which has been developed. So, for that purpose testing is carried out and testing helps to assess the suitability of the weld joint for a particular application. And it also helps to take the decision on whether to go ahead with the further welding, further processing or accept or reject the component, say if it is being done, in testing is being

done in processes stage then it can reveal the major deficiency in the weld joint which is being developed.

Then this will avoid the further processing of the defective components. So, basically when the testing is done, it helps to take the decision whether to go ahead with the further processing of the in process component or not. So, the testing methods of the weld joint are broadly classified as the destructive tests and non destructive tests means, once the joint has been developed either it is in process stage or it has been completely over this tests are carried out in the weld joints mainly using two approaches, one is the destructive test and another is non destructive test.

In the destructive test, some sort of the damage takes place in the component which is being tested, the extent of damage may be more or less, but most of the time it is observed that component, which has been tested by the destructive test is damaged to such as extent that it cannot be used for further, for the targeted application. And therefore is the tested pieces are normally kept and retained, but they are not used for the purpose for which it was developed.

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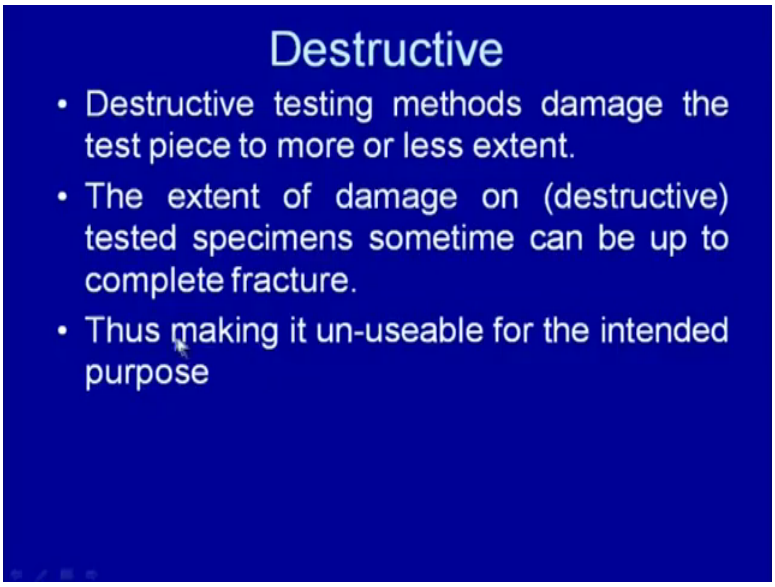

And thus once the either complete fracture, takes place after this destructive testing or the damage takes place to such an extent that it cannot be, used for the intended purpose. So, this is the main negative side as far as, the destructive tests are concerned.

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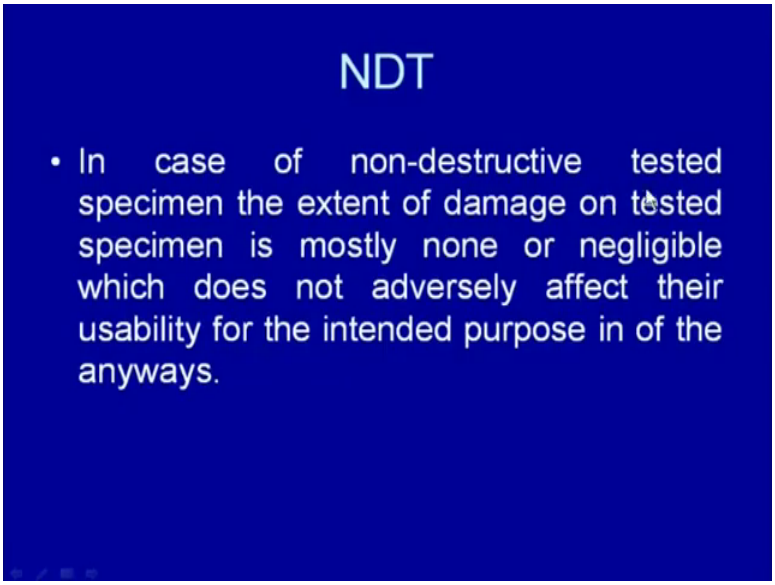

While in case of the non destructive tests, these are the quality most of the time these are the qualitative test and the extent of damage in these test is not, so serious. Even in some of the cases the negligible or the no adverse effect is observed on the component, which is being tested by the non destructive test methods. And therefore, the component which has been tested by the non destructive test methods can be used for the purpose for which it was developed. So, it is usability is not adversely affected, even after the testing of the component or the weld joint by the non destructive testing method.

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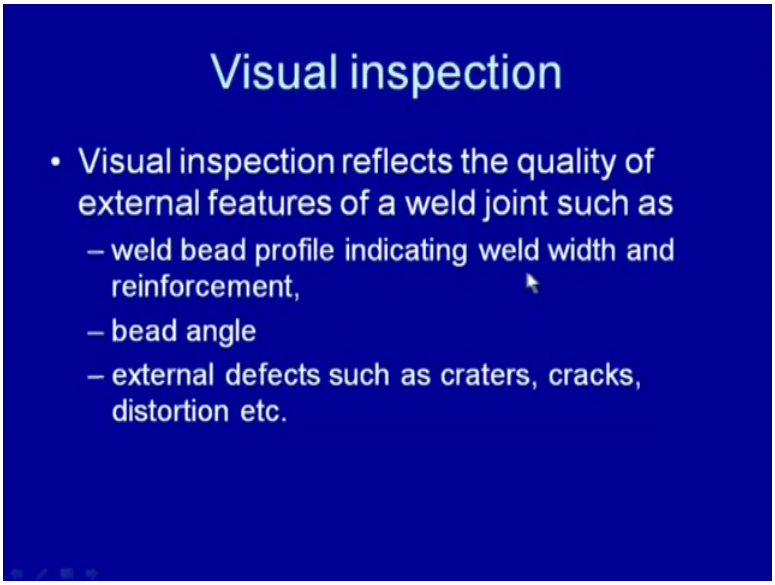

So, as far as inspection is concerned the inspection normally, the visual inspection is found very useful, during the development of a stage of before the development of the weld joint even after the development of the weld joint. So, what are the different aspects that can be assessed through the visual inspection, visual inspection reflects the quality of the external features of the weld joint, such as the weld bead profile, indicating the weld width and the reinforcement bead angle and the external defects such as craters cracks and the distortion.

So, these things can be done, using the suitable metrological instruments to measure the weld bead geometry related parameters such as, the reinforcement or weld bead width or the bead angle. And the visual inspection during the processing itself if these have been developed then either the weld joint can be discarded or the suitable steps can be taken to repair these defects which have been developed in and the weld joint.

So, further processing of the defective components can be stopped. Once if the major defects are established through the visual inspection and during the in process stage. Then there is a huge range of the tests, which belong to the destructive test category. Destructive tests are those, when these are performed the material of the tests means the sample which is to be tested by the destructive test and gets damaged.

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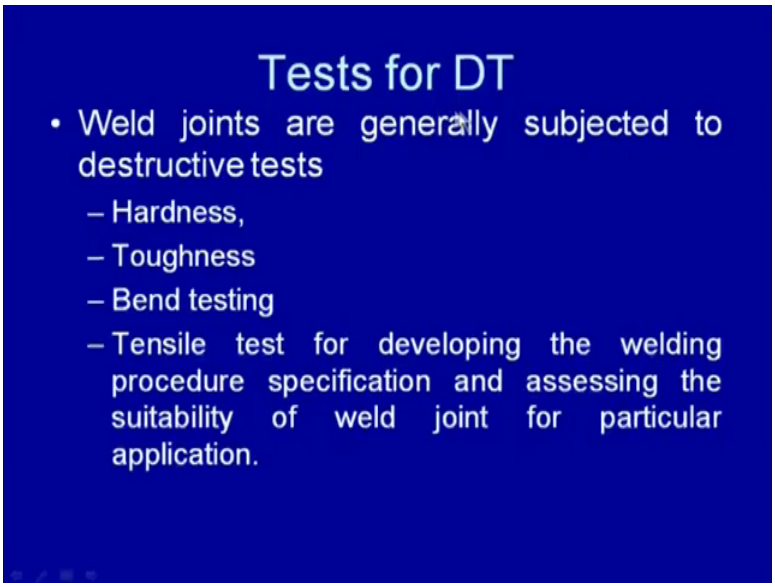

To such an extent, that it cannot be used for the purpose for which it was developed and it gives, means the destructive tests most of the time gives the characteristic value, in the numerical terms. So, the quantitative data is obtained regarding the characteristics of the weld joint after the destructive test. So, there are many destructive tests which are commonly performed to assess the capability of the weld joints, and most of the time these are the mechanical tests, in which one or other kind of the load is applied on the weld joint which is to be tested to assess it is capability to carry the external load.

And these tests involve these common destructive tests; include the hardness test which indicates the resistance to the indentation or the resistance to the abrasive we are as abrasion. And the toughness which indicates the amount of the energy that it will be absorbing under the impact load conditions. So, basically it indicates the ability to withstand under the impact load conditions and the bend test, in which the sample is subjected to the bending and this test basically, used to assess the extent of the elongation or the ductility of the weld joint which exist, with the weld or it is also used to see whether there is a internal defect or not.

