Marine Construction and Welding
Prof. Dr. N. R. Mandal
Department of Ocean Engineering and Naval Architecture
Indian Institute of Technology, Kharagpur

Lecture No. # 37
Welding Defects and NDT

So, continuing with Weld Defects and Non-Destructive Testing, let us try to look into what are the kinds of defects one may expect in case of a welded joint, a fusion welded joint, because these defects will be talking about, not necessarily they will be there in case of solid state welding or friction stir welding. These are the this defects you may find in joints done by electric arc welding, electro slag welding, electro gas welding, or in other words fusion welding.

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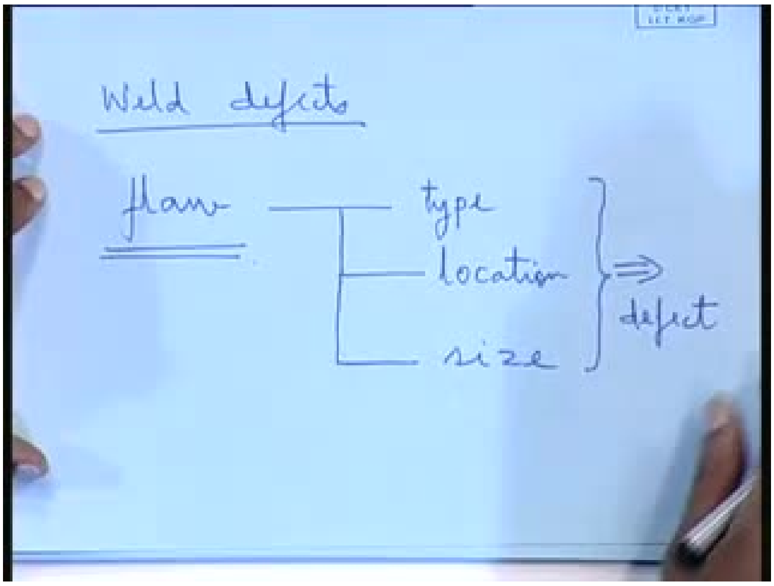

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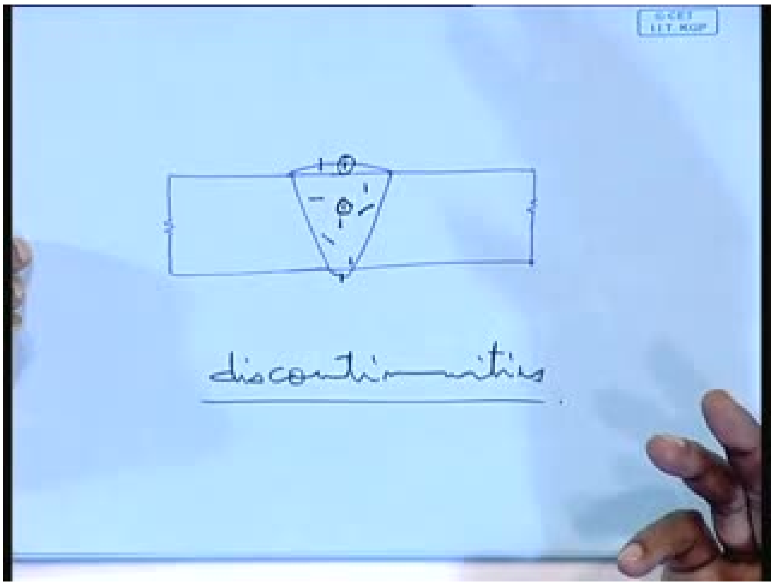

So, as I was saying, the flaws depending on type location and size, well as far as the location is concerned, as we can see, this is a, say, a welding has been done. Now, a flaw can be at the surface, a flaw can be somewhere here on the upper surface of the joint, can be at the lower surface of the joint, can be at the bottom, can be at the middle; different location in different orientation, right?

Depending on where it is taking place also is important, right? Because, depending on the location, its detection becomes different, that is, number 1, number 2 depending on location; it may may qualify for a for a flaw which can be ignored.

Like for example, a small crack inside and similarly, small crack outside, the outside is not the inside, one may be can be ignored, say the size; now, next comes the size. Size is beyond the critical limit, I mean, less than the critical limit, so, you can ignore this, but this, you cannot ignore.

Why? Because of the simple reason, the critical length of a crack is half when it is a surface crack, say l is the critical length and suppose, what is that critical length? Suppose, well, assume some critical length like when you talk about fatigue failure, right? Whether the crack will propagate or not depends on whether the crack length is less than or beyond a certain critical length. If it is beyond, more than the certain critical length at the operating stress level, then the crack will propagate faster.

Right, so, if we talk about that critical length, the critical length becomes half, if the crack is at that surface. So, that is how the size of the crack, I mean, the location of the crack also depends or location of the flaw in generalized term. We are talking about flaw, it can be crack, it can be something else, it can be for a particle get got lost inside the molten metal; that is also a discontinuity, a crack is essentially a discontinuity, so, we will essentially look for discontinuities whatever is there inside the inside a welded joint.

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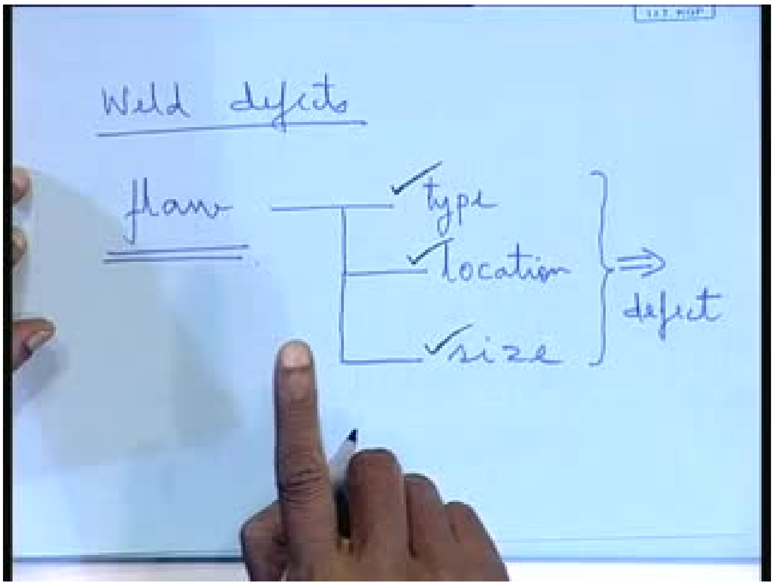

Right, wherever it has caused discontinuity, those are flaw. Now, that flaw will become a defect depending on the type of the flaw, depending on its location, depending on its size, right? So, these are to be certain once you find; so, those will be a certain through a Non-Destructive Testing technique which is called NDT. Through NDT, we will ascertain what is the type of the flaw where is the location and what is the size.

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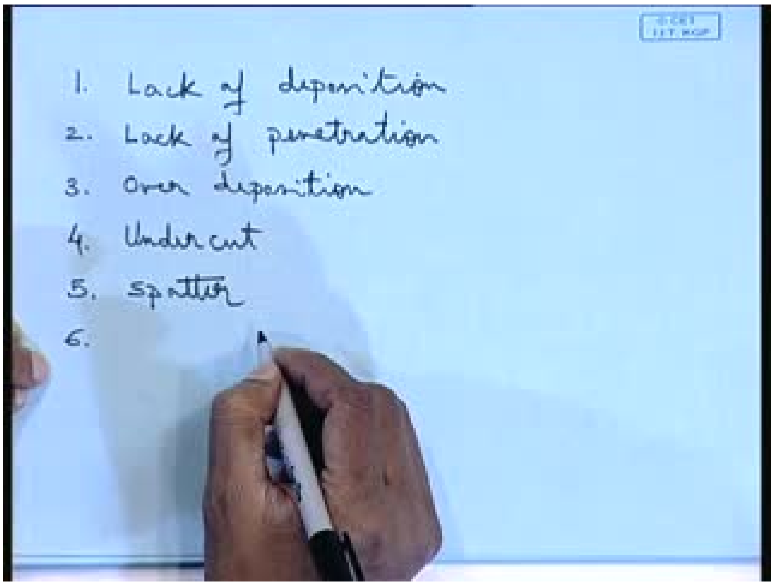

Then, that will tell us whether that flaw is a defect or not; if it is a defect, remedial action has to be taken, right? So, that is how. So, let us see now, what are the so called defects one may observe in case of fusion welding. We will talk about the ones which are more, well, I mean, so called mostly observed and which are more, which has a predominant effect on the performance of the structure.