And the tensile test, which is mainly used to see under the tensile load conditions, how the weld joint will perform and this test is commonly used to identify the parameters like the modulus of elasticity, of the weld joint then the yield strength of the weld joint, ultimate strength of the weld joint and the kind of the deformation which will be occurring at the different stages of the tensile loading, and the total elongation of the weld joint, till the fracture means in the up to the fracture stage.

So, the tensile test for developing the welding, this test is very commonly used in the industry and it is mainly used for developing the welding procedure specification and assessing the suitability of the weld joint for particular application. So, when the welding procedure is to be established for the new material system or for new application. And normally the weld joints are developed using the different set of the welding parameters.

And then the capability of the weld joint is assessed, through the tensile test to see whether the weld joint will be able to take up the service load or not and based on that, suitable decision regarding the welding procedure specification is taken. So, this test is mainly is also used for establishing the welding procedure, specifications apart from assessing the suitability of the weld joint for particular application.

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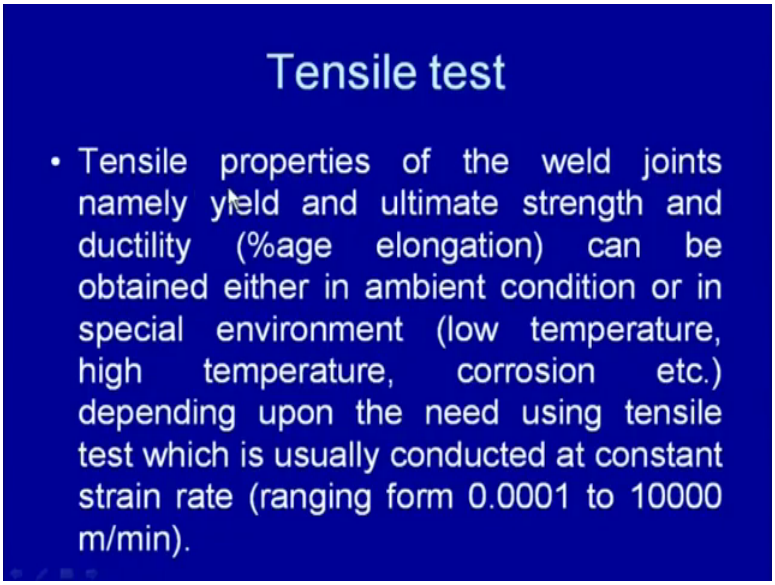

So, for conducting the tensile test are basically, conducted to quantitatively measure the tensile properties of the weld joint, which are in terms of the yield, strength ultimate strength and the ductility. Ductility is measured in terms of the percentage elongation, and these tests can be performed in the either in the ambient conditions or in the low temperature environment or in the high temperature conditions or in corrosive environment.

Depending upon the application for which this test is to be conducted these; the tensile test can be performed in the different environmental conditions. So, as to assess it is capability to take up the tensile load, under the different type of the service conditions and also to see that under those conditions, what kind of the yield strength it offers, what is the ultimate strength and what is it is ductility under those either low temperature, high temperature corrosive environmental conditions.

So, all that will depend upon the need for which, the weld joint is to be developed and the tests will be conducted in the suitable environment and when these tests are, conducted the load magnitude is increased gradually. So, that the strain rate is significantly lower and it is in certain bend of the increase in strain per unit time. So, means this the load is applied at certain constant strain rate. So, that will depend upon the kind of material which is to be tested.

So, this load is applied at constant strain rate, until the fracture takes place and during this, the different and during this the load versus the elongation curve is obtained and using this many times the engineering stress and strain curve is obtained using the suitable plot. And when this plot is obtained that plot helps to see, that what is the elastic zone and the where the plastic zone starts in. So, what is the yield strength, what is the ultimate strength and where fracture is occurring.

So, different parameters which can be obtained from the tensile test, can be easily obtained from the load elongation curve or from the engineering stress and strain curve which is obtained after the tensile test.

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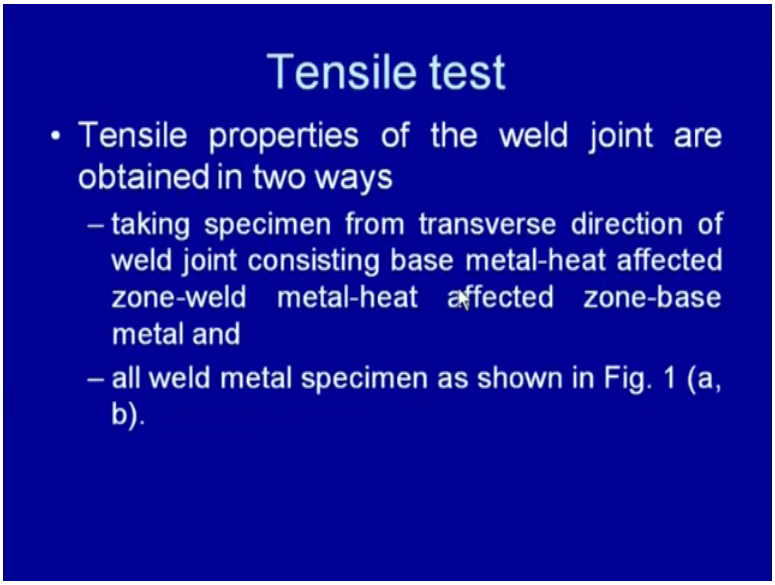

So, the tensile properties of the weld joint are obtained in the two ways, one means that is how means the tensile test can be, conducted in the weld joint in two ways one is where the specimen is taken completely from the weld region only or in another case when the specimen is taken from the transverse section of the weld joint. So, for that purpose and according to that we have the two types of the sample.

One either tensile sample is taken from the transverse direction of the weld joint which will be consisting the base metal heat effected zone, weld zone and then heat effected zone and the base material. While in case of the all weld specimen the entire the tensile specimen is taken from the weld region only. So, these two types of the specimens means the tensile test in case of the weld joint can be conducted in two ways, one is sample is

taken from the transverse direction of the weld joint or the entire weld or the tensile sample is made of the weld metal only and this is what can be seen in the next diagram.

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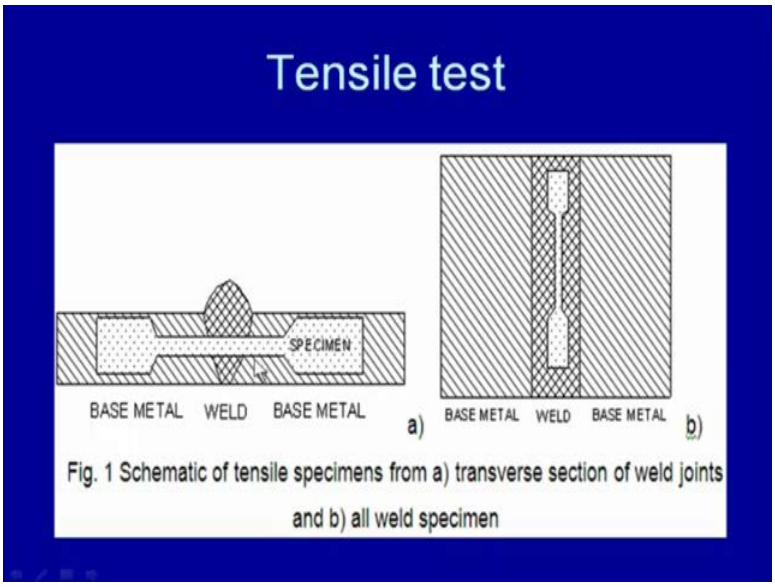

So, say this is the case when the weld the tensile this is the plate, with the weld joint, this is the weld region and the sample is obtained from the transverse direction of the weld this is the weld centres say. So, the specimen is being taken from the transverse direction of the weld. So, here at the centre of the weld we will be having centre of the specimen we will be having the weld region.

So, this is the first case where transverse section of the weld is obtained, and this specimen will have the base metal then the heat effected zone close to the fusion boundary, and then weld region and then again the heat affected zone and thereafter base metal. So, the second is the type of the sample is that all weld specimen, where say this is the top view of the weld joint the two base metals and this is the weld region. So, a specimen is obtained only a from, the means entire tensile specimen is made of the weld metal only.

So, all other things are discarded and the machine sample is obtained from the weld region only to develop the all weld specimen. So, depending upon the application we can if we want to assess the weld quality, only then all weld specimen is made otherwise the transverse weld joint weld transverse section is used for developing the tensile specimen.

So, these will it is very common to use the transverse section of the weld joint because in this case we get the mechanical performance of all regions.

And the not just of the weld metal and it will give the real performance of the entire weld joint which will be the combination of the base metal heat effected zone and the weld region. So, wherever is the weak zone the failure will be occurring accordingly.

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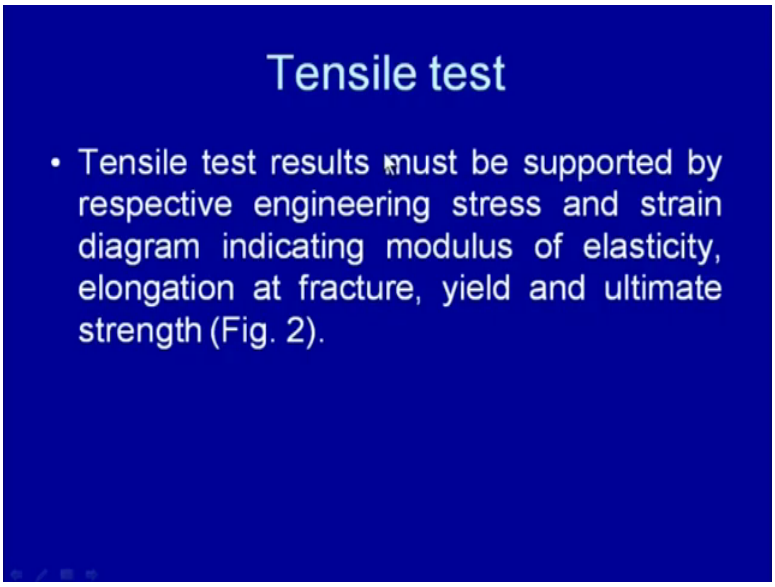

So, that will form the bases for deciding that what kind of the load it can take up during the service under the real life conditions. So, the tensile test results, once the tensile test is completed the tensile tests are reported for the yield strength, ultimate strength the ductility in terms of the percentage elongation and these results are most of the times are supported by, the suitable engineering stress, and strain curve or the load extension diagram, which will be showing the modulus of elasticity elongation at fracture yield and ultimate strength.

One typical engineering stress and strain diagram which is showing the basically, the kind of a the stress and strain curve relationship, this is the elastic zone and thereafter we get the plastic zone and here, this is the ultimate strength and this is the elongation corresponding to the fracture this is the fracture zone. So, the typical stress and strain diagram for say, this is for stainless steel this will be showing means this diagram shows.

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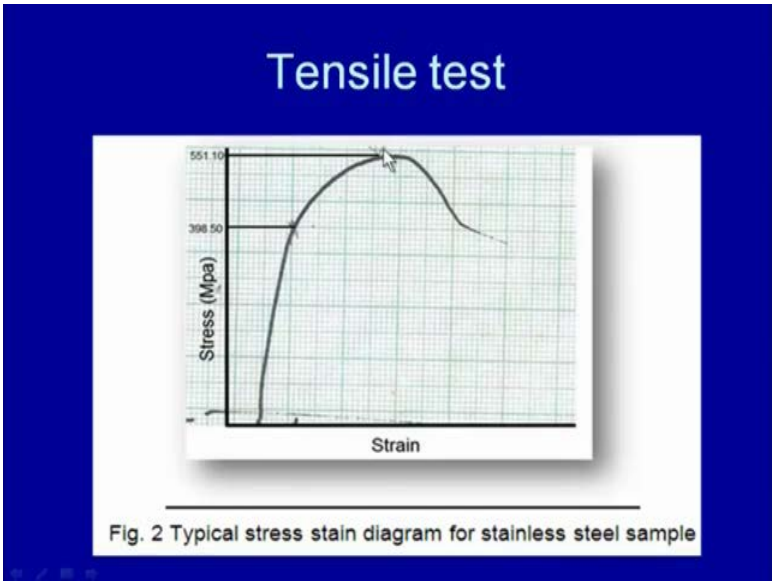

That the what is the elastic means the linear portion of the diagram, corresponding up to the elastic limit then what is the yield strength and what is the ultimate strength and what is the level at which the fracture will be occurring and the it will also, be showing the elongation corresponding to the different stages of the loading. So, say this is the elastic deformation then the that uniform deformation, which will be occurring in this particular zone after the elastic deformation to the after the you can say, yield strength limit to the ultimate strength.

So, this is the portion of the plastic deformation zone and this is termed as the uniform deformation zone, which will be occurring in the entire length of the gauge, entire gauge length of the specimen. So, once the test is completed, we will port the results in terms of the modulus of elasticity, yield strength ultimate strength and the elongation at the fracture and these results of the tests, must be given along with the certain information like what type of the sample was used for conducting the tests, whether sample was taken from the transverse weld or all weld. A specimen was used what kind of a strain rate was used for conducting the test.

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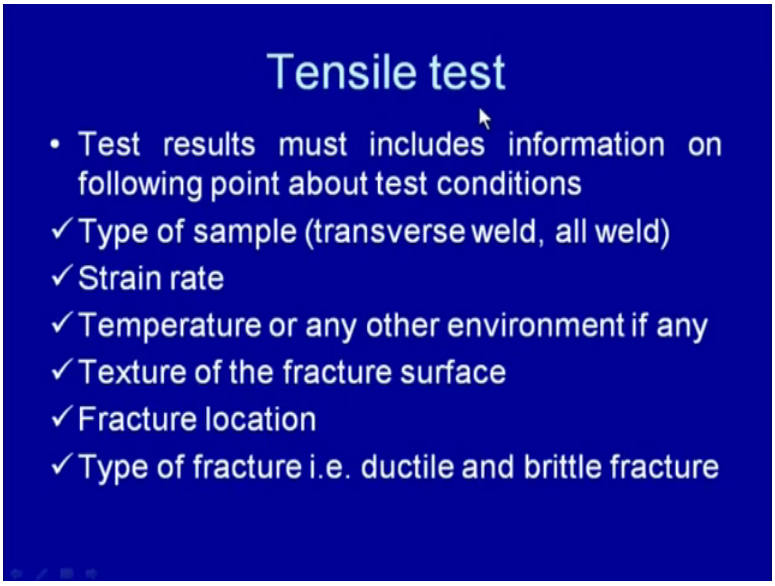

And at what temperature test was conducted or any other specific environment was used for conducting, the tests or the texture of the fracture surface. Once the test is conducted like, it was the flat fractured or very the dull or very bright and the crystalline surface is observed. And then the fracture location where from fracture took place during the test, that is mentioned whether it is it took place from the base metal or heat effected zone or from the fusion boundary or from the weld centre.

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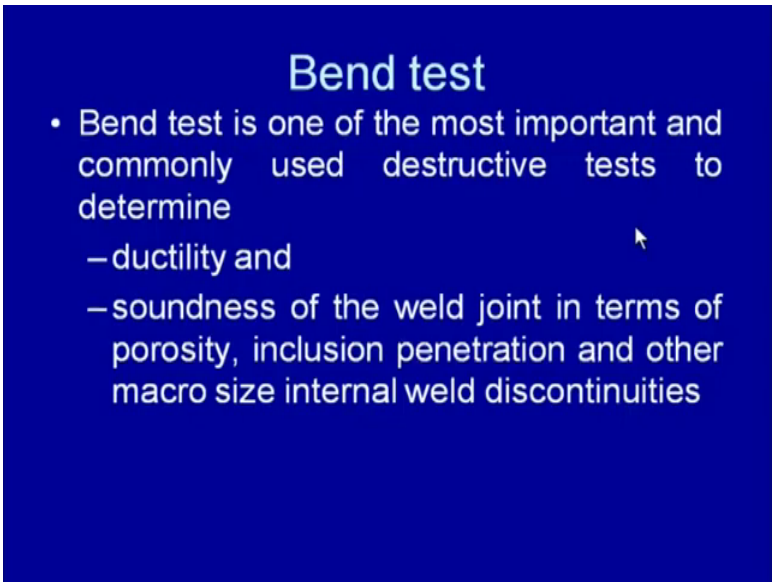

So, that location of the fracture is specified and what type of fracture, was observed whether it was ductile, where typical localized necking is observed near the fracture zone or the brittle fracture took place that is observed from the very straight flat fracture surface and the necking is very negligible.

Then we will be talking about another important test, that is the bend test and it is commonly used destructive test. In this test basically, the specimen is loaded to bend under the controlled condition. So, that the controlled bending leads to the cracking of the specimen from the weak zone and when the sample is cracked then it will be, revealing, the internal details of the welded specimen.

So, in especially in case of the weld joints, the bend test is carried out mainly to assess the ductility and this test that is ductility assessed, based on the extent up to which the weld joint can be bent, before cracks appear on the surface, of the joint which is subjected to the bend test. And it is also used to assess the soundness of the weld joint, which we can see when the surface fracture after the bend test, and we can see, whether there is internal porosity inclusions or penetration is perfect or not or other micro size defects are present in the weld joint.

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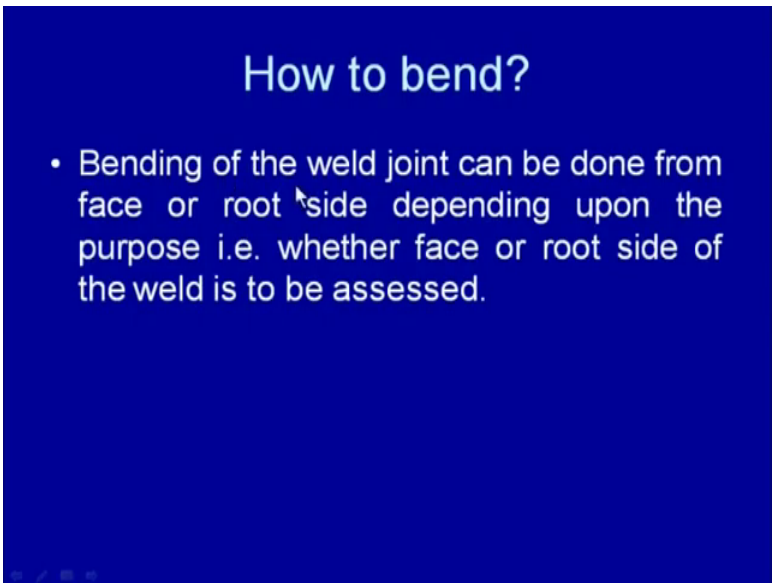

So, in order to conduct this test basically, bending of the weld joint is done either from the face side, that is the upper side of the weld or the root side depending upon the purpose, if we expect means which side of the weld joint is expected to have the defect

or will have the tendency to fail, that side is subjected to the bend test. So, bending we can do either from the face side or from the root side, depending upon the purpose whether the face or the root side of the weld is to be assessed. So, for the performing the bend test is performed using the simple compressive or the bending load and the suitable standard size, the die is used for this purpose or very free bending is done depending upon the case we can use either free bending or the guided bend test.