So, first and foremost is a so called lack of deposition. We will first see, try to sort of, make a list of the defects which are probable, and then we will see how and why, how they are forming, why they are forming and what it to be done with that. So, lack of deposition, similarly, lack of penetration over deposition, just reverse of lack of deposition over deposition something called undercut, right?

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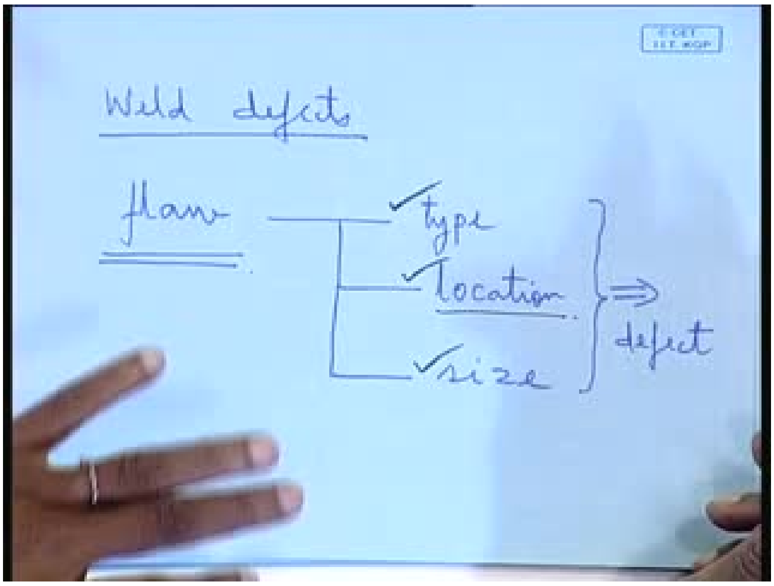

Spatter, we will come to that. I am trying to sort of, you see, again if you go by this location, some will be surface defect, some will be internal defects, so depending on the type of surface defect or internal defect, again you will have different methods, mechanism to find them out.

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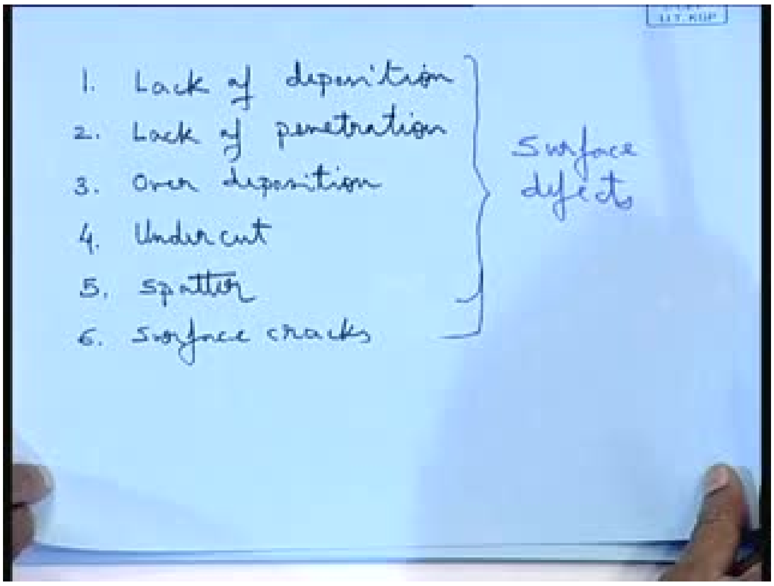

So, we are trying to group them as the surface defects then, we will go for the internal defects. So, as of now, I can see these are the ones I can recall which are the kind of surface defects; within that also, you have surface crack surface cracks, right?

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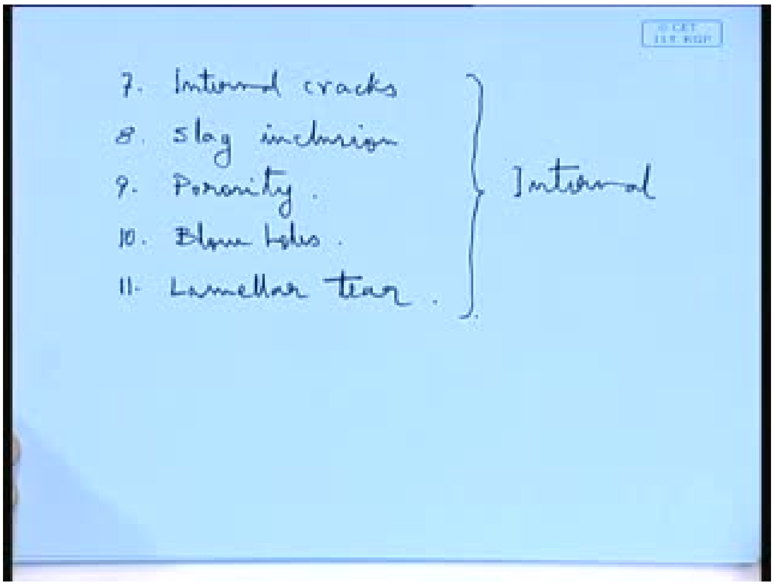

Then then, you have internal cracks. Once we have talked about surface cracks means, there can be internal cracks, right? There is something called slag inclusion, slag inclusion the name suggest what it is, right?

Then, you have what you called porosity. Then, you have well, blow-holes also. You can, one can talk about blow-holes, then something called lamellar tear, so, these are the defects internal; they were internal defects, right?

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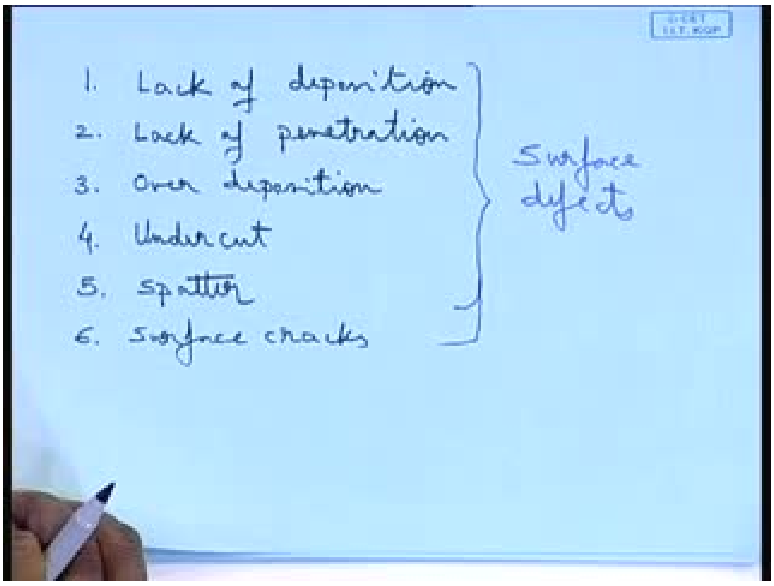

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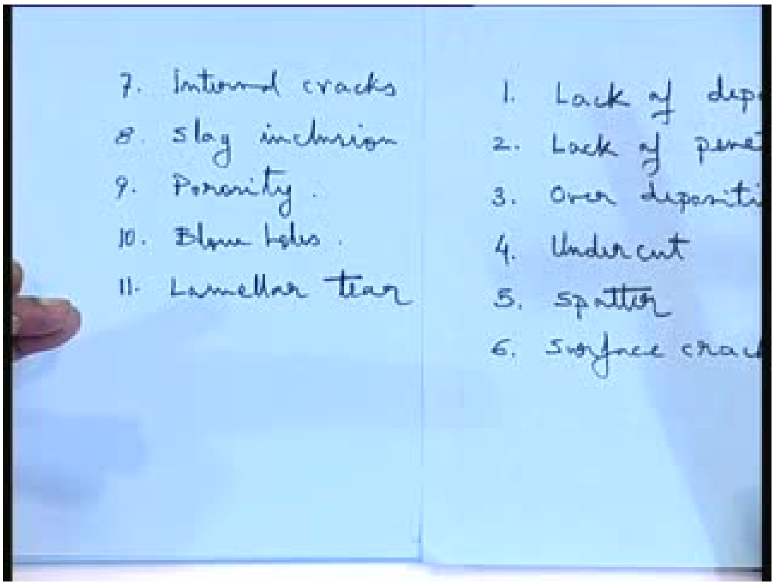

So, that that is how we see, there are surface defects, internal defects. Now, all these, all these, they they may take place because of again improper weld parameters, right? Because of improper weld procedure, because some may depend on improper procedure means, well, the welding welding parameter is a is a part of welding procedure, because welding procedure will tell you about the entire process which is to followed.