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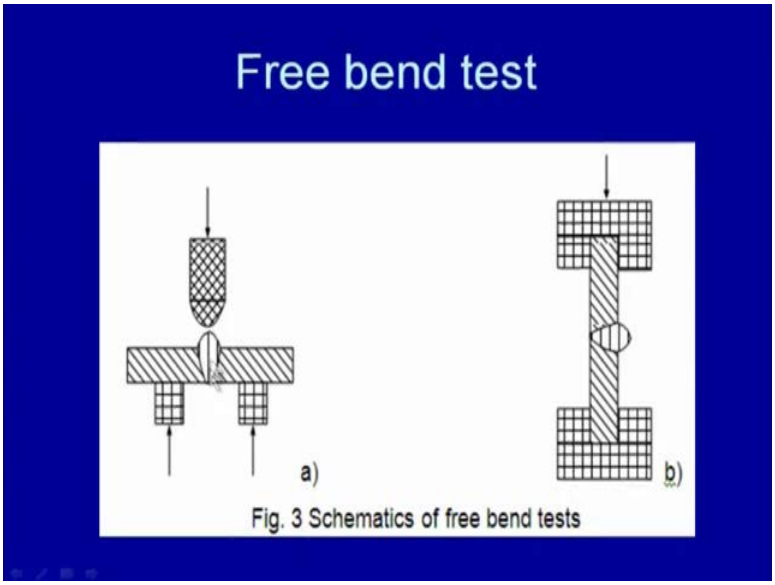

In free bend test between the two supports, the weld joint is placed and then the compressive load is applied for the bending to take place. So, in this case like the root will be bent because this bending will be basically, occurring from this side and the specimen is largely kept free and the bending takes place through these supports and in case of this is the another situation where the bend test a conducting the bend, test the compressive load is applied on to the specimen to be tested. And, but the in this case the bending can take place from any of the sides. So, to avoid that possibility the free sorry guided bend test is performed.

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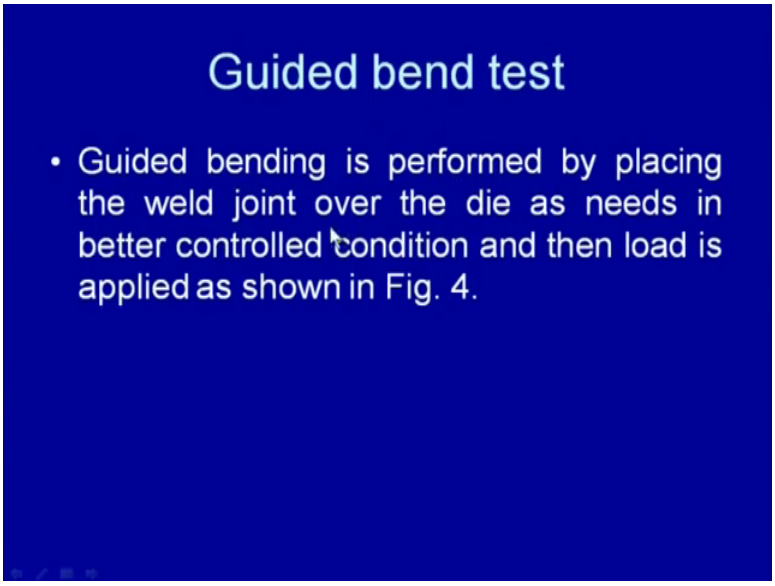

In the guided bend test guided bending is performed by, placing the weld joint over the die, as per needs in and it offers, the better controlled conditions of the specimen and of the loading. And then load is increased gradually. So, that the bending takes place.

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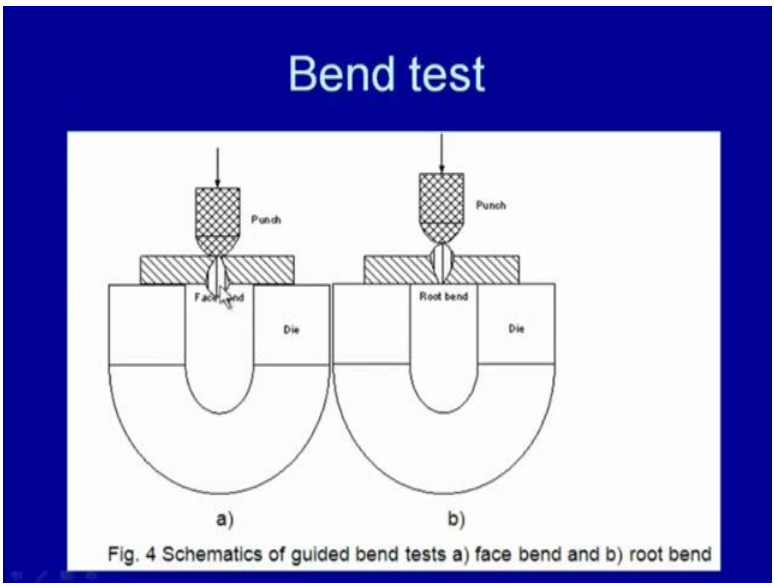

So, in this case very guided bend, the die is used and the load is applied from the top and above the die the weld joint to be tested is placed. In this case, the face will be subjected to the bend when the load is applied and we keep on applying the bending load until the cracks start to appear on the surface which is being bent. So, here in this case the face

bending will be done while in this case, the root bending is done. And this bending is continued until the cracks start to appear in the surface which is being bent. So, according to the need, we can perform either free bending or the guided bending. Guided bending is considered to be better because the bending is done in very controlled conditions using die and with the application of the load.

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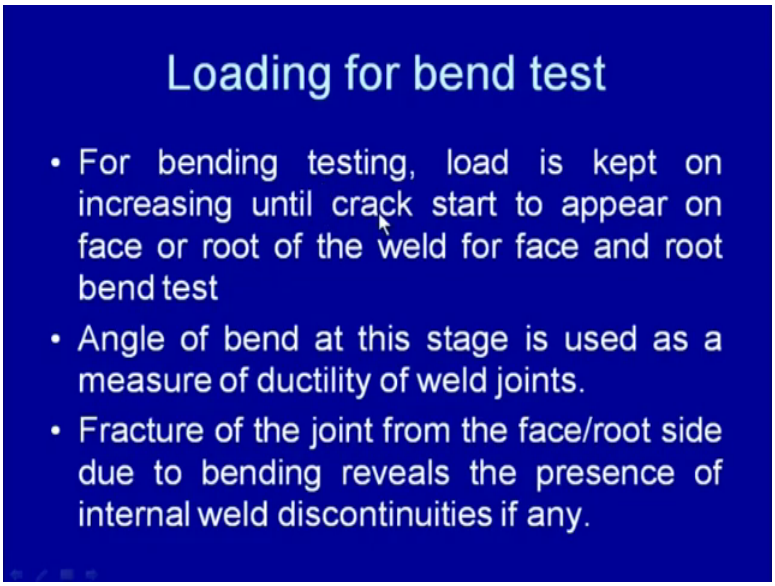

And this bending is allowed to happen means the this load is applied, on to the specimen's until the cracks start to appear either, on the face or on the root of the weld according to the face and the bend test and the root bend test. And the angle of the bend at this stage when cracks start to appear is used as a measure of the ductility greater is the bending is possible means higher is the angle of the bend and greater, will be the ductility.

So, greater is the kind of amount of the bending which is possible prior to the cracking of the specimen, that will indicate the greater ductility of the weld joint. So, the fracture of the joint from the, face or from the root side due to the bending reveals the presence of the weld discontinuities if any present any surface of the component.

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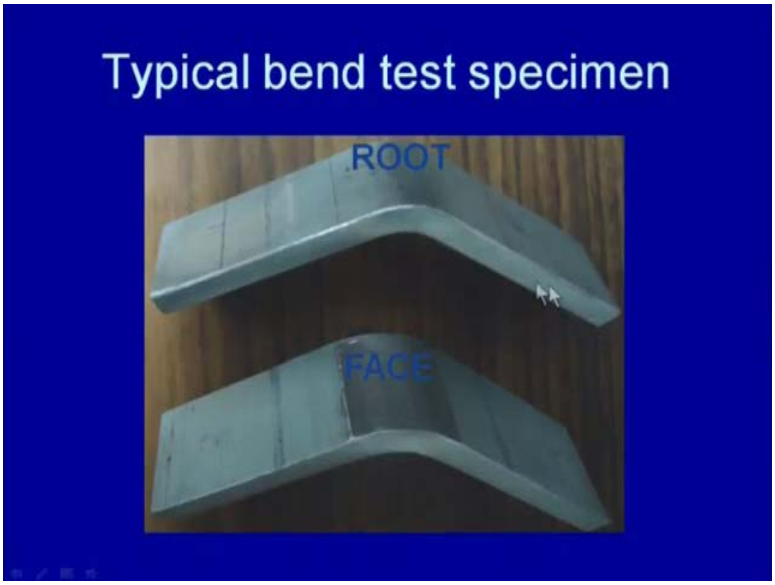

This diagram shows the typical bend test of the aluminum, 7039 aluminum weld joint which was welded using the friction stir welding and the top side shows the root bend test and here, this shows the face bend test. So, depending upon if we want to see whether whatever, welding process was used for development of the weld joint it had developed the sound weld joint, which is free from the defect then under the bending test, during the bending test all these defects if any they are present in the weld joint they will be revealed.

And they will facilitate the growth of the crack and the fracture will be facilitated by, these discontinuities if they are present in the weld joint. So, the bend test will help us to see, that what extent of the bending is possible prior to the cracking of the component a from the weld region or what or it will also help to see that if any weld discontinuities are present inside the weld, because fracture surface helps us to show, helps us to see whether the discontinuities are present in the weld region or not.

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Then another important test is the hardness test which is commonly performed on to the weld joint because it is common to see that due to the application of the heat during the welding. And the weld thermal cycle experienced by the, heat effected zone the very desirable and undesirable effects are observed in the weld joint. And to see that and many times it has been observed that some of the metal systems get hardened like the hard enable steels and the cast irons while other metal systems, like precipitation hard enable aluminum alloys they are softened with the application of the heat.

So, both hardening and softening are the common phenomena, which is, observed in the heat effected zone during the welding of the different types of the base metals. So, whether the hardening is taking place or the softening is taking place and up to what extent they will be affecting the mechanical performance of the weld joint. To assess that it is common to conduct the hardness test. So, that, there the effect of the weld thermal cycle on the performance of the weld joint can be assessed.

Because, the hardness test, is very simple test and it gives the lot of information about, that if any micro structural transformation has taken place or any embrittlement has taken place due to the application of the weld thermal cycle. So, what is the philosophy or the approach which is used for conducting the hardness test that is what, we will see in this part now.

The hardness test, hardness is defined as the resistance to the indentation means up to what extent it can resist if the load is very pointed, very pointed load is applied on to the specimen surface. So, whether it can resist that indentation or penetration by the external load which is being applied through very pointed body. So, it is commonly used as a measure of the resistance to the abrasion or to the scratching.

Because, once the indentation has taken place through the pointed body then due to the relative motion between the surface and the pointed body, this will lead to the development of the scratch and the abrasive wear. So, that resistance if there is a great resistance to the indentation, then there will be resistance to the abrasive wear and scratching also and that is why hardness is commonly used as a measure of the abrasive wear or of resistance to the scratching.

The formation of the scratch or the abrasion involves the relative movement between that hard indenting body and the surface. So, when there is a relative motion between the two it these will be, resulting in the formation of a scratch or one abrasive mark will be left in provided there is indentation. If the two bodies are having the relative motion with respect to each other even if they are in contact, but if the two are not means out of the two one is not indenting on to the other, then there would not be any scratch or any kind of the abrasion. So, it is important that some sort of indentation takes place for a scratching for abrasion to occur.

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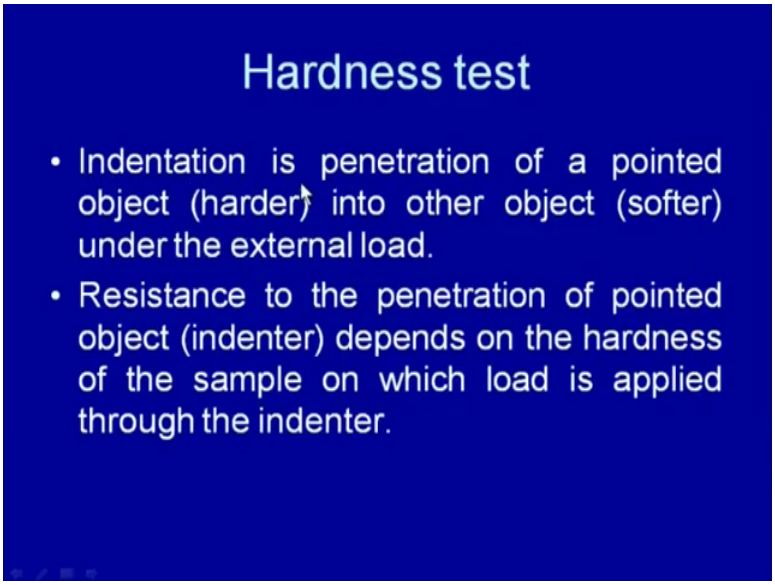

So, the indentation is a penetration of a pointed object into the other object which is softer under the external load conditions. And the resistance to the penetration of the pointed object that is known as the indenter, depends upon the hardness of the sample on which the load is applied. So, approach of this test is very simple that, you see to understand this we can use this diagram here.

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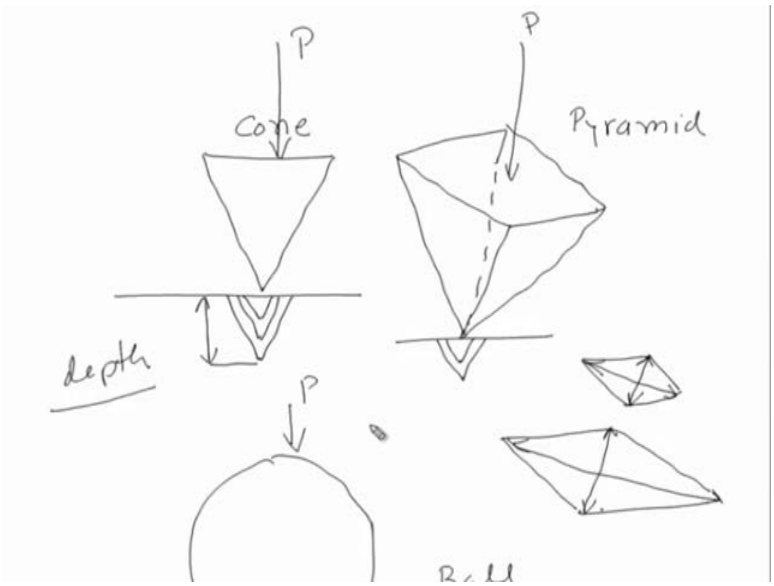

We can take the object of any shape, but it is common to use the conical shape objects or the pyramid shape objects, where a square pyramid is used. And here these objects like this or the ball shape object is used through. So, whatever is the shape all these are of we can say the pointed, this is cone, this is pyramid and this is ball shape. So, whatever is the surface say this is the surface, then a standard load is applied through this object, say load p or the load p is applied through this pyramid on to the surface or load p is applied on through this ball onto the surface.

So, under the given load when it is transferred through a particular object, how this object is going deeper into the surface. So, in case of this conical shape it will be, on the application of the load it will be going deeper like this. So, if the material is soft it will be going very deep and forming the deeper indentation and if it is, hard then the indentation will be limited. So, the softer is the material greater or the deeper will be the, depth up to which the object will be able to penetrate.

So, this is what we can say, this depth will be indicating us the hardness of the material. So, for conical indenter for a given load if greater is the depth of indentation, softer will be the material means the hardness will be lower. Similarly, for the pyramid test up to how deep it goes in, that will indicate the, it is resistance to the indentation, but in this test instead of since this is the square pyramid. So, instead of measuring the depth we try to measure the size of the indentation, which is being formed at the top surface.

So, this the length of these diagonals are basically, used to characterize the extent of damage which is taking place at the surface. So, greater is the size like say, if deeper is the penetration. So, greater will be the size of the indentation which will left at the top surface. So, greater will be the dimension of these diagonals. So, average length of these diagonals is used as a measure of the hardness.

So, greater is the length, means deeper is the penetration and the deeper is the penetration indicating the deeper means the lower resistance to the indentation and so the lower hardness. So, here very simple that in this case, the depth is an important criteria and here the size of indentation which is being made at the surface That is important criteria and indicating.

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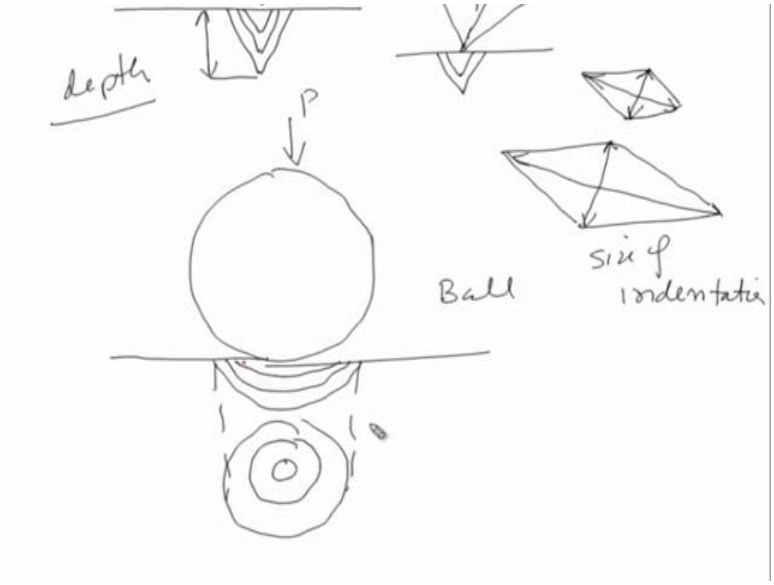

So, lower is the depth or lower is the size of indentation, means lower average length of these diagonals, that will be and. So, lower is the depth or smaller is the size, average size of these diagonals these will be, indicating the higher hardness. Similarly, for the

ball shape, one indentation will be formed for the hard materials it will be very shallow, then for the softer materials it will be deeper and the deeper.