That includes, what should be the welding current; that also includes, how much restraint is to be applied to the plates, right? So, depending on all those factors, working together may lead to one of these defects, right? If these defects, I mean, here we are talking about the defects, we are assuming that the size of the porosity, the size of the undercut is such that they are to be removed.

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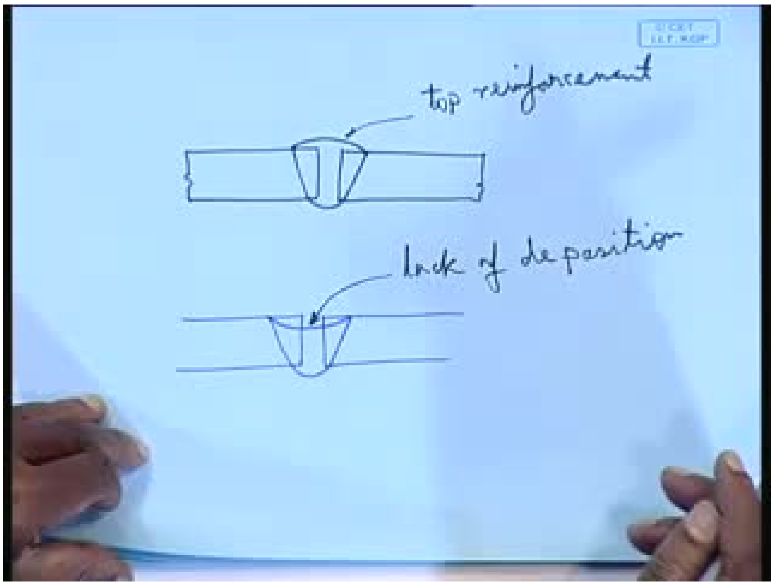

That means, their location is in the cracks, the surface crack or the internal crack is in such a location that they are to be removed, right? The size is such that, they are they qualify for defect any way so, lack of deposition; as you can see, the very name that means it leads to a good welded joint. Suppose a butt welding is being done, right? It should lead to a weld profile like this, right? Instead, if it leads to a weld profile, say like this, then this is lack of deposition, right? It should be a convex; the bead profile has to be convex, that means, there should be a crown on the metal, on the over the fusion zone where the metal has been deposited; a crown, a top, a reinforcement should be there; this is what is referred to as top reinforcement, so, this is what is lack of deposition.

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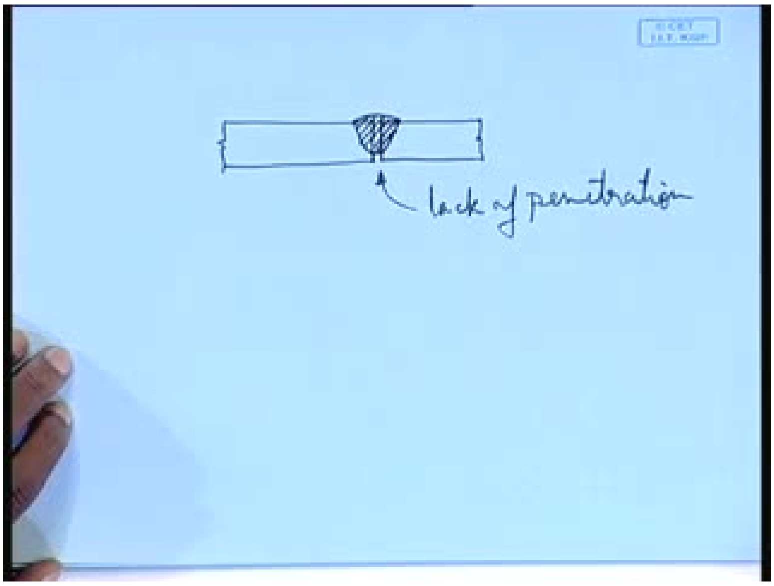

Lack of deposition: this may happen because of improper weld parameter like higher welding speed, less melting rate of the electrode as lead to improper deposition proper, full deposition has been taken place, that is, lack of deposition.

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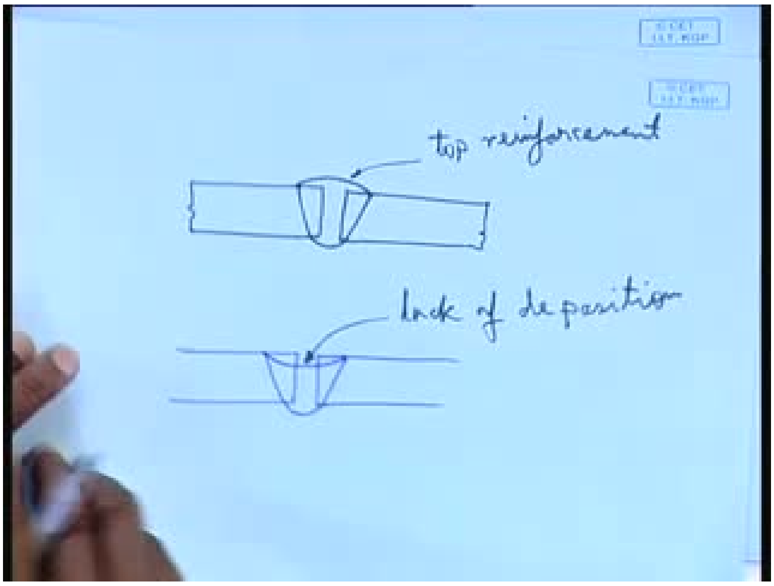

Then, lack of penetration: lack of penetration is, that is, say again, suppose a butt weld is being done, right? And, the fusion zone looks like this; that means, deposited metal did not penetrate through the thickness, did not penetrate through the thickness, and there is a lack of penetration at the root root. Deposition has been taken place, this is a lack of penetration, so, this is obviously, is not acceptable like lack of deposition is not acceptable; because here, the cross sectional area becoming less, so, your strength of the joint might be less.

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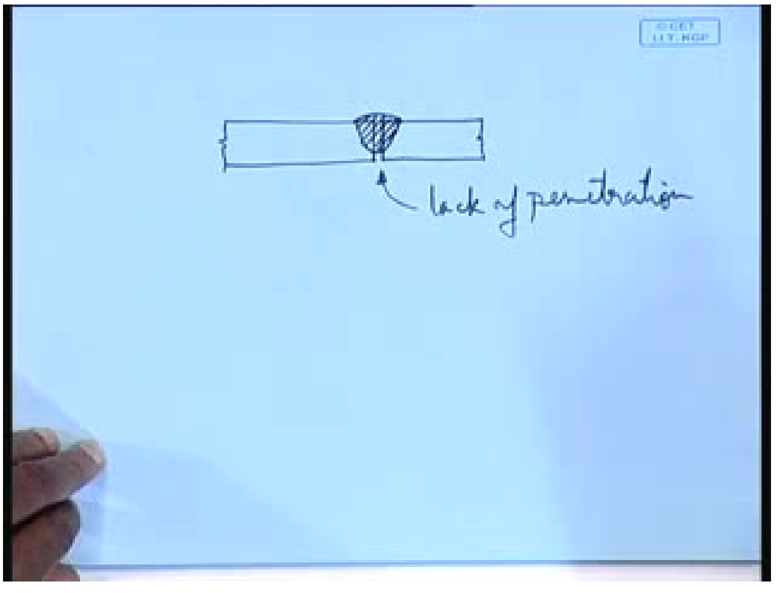