So, in this case in the ball shape basically, that kind of the impression being formed at the top surface, whether it is of very small or of it is very large size indentation is being formed at the surface, this is what, we can say corresponding to this. If it is small then it will be corresponding to like this. So, if the surface is having the larger indentation that in case of the ball indenter that will indicate the lower hardness of the material.

So, we apply basically, one particular load through the a pointed objects and then try to see, that up to what extent it is either penetrating or the kind of impression is being formed on the surface of the specimen which is being tested. In general deeper is the penetration or larger is the size of indentation lower will be the hardness of the material. And this approach is used in the different hardness test methods, which will be described further in these.

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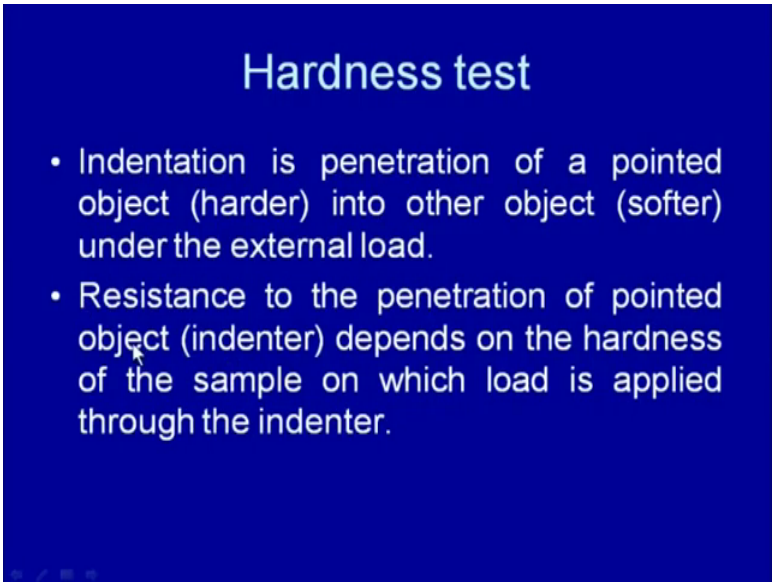

So, basically the resistance to the indentation of the pointed object resistance to the penetration, of the pointed object depends upon the hardness of the sample on through which load is being applied on to the object.

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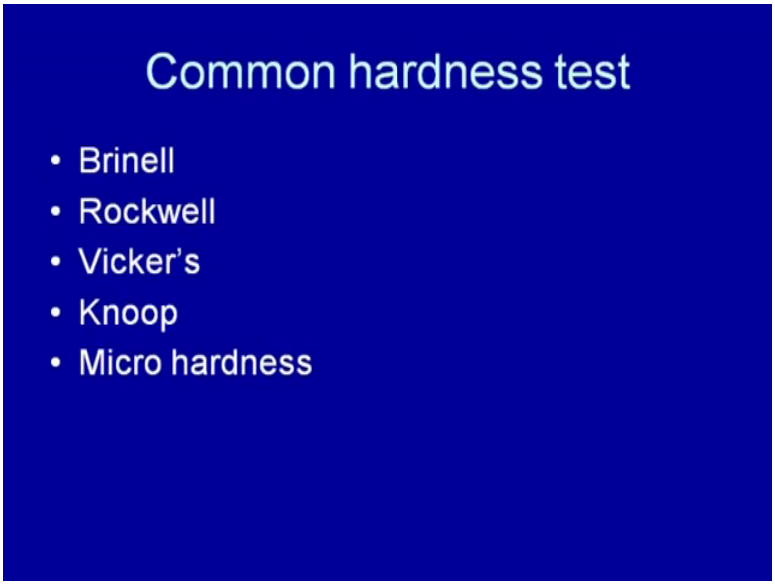

So, the different hardness tests are, there which are commonly used like Brinell, Rockwell, Vicker's, Knoop and the micro hardness.

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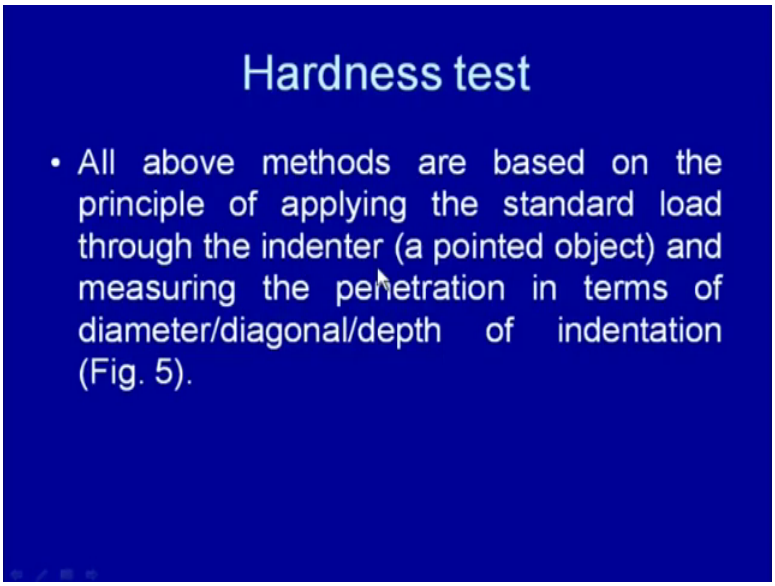

So, in these hardness tests all these hardness tests use the same principle, that in all these methods a very standard load is applied, through the indenter and the measuring the penetration in terms of either diameter or the diagonal length or the depth of indentation. So, what the form in which, the indentation, which dimension of the indentation is measured, that will depend upon the kind of method which is being used for performing

the test, but the general principle is same in all these hardness tests that a particular load is applied and then indentation is developed. And then either the diameter or the diagonal or the depth of indentation is measured.

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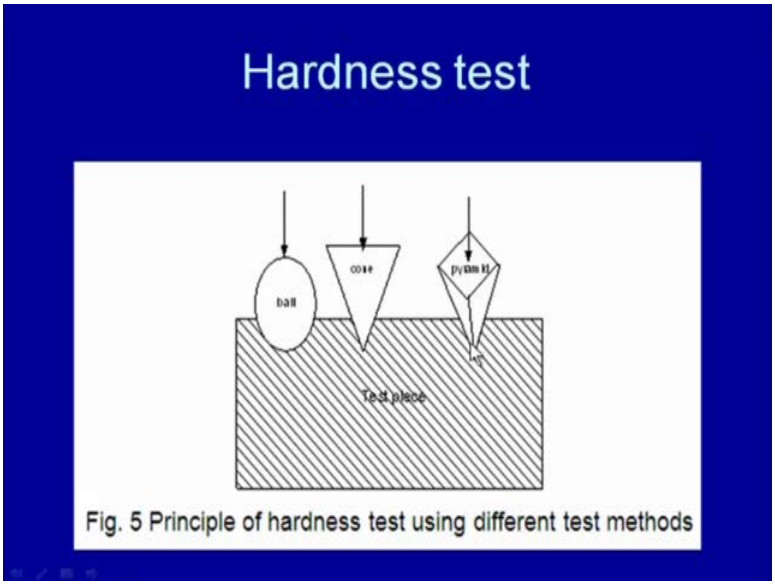

And this is the example say in case of the ball; the indentation is taking place like this. So, the indentation diameter is measured at the surface, in case of the cone here, the depth of indentation is measured and the average length of the diagonals is measured in case of this pyramid shape indenter. And in all the cases say the extended load is applied and then the extent of damage at the surface is taking place in terms of that indentation, that is characterized to measure the hardness.

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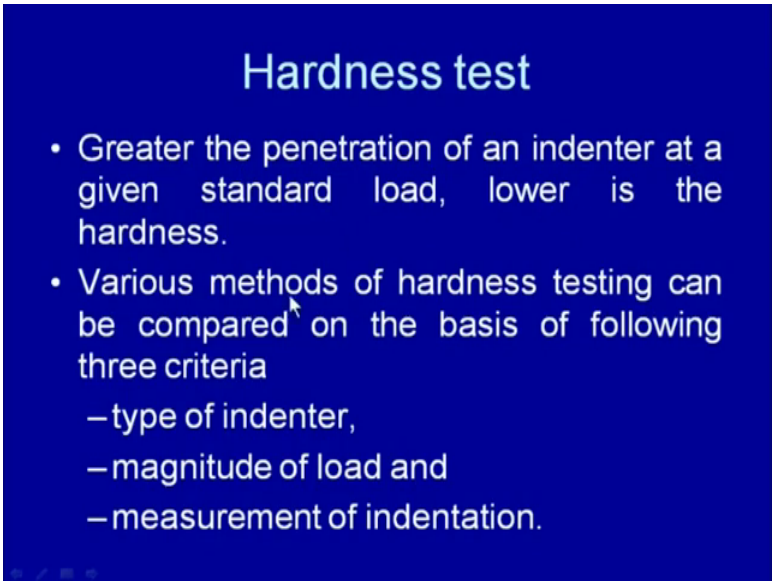

So, greater the penetration of the indenter at a given standard load, lower is the hardness. Various hardness test methods means the common principle is same in the various harness test methods, but these can be compared on the basis of these three parameters. Like the type of indenter, we can use the ball shape, pyramid shape or the cone shape and there will be difference in the magnitude of the load. And then which aspect of the indentation, we are measuring whether it is the surface diameter it is the depth of indent indentation or it is the average length of the diagonals.

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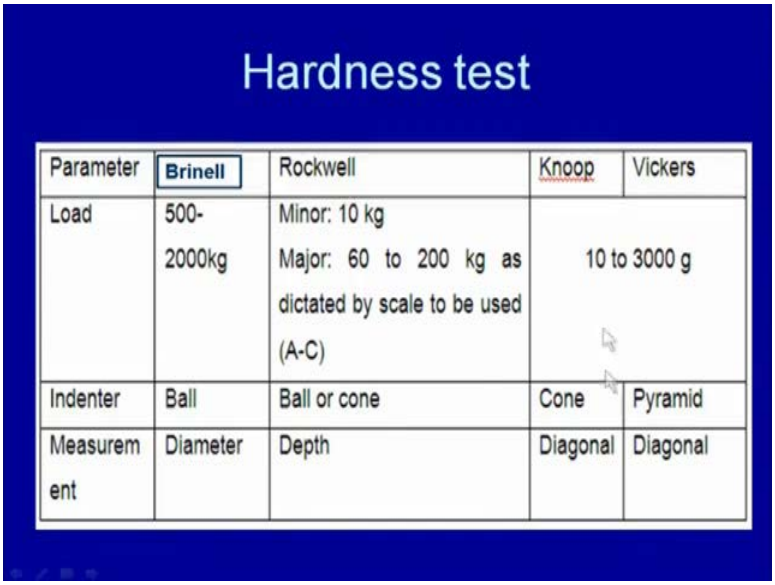

These are the different kind of the loads, which are used in the different test methods and the different kind of the indenters, which are used and the different aspect which is measured for characterizing the hardness. In case of brinell it is the diameter, in case of the Rockwell it is depth, in case of the knoop and the Vickers hardness it is the diagonal means the average diagonal a length of the indentation is measured.

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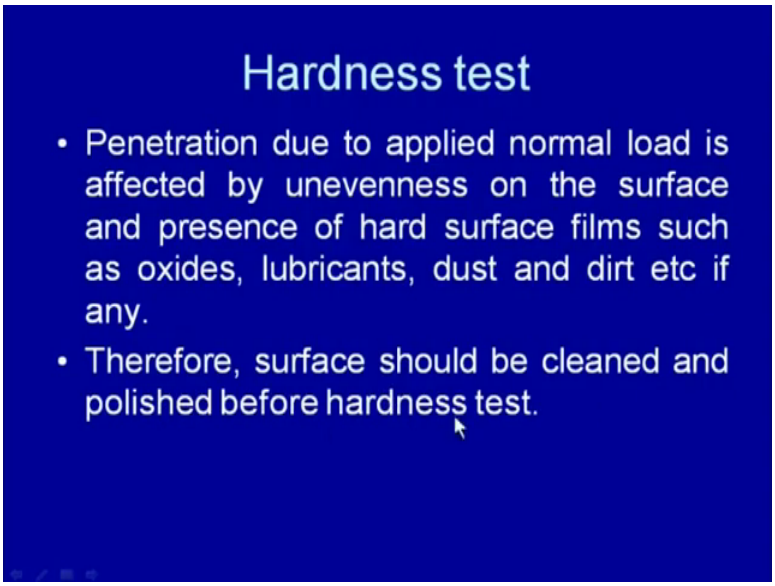

The penetration due to the applied load is affected, by the unevenness on the surface and the presence of the hard surface films such as, oxides, lubricants, dust, dirt, etcetera, if these are present. So, the means hardness is affected by the impurities present at the surface, and these should be removed if we are applying the major load directly to cause the indentation. So, the surface therefore, must be cleaned and polished before conducting the hardness test. But, in some of the methods no major load is applied directly, while in other methods first minor load is applied and thereafter major load is applied. So, what is the logic behind use of the major and minor loads.

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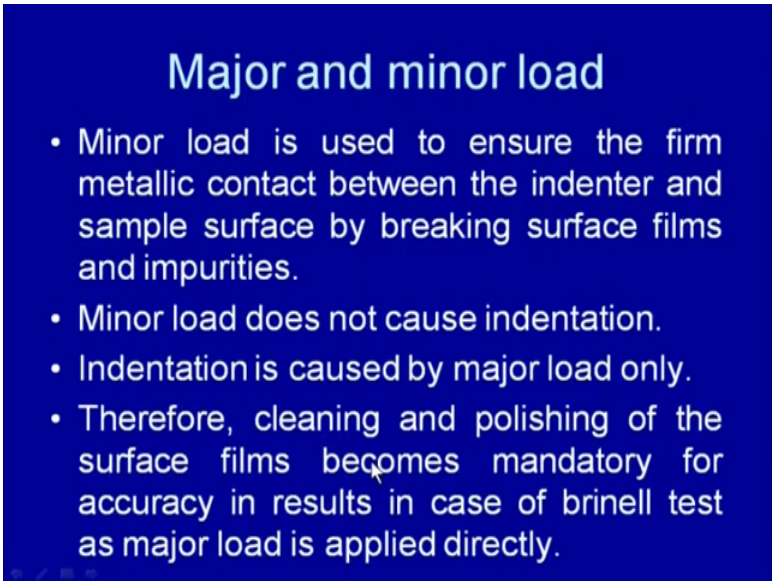

Minor load is used in case especially, in case of the Rockwell hardness test. And this is used to ensure the firm metallic contact between the indenter and the sample surface by, breaking the surface film and impurities present at the surface. And because of this but the minor load does not cause, any indentation and indentation caused by the and indentation is mainly caused by, the major load.

So, minor load of the 10 kg is normally applied and therefore, the cleaning and polishing of the surface films becomes mandatory, in all those cases where the major load is applied like in the brinell test, but in those methods where minor load is applied first like in the Rockwell test, this polishing and perfect cleaning is not required because minor load helps to make the firm metallic contact between the indenter and the surface which is being tested.

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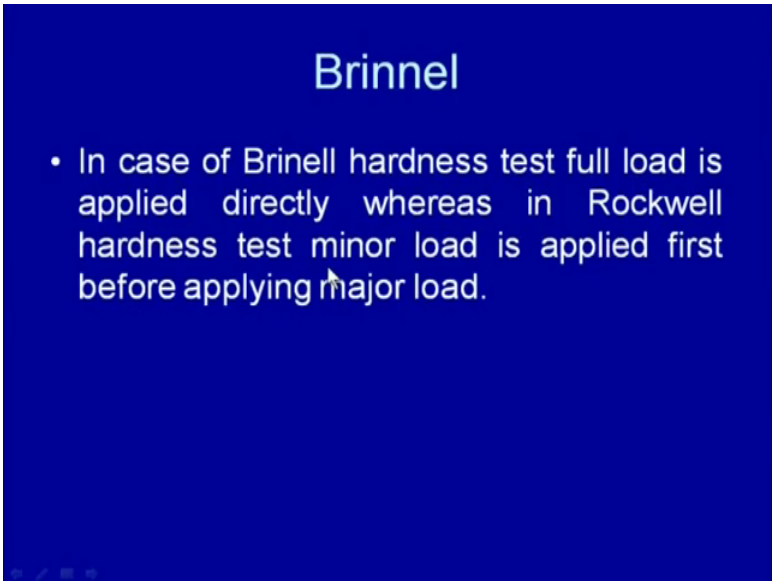

So, in case of the Brinell hardness test full load is applied directly whereas, in case of the Rockwell test minor load is applied first, before applying the major load.

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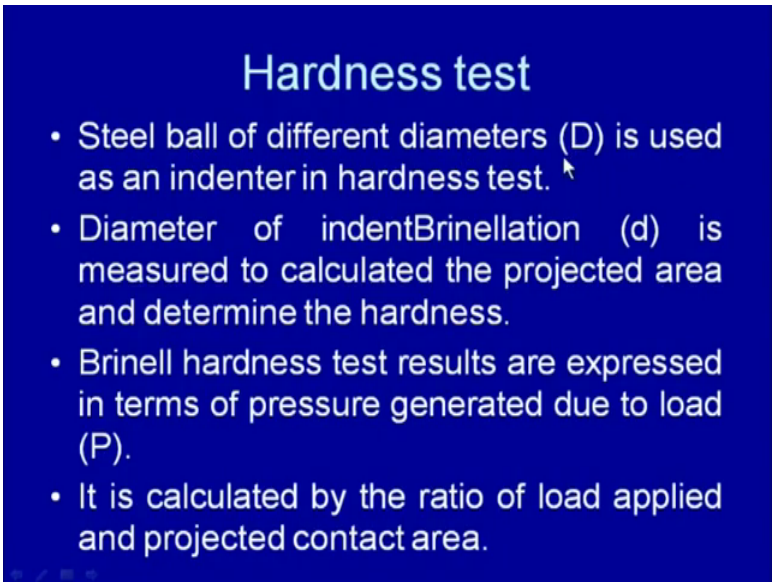

So, in case of the Brinell test the steel ball in of the different indenters, steel ball of the different indenter diameter is used as an indenter for hardness test means the steel balls of the different sizes can be used for as an indenter for the hardness test. And the diameter of the indentation in case of the Brinell is measured to calculate the projected area and determine the hardness, so either the diameter of the indenter and the kind of

indentation which has been formed. That is measured and the Brinell hardness test results are expressed in terms of the pressure generated due to the load p. And it is calculated using the ratio of the load applied and the projected area of the contact means that is effected by the indenter.