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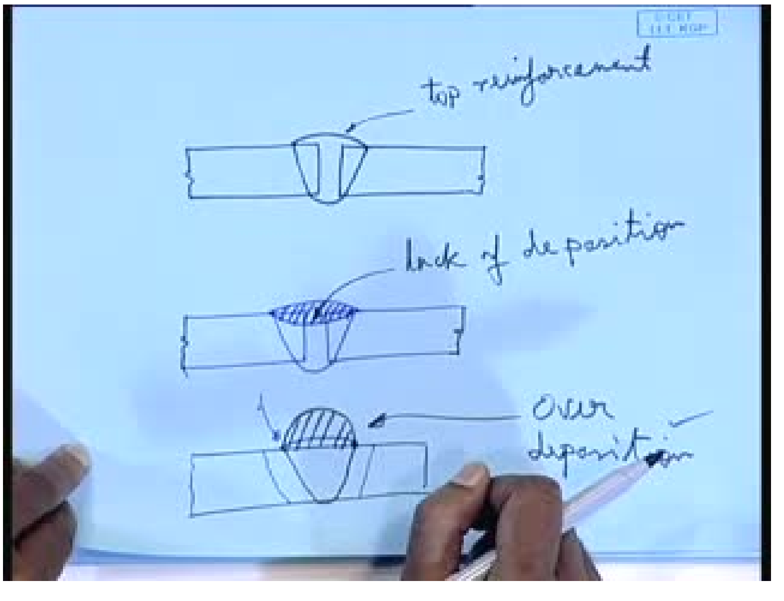

Similarly, here it is more serious lack of penetration, because, this part will act as a gross discontinuity in the structure, will behave like a crack as if... So, there will be a much greatest stress concentration, lack of penetration is more sever defect than lack of deposition, right? So, this is what lack of penetration is.

Then, well, over deposition: over deposition is just the reverse of it. Over deposition is this; well, what is the problem with over deposition? Over deposition means, you see that will, yeah, firstly it is unnecessary; too much of heat has gone into the structure, extra metal has been deposited; man's extra heat has gone there, so, that already has an adverse effect by increasing the heat effected zone. The heat affected zone will be more, which is an indirect defect, which is not immediately visible, whose effect will not be immediately visible, but in the long run, that might affect; I have a wider heat affected zone.

Wider heat effected zone means, a wider place of inferior mechanical property, right? Heat effected zone is not only is inferior in mechanical property compared to the parent metal, it is also a zone where corrosion rate is higher; why? Because, there you may have a residual stress plus the corrosion may get initiated there; why? Because there is the microstructure is different to the adjacent microstructure, so, the cathode-anode formation will take place; in a galvanic cell, localized galvanic cell will take place.

So, that is one aspect; that, because welding procedure also should look into such that, it it will lead to not not only a joint defect free, but also a joint leading to minimum width of heat affected zone, minimum residual stress, minimum distortion, right? So, over deposition, one aspect is this; other aspect is of course, as you said that local stress concentration; because here, at this corner, there is a sudden change in the cross section, a sufficient change in the cross section so, a stress concentration is expected.

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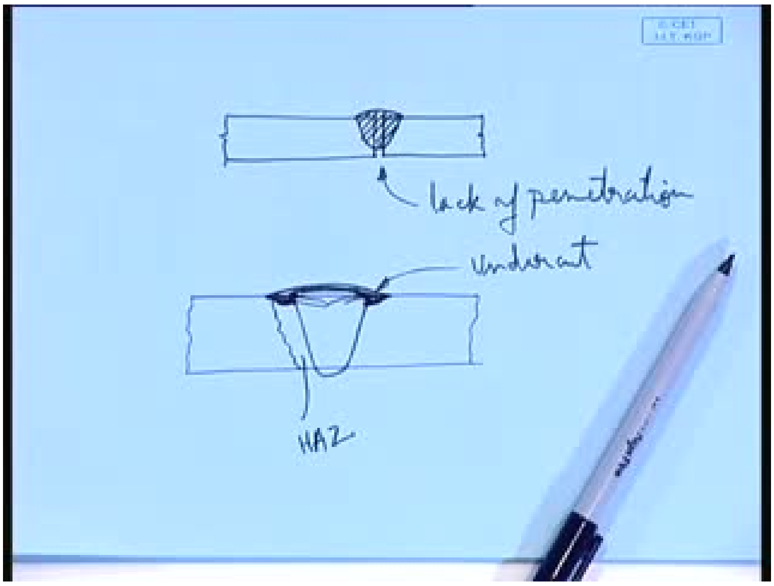

So, that is also not, I mean, that is not desirable, so, over deposition can also be taken as a defect. What is to be done? Lack of deposition, if it differs; what is to be done? Well, simple; you will have to deposit additional layer; you will have to re-weld it, simple; to get the proper deposition here, what is to be done? You have to grind it, you have to use a grinder, cut it off, right? So, that is what is over deposition.

Then, undercut undercut: we have already talked about; before it is a case, what happens is, well, when welding is done, now, if the welding speed is too high, then at the at the edges of the weld bead, the weld reinforcement forms like this, and at the edges, right, a small narrow channel like a like a thing forms.

Why? Because essentially, the metal gets melted, right? If the speed is fast, metal gets melted, and the metal because of the high speed, the metal gets solidified faster, before it could flow back and fill up the entire place. So, a kind of a spatter is formed. A longitudinal spatter all along the length of the weld; it is speed dependent, means, if speed is high, generally leads to undercut; that is what is referred to as undercut. Though nothing is happening at the under, below the weld bead, but it is at the side of the weld bead; this is my weld bead at the side, right? Small such channels will form as if. So. that is what is referred to as undercut.

So, if this undercut is there, now the trouble is this, is happening where? Where you have the heat affected zone; the undercut is near the zone, is above the heat affected zone and as it is heat affected zone is mechanically weak, so, having a undercut is a serious flaw. So, it has to be taken care of; that means, the weld beads to be it has to be re-welded and this under cut to be removed.

And, what happens? Since it is a it is related to speed, so, whenever there is a case of undercut, it continuous for a certain length before the welder observes that this is happening; then only you stop the weld process, check the parameters and redo it, so, that is what is under cut.

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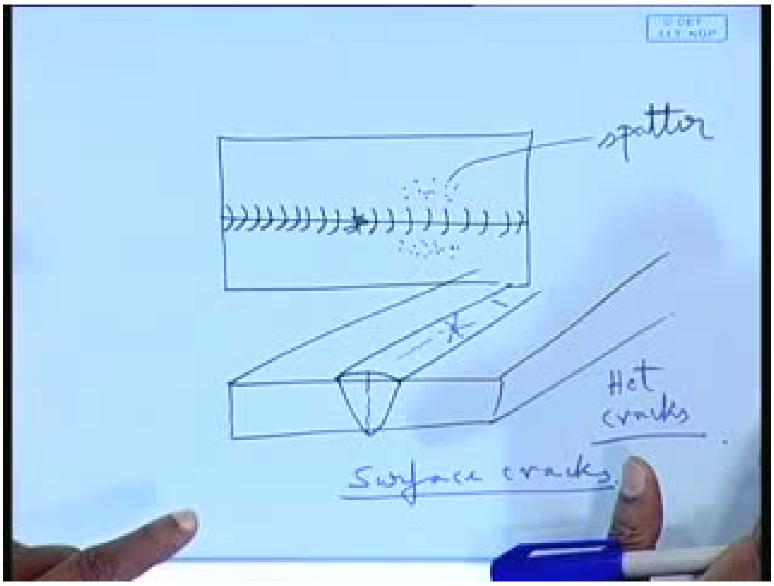

Then, spatter spatter is a thing, you see it is not a directly itself, is not a defect; say, this is my weld line, right? This is my weld line, that means, along this, the welding has been done, say a butt joint has been done; a butt welding, that means, two flat plates have been welded, and you see in some location, there are lots of such small small droplets of metal droplets are there, this is what is refer to as spatter.

Spatter in itself is not a flaw or a defect, but it indicates that there might be a flaw here. Wherever the spatter has taken place, there might be a flaw there, inside. Because, why is spattering has taken place, what is spatter, what cause spatter? That means, explosion of metal has taken place for some reason or the other, right? If so, that has taken place; there can be a possibility of gas has got entrapped in the flaw, that means there was turbulence in the weld pool.

Because of that, molten metal has got expelled from the weld pool in the process. There could have been a entrapment of gas, so, spatter means, there can be a possibility of porosity; inside, a porosity may have formed, right?

So, spatter, though itself it is not a defect, but it points to a defect that is what it is; and also, at the same time, wherever spatter has taken place, these droplets are to be removed; they are to be removed by grinding, because, if they are not removed, then later when you do painting, corrosion will start there. Because, paint film will get damaged because of this spatter and corrosion will start there.

So, that is what is spatter; and then, you have the so called surface crack; say, a welding has been done; this is the weld bead and you see a crack in the surface. The crack can be vertical crack, this crack can be through, and through crack it can be on the on the surface localized crack, right?

That means, a line crack or a star like crack, all kinds of cracks that that can be on the surface, right? So these are essentially surface cracks. Surface cracks means the cracks which are fusible on the surface; they may be few micron deep; they may be few millimeter deep; they may be several millimeters deep; they may be through and through crack, all kinds; that means, just just on the surface, the surface thin layer has got cracked.

Or it can be deep; it can be as deep as the entire thickness through and through there, is a crack that can also happen. Generally, these cracks, these surface cracks are because are generally referred to as generally hot cracks. Hot cracks means, they take place, they take place during the during the welding phase itself, during the welding process itself; that means, you are welding a joint, and as you look back, at the back, it has already cracked; that means, still the weld is hot.

By hot, I do not mean that they still in a liquid state. Because, in liquid state, there is no crack; means, it has solidified, but, but it is still hot, it has not fully cool down, but it has already cracked. So, that is also referred to as solidification cracking. Solidification cracking, that means as if during the process of solidification, it has cracked, right?

So generally, surface cracks are due to solidification cracking; they are generally hot cracks. Well, what happens because of stresses? Because of unfavorable thermal stresses taking place, the structure is unfavorably restrained. So, the kind of tensile stress taking place in the in the weld metal, and the weld metal composition taken together, it cannot sustain that stress and crack develops.

So, what could be remedy? Well, remedy is, once the crack has developed, if you have detected, if you have detected it, that has to be scooped out, cut out and re-weld. There is a remedy, otherwise, procedural remedy would be, you have to look into the weld parameters; you have to look into the filler metal composition; you will have to look into the structural restrains, say a butt welding, a fillet welding; you are doing, in fact, just the other day we had been doing a…

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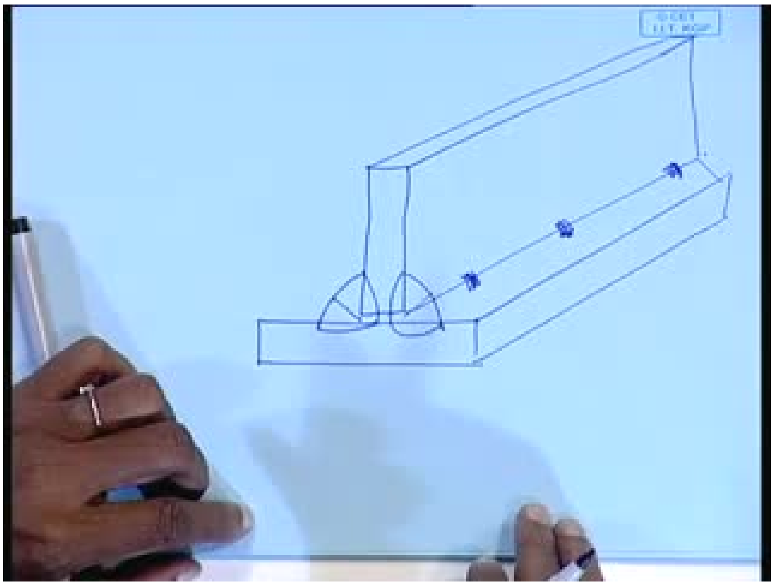

I was telling you probably in the previous class, just a simple case of fillet welding we had been doing, right? So, with a submerged arc, the fillet was like this; both sides fillet, right? And, and a crack was observed in, right? In the center line, through and through crack from the surface; still inside, through and through crack took place.

In the second case, when we did some, means this, was a case a small test, sample hardly 300 millimeter long like this, right? When it is welded, it is it it crack all through, all along the length. The next, before welding, we did some tacking at at some small intervals, small tack welds, and then welded. There was no crack, that means, the stress redistribution taking place are simple because of some tack welds. Some tack welds have been done, and then when you are welding it, the stresses developing are totally different or the extent of tensile loading coming on the fillet, it is not cracking it.

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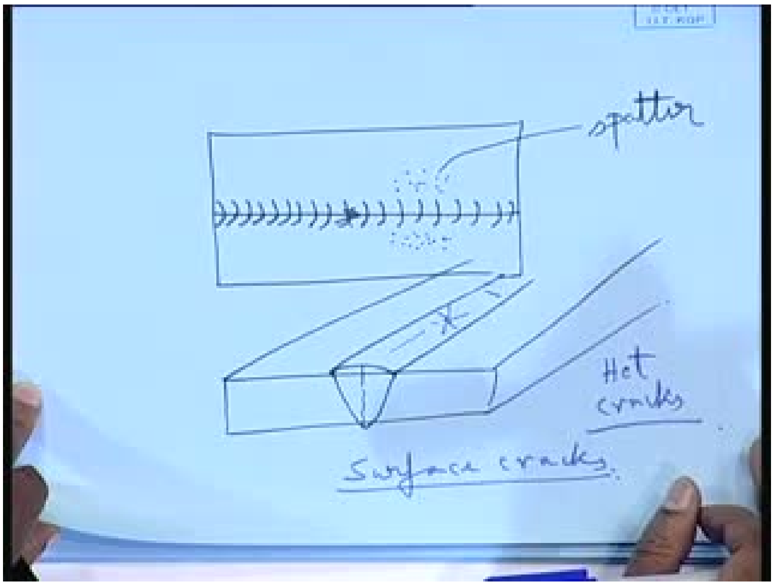

So, that is why the surface crack, it will depend on, well, it will primarily depend on the welding procedure; it will depend on the restraint on the structure, what kind of stress level is taking place. So, if a defect is observed, well it has to removed and re-welded. But, thereby, you are not removing the cause of the defect; so, to remove the cause of the defect, means, you have to look into the welding procedure, such that, newer, fresh welding you do.

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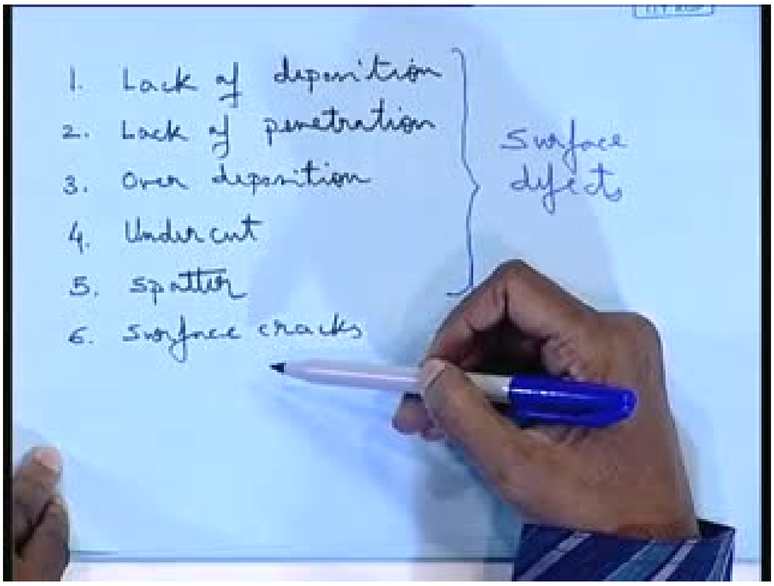

Crack or defect should not occur, so, these are the defects we talked about. They are the surface defect, lack of deposition, lack of penetration, over deposition, undercut, spatter and surface cracks; though surface cracks can go inside, right?

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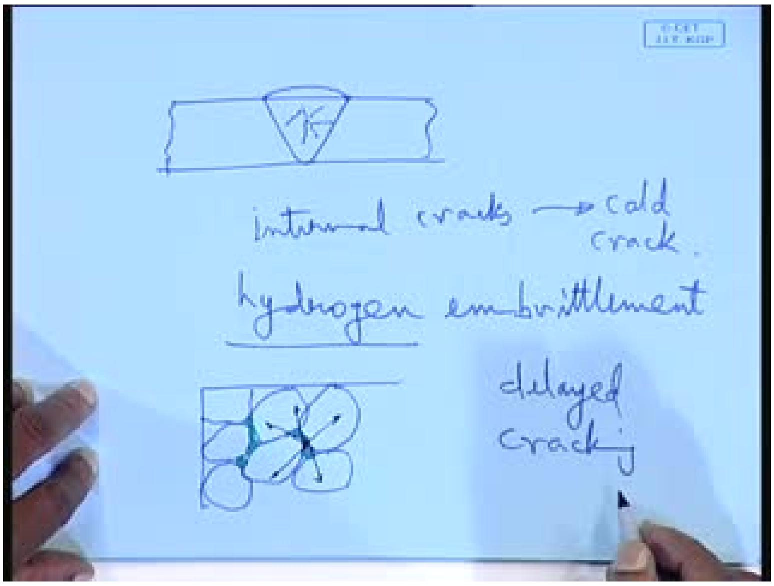

So, they are the kind of surface defects and then, you have the internal defects, internal defects you started with internal cracks. In this case, what happens? In this case, when when the welding welding has been done from outside both sides, top, bottom; everywhere it looks absolutely perfect, that means, nothing is visible.

But, there can be a crack inside, not visible; crack can be vertically downwards, can be oblique and can be horizontal, anything, right? Or it can be even in in several directions like these internal cracks. These internal cracks are generally generally referred to as cold cracks. Well, once again the internal crack like surface crack, the cracking has taken place at the surface and propagated inside. Internal crack can get initiated internally and may get propagated outside; so, it may or may not become visible outside; generally not visible; remains strapped within inside internal cracks. They are generally cold cracks, and cold crack is due to no due to a phenomena called hydrogen embrittlement, right? Because of hydrogen embrittlement means, this hydrogen is making the rendering the material brittle is, as if its rendering the material brittle; and and thereby, the material is cracking, that means, it is losing its ductility, natural ductility becoming brittle, and under the under the thermal stresses or under the well formation of the residual stresses after the welding, everything is over; it is getting cracked. So, that is what is generally the internal cracks are like that.

What basically happens is, little bit if we look into this, once again you see, go back to the so called microstructure. If we look into the microstructure, we see somewhat like this; that means, in between the grains, there are spaces which are some voids are there. These are the voids in between the grains like... So, what happens when you are doing welding? If there is a hydrogen present in the environment, from from where the moisture moisture in the flux moisture, in the plate moisture, in the electrode wire or environmental moisture. If there is too much moisture is there, that from the moisture, that hydrogen gets that H 2 O gets dissociated, right? And, in hydrogen, in atomic form, they get lost in this wedge, micro structural wedge, right? In between the grains, the voids are there; the hydrogen in the atomic form, it gets lodged; there they occupy those spaces.

And, as the welding is over, the entire materials gets cool down; at that condition, those atoms, they combine and form the molecules, right? Once that, that, is formed, they exert a tremendous force in all direction, why? Because, it seems the molecule, the volume is more than individual atoms that means two atoms combining forming a molecule, the volume occupied by two atoms is less than one molecule, right?

So thereby, once the atomic hydrogen gets converted into molecular hydrogen, it exerts a tremendous pressure, because the volume it was occupying is becoming short. So, in that pressure it cracks, right? In that pressure, it cracks; so, thereby, as if the hydrogen has made the material brittle and the metal has cracked, right? So, that is what is referred to as hydrogen embrittlement. So, in that form, such cracks may form inside and may get initiated and stopped within.

That means, it does not further propagate; later, under action of external forces etcetera, other kinds of loading that may act as a may act as a so called may act as a further crack initiator; means, from there the crack may grow, crack growth may take place and eventually lead to a catastrophic failure of the entire structure. So, that are what are the internal cracks, right? So, they are generally because of this hydrogen embrittlement and that that is why they are referred to cold crack, means it is something like this.

Also, they are referred to as delayed cracking; delayed cracking means the welding has been done today immediately; after, say few hours, if you check the welding, you may find there is no crack; but after two days, you might find a crack. That also happens so, that is an internal crack.

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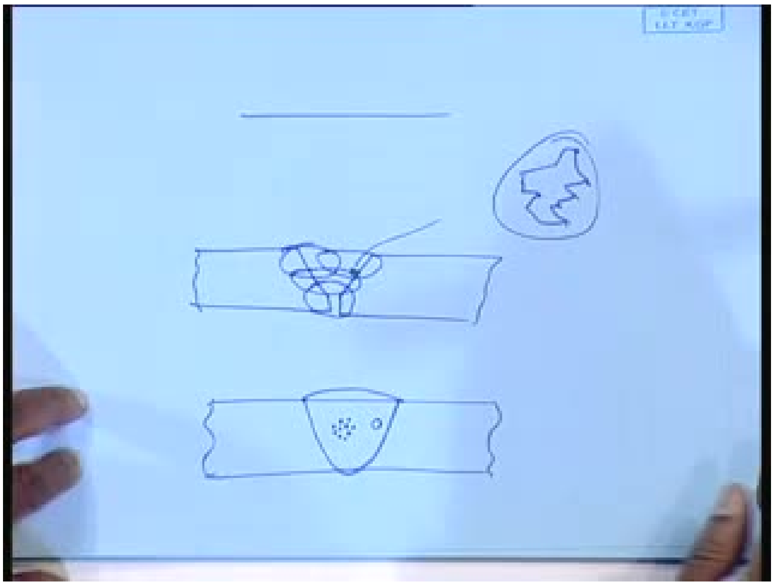

Then, you have slag inclusion means, when you do a multi, multi-run welding, suppose, with a manual manual metal arc welding with a multi-run, means, one run you have given, then whatever slag was there you have removed it; you have given a second run, a third run and so on. Every run you are giving, you are removing the slag; if you do not remove, it meticulously a small speck of slag may remain inside. Suppose a slag has remained here and and you have done welding on top of it; so, what will happen? The slag does not get re-melted, it remains, neither it floats up, it remains; so, that is a slag inclusion, a slag has got included.; Slag inclusion is, if I look it in a enlarged form, the slag can, that slag particle can have any arbitrary shape; and in all probability, that arbitrary shape will have very many sharp peaks, why? Because, the slag is a brittle material; it is the hardened, the burnt flux, right?

It is a brittle material, so, a small speck remaining, means, it will have all kinds of sharp edges. So, this, the slag inside will behave, as these edges will behave like a crack tips; and, if there is a crack tip, means, chances of stress concentration. The moment there is a stress concentration, means, they can be the potential crack initiator, the location for crack initiation; so, this is a slag inclusion, again internal defect porosity.

Porosity is again, if your welding speed is not adequate; rather of the higher side, then what may happen? The gases what has been formed because of depending on the process, suppose you are using shielded metal arc welding, the flux is burning, giving out gas which is shielding the molten metal or you are using gas metal arc welding; the gas is injected on the weld pool surface for shielding. So, the gas bubbles, they get entrapped before they they can float out; they get entrapped inside.

Before they can float out, the metal solidifies and gets entrapped, and a cluster of such small small, that is the difference between blow hole, and porosity blow hole is rather a bigger diameter void; a void of bigger diameter, that is a blow hole, a gross entrapment of a gas bubble, right? Whereas, porosity is fine droplets kind of a thing, much much finer sizes of cluster of small small blow holes, as if, very small blow holes, a cluster of them; this is referred to as porosity.

So, porosity can be caused due to higher welding speed. It can be due to the presence of impurities in the welding side. Suppose, some grease or oil is there that gets burnt, that also generates gases fumes which gets entrapped; so, porosity, naturally porosity has to be removed, that is a gross defect; and it is a internal defect at the same time, because it forms with in the fusion zone. Blow hole is same thing, it is a formation of a well porosity is cluster of small small bubbles; blow hole is one big bubble.

For some reason, some gas gas bubble may got entrapped. Generally, blow hole is not observed; blow hole is observed in casting in casting operations. When you do molding and casting of big parts, suppose you are doing the casting of the stern frame of the ship, right? If it is not properly done, the mold at certain, not properly prepared gases may form which cannot escape and forms as a remains as a blow hole.

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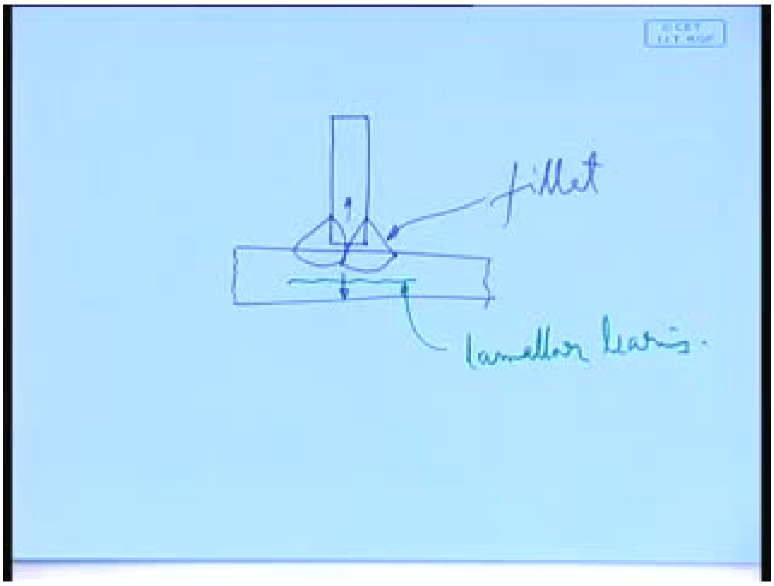

Here, we have generally porosity, the lamella tear; it is a typical failure in case of fillet joints, in case of T joint suppose a structure is like this, right? The welding is done in this fashion, these are the fillets. Fillet welding like immense amount of fillet welding is done in the ship structure; all the stiffen panels, essentially fillet welding, so, you need to… In Fillet welding, what is happening? The material here, material around the weld zone, I mean a shrinkage force works there.

It shrinks isn't it? This is shrinking in this direction; this part is shrinking in this direction, right? A shrinkage force works, and depending on a situation, sometimes a defect of this type is observed; a crack forms in the base plate over which that team member or, that means, this is fillet welded on the best plate; a crack forms this, is what is called lamellar tear, lamellar tearing, right? This is because of the thermal stresses here, it has this; lamellar tear has nothing to do in the weld zone, it is generally just beyond the weld zone; it can be in the heat affected zone just below the fusion zone, right?

So, that is what is lamellar tear. Once again, lamellar tear is also a internal defect, so, these are the typical weld defects; as we can see now, the job is to should should have a mechanism through which you can detect all these defects. So, we have seen that there are surface defects as well as internal defects, that means, we will have to have mechanism by which we can see what is there in the surface, as well as what is there inside.

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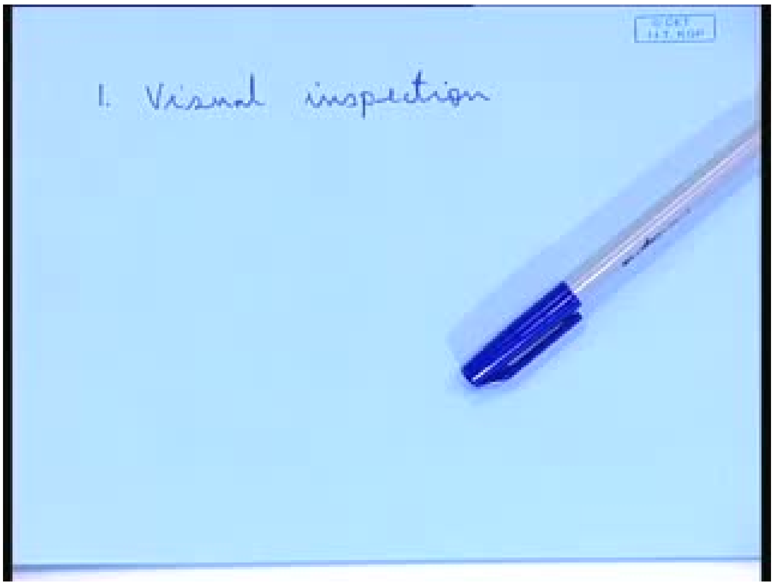

So, based on that, in fact, to tell you as far as welding, so called; as far as Non-Destructive Testing techniques are concerned, there are several techniques are there, several methods are available.

But obviously, many of them are not suitable for shipbuilding applications or the kind of structures we do; there are many of them, are not suitable; so, we will discuss about only those which are relevant to shipbuilding. What could be the first and fore most and most important and most, sort of, what to say, most effective efficient means of NDT, Non-Destructive Testing? What visual inspection? Nothing, but visual inspection means a very trained eye inspection, through a very much skilled and trained eye visual inspection.

Why? Because, you can very well appreciate the extent of welding which goes in in a ship structure or in a offshore structure or any structure of that type. Extensible amount of welding goes in, isn't it? I mean, if you really put together the in terms of meters, it will be few hundreds of few kilometers; probably, the total weld length that will go in in a in a vessel of probably 200 meters long, right?

I mean, few hundreds of kilometers, total weld length will be there, probably; so, obviously, now it becomes, probably, physically impossible to have a very extensive check on the entire weld length; so, what is done is, visual inspection is the most important that is done for the entire welded or or the entire weld length is subjected to visual inspection.

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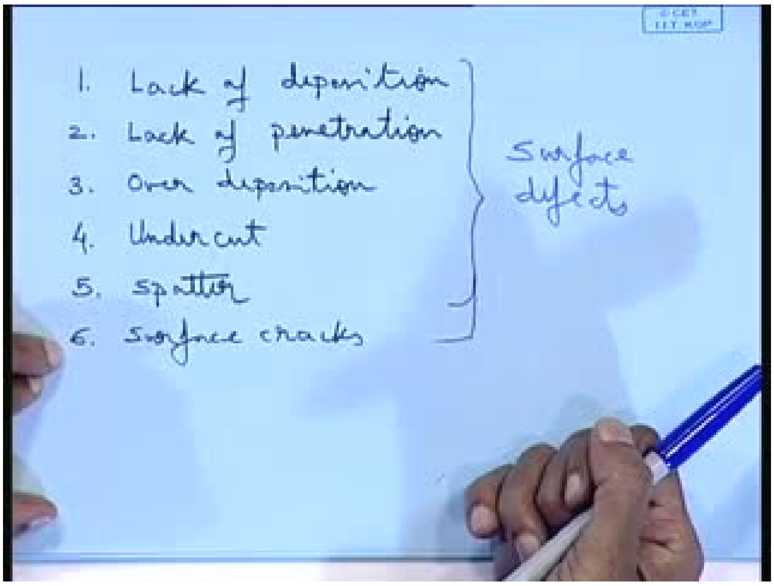

What does it mean? It means that a proper weld inspector or a person trained in welding defects, and these these things, he he physically checks, he physically checks the welding from outside through visual inspection, thereby you can already detect as many as these six defects which are there on the surface. So, already, so many could be detected; there can be something like, some of the surface crack may not become visible in the naked eye. There are some other methods then one can apply, but at least others, lack of deposition, lack of penetration, under cut, over deposition, spatter all these can be detected.

So, visual inspection is is a is a technique which is in fact the most effective means of testing or assuring whether the welding has been done defect free or not. But obviously, its limitation is, you can only, through this, check the external or surface defects.

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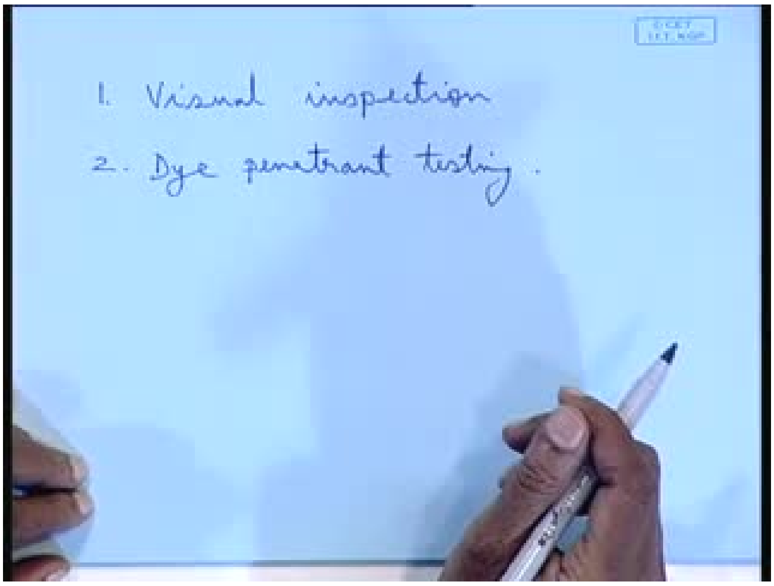

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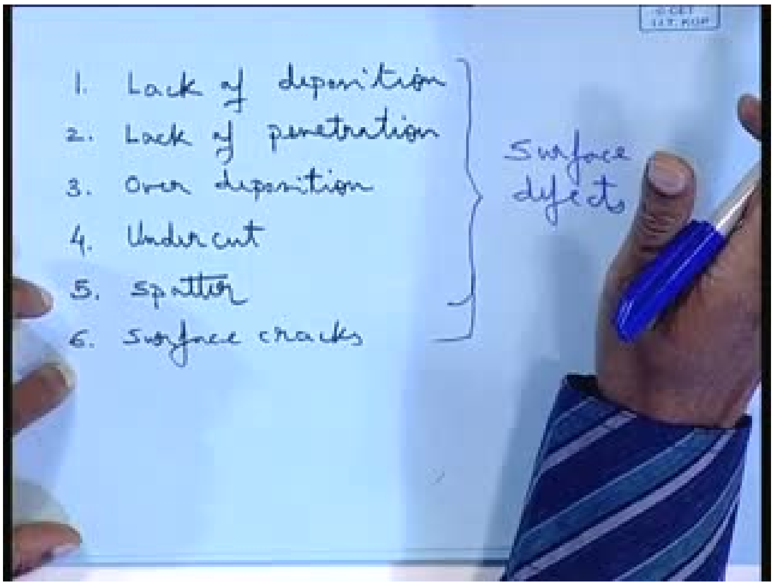

Next is, what is called dye testing? This method is also used in in ship building applications. What is the dye penetrant? It means, essentially this is used like, as far as visual inspection is concerned, lack of deposition can be very easily detected, lack of penetration, over deposition, undercut, spatter all these five can be very easily detected; but, surface crack may, at times, evade your naked eye; means, they might be so fine that you may fail to notice it. And obviously, you know will not go about with a magnifying glass, that is not done anyway; so, surface crack, you may evade unless until it is a very wide at visible crack, right? So, to help that visual inspection, one can take help of dye penetrant testing; so, through using a kind of dye, it enhances your capability of visual inspection; what is done is, over the weld surface, a fluorescent dye is spared over the weld surface.

By capillary action, the dye gets, dye propagates through the crack, right? And then, what is done is, you just clean the surface, wipe out the surface; so, whatever dye has got penetrated in the crack, the crack may be surface crack; means, I am not talking about through and through crack; it can be just surface crack, it can be to a certain depth.

Starting from the surface, so, dye will penetrate by capillary action, and if you rub the surface, I mean, wipe it out; what will happen? And that surface is eliminated with a fluorescent, with an ultra-violet torch, with a ultra-violet torch that fluorescent dye will grow in that, right?

So, the cracks will become easily visible, that is the logic, that is how you can detect those cracks; of course, this does not tell you how deep the crack is. Obviously, it does not tell you, but it gives you that, well, there is a crack on the surface, there is another aspect of dye penetrant testing. If you are testing a flat plate, this side you put a dye and you go on the other side and illuminate that with a ultra-violet light. If some part glows, that means there is a through and through crack; because through capillary action, it will suck to the other side, it will go; the dye will go to the other side.

So, if something is bleeding on the other side, which becomes visible in that fluorescent because of its fluorescence under ultra violet light. So, you can make out that there is a crack through and through, so, that is what the dye penetrant testing is. This is a very simple method of testing in a inexpensive, but effective.

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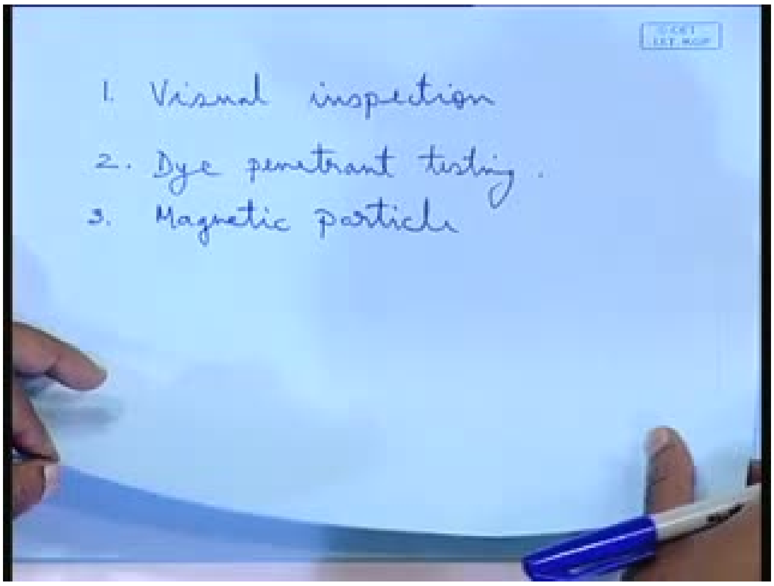

What the primary drawback is, limitation is that, it cannot say whether, it can only say either it is a surface crack or it is a through and through crack. If it is half way between, how much it cannot say; because, if you have to repair the crack, then you should know how much it has gone in, right?

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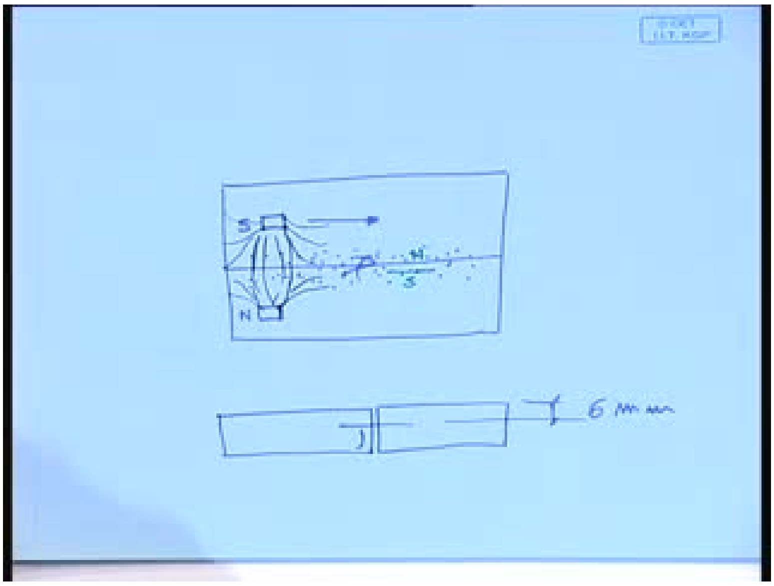

Also, another drawback is, it does not have any same drawback for visual inspection; no record, you cannot. Automatic records are not generated; you will have to later prepare a record that there was a crack that was the defect etcetera, right? That is also a limitation.

Next method is called magnetic particle method. This is another method called magnetic particle; in this magnetic particle, what is done is, you you have the, suppose the welding has been done along this line, right?

Over this, you spray iron filings, iron power, rather over the entire, over the welded surface, say iron powder is put, and then you move a magnet, a horseshoe magnet suppose, right? In this direction, you just move the magnet along the welded zone; so, what will happen? You know, the magnet lines of force will act through this; so, these will, all all these magnetic filings will align themselves as per the magnetic lines of force.

Now, if there is a discontinuity in between, about the discontinuity, again the north and south poles will form; as you know, since here, I am having a North pole and there is a South pole, right? Say, there is a discontinuity here, so, in this discontinuity, closer to this, this side will become South Pole and the other side will become North Pole, isn't it? Just reverse magnetic fields will form; so, this side it will it will form a south pole and the other side of the crack will form a north pole.

And, again there, the magnetic lines of force will be districted, so, the mechanic... So, those powders, iron powders will align themselves along that crack, right? And the crack will be visible through the arrangement of those magnetic particles of the iron powder which has been spread over it. They will align themselves along the crack, and the crack will be visible, so, that becomes a very simple method of testing.

But, what are the limitations? Well, first and foremost limitation is, it has to be done in a horizontal case; that means, the plates are remaining in the horizontal form. In a vertical, you cannot do magnetic testing; dye penetrate in vertical also, you can do over it, not possible. So, in a horizontal and second limitation is the material, the welded material has to be magnetic; that means, for aluminum welding, I cannot use; third