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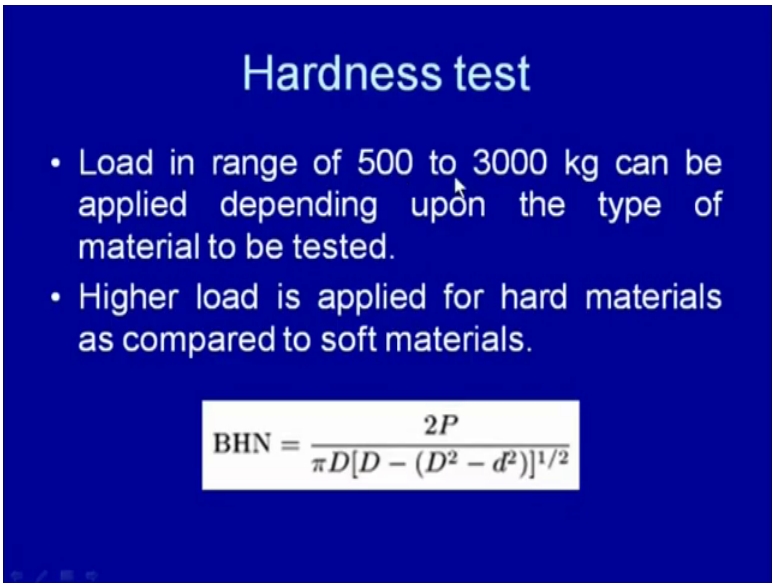

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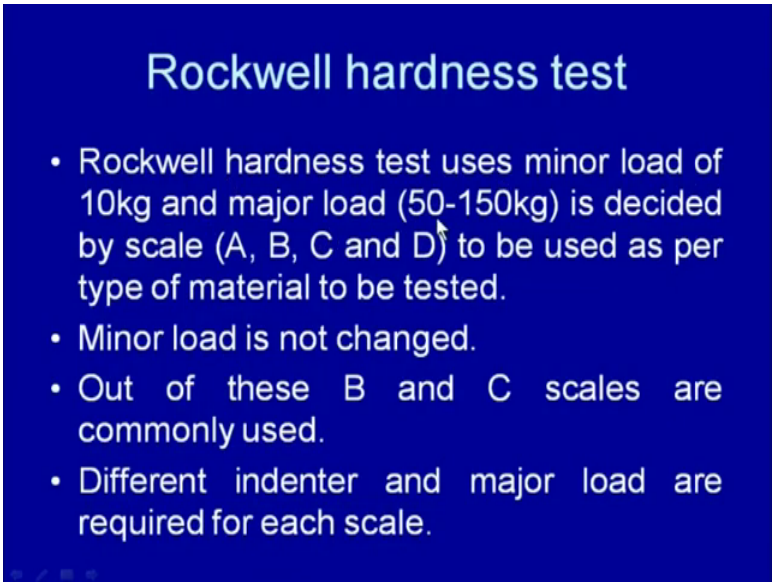

Load range can vary from the 500 to the 3000 k g and can be applied this range of the load can be applied depending upon the type of material to be tested. And higher is the load applied for the harder material as compared to the soft materials, and Brinell

hardness number is calculated using this equation, where p stands for the load applied and capital D is the diameter of the indenter and small d is the diameter of the indentation, which is formed at the surface of the component.

Then Rockwell hardness test, Rockwell hardness test uses the minor load of the 10 k g and the major load of the 50 to 150 k g range, and that is decided by the kind of scale which is to be used as per the requirement of the material to be tested. Minor load is not changed and out of these B and C scales are normally, used. And the different indenter and the major loads are required for each scale.

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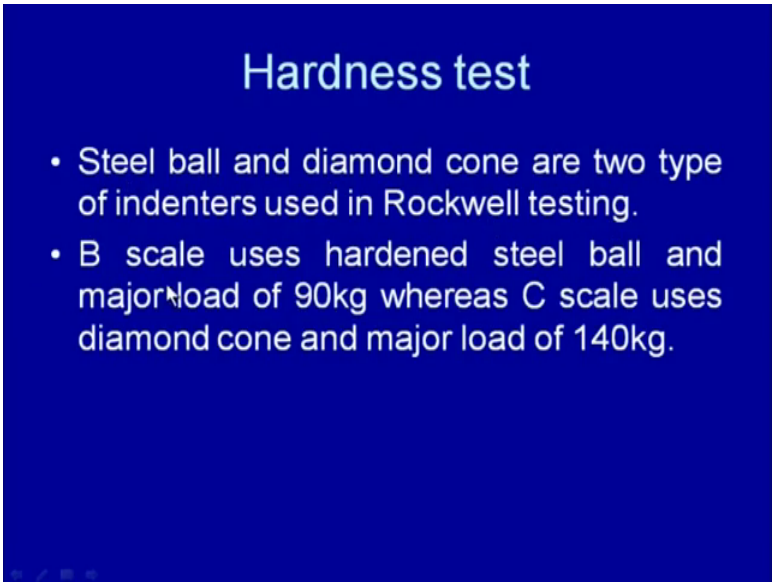

The steel ball and the diamond cone are the two types of the indenters which are commonly used in case of Rockwell testing. B scale uses the hardened steel ball and the major load of 90 k g where as, C scale uses the diamond cone and the major load of 140 k g.

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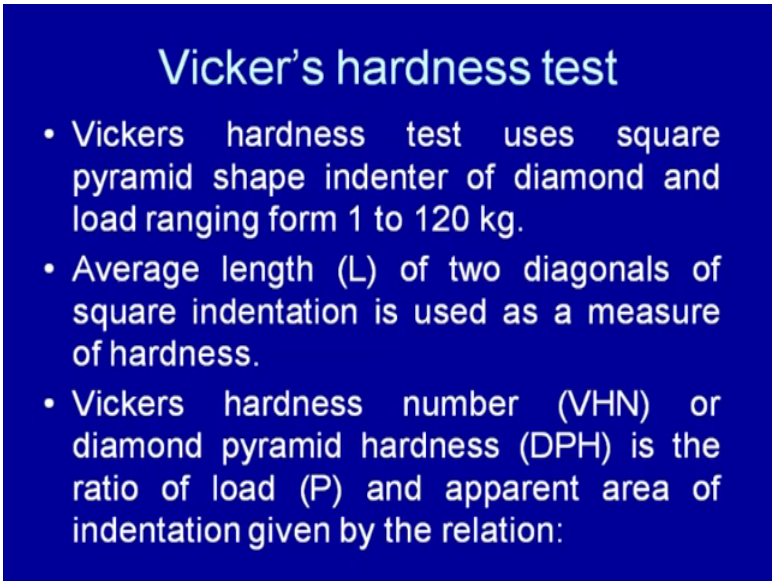

Then the Vickers hardness test uses the square pyramid shape indenter of the diamond and the load is ranging from the 1 to 120 k g. Average length l of the two diagonals of the square indentation is used as a measure of hardness and the Vickers Hardness Number VHN or the diamond pyramid hardness is the ratio of the load divided, by the apparent area of the indentation is given by this relationship.

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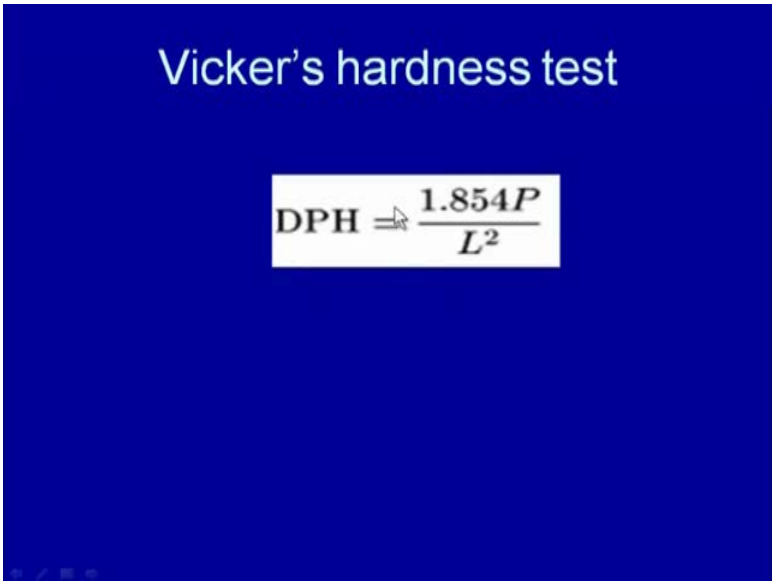

Indicating the diamond pyramid hardness number or it is also termed as the Vickers hardness number, is obtained from the 1.854 P, P is the load applied and l is the average

length of the diagonal. So, now I would like to summarize this presentation in this presentation, we have tried to see the purpose of the inspection and testing which is commonly used, we have also observed that what are the different stages of the inspection and testing?

And then if after the completion of the weld joint to assess the weld qualitatively and quantitatively different methods are there. So, in this presentation mainly we have talked about the three destructive tests, these were the tensile test, hardness test and the bend test. And these tests are very commonly used in the industry to assess the quality of the weld joint, in the coming lecture we will try to see the other destructive tests, which are commonly used to assess the quality of the weld joint.

Thank you for your attention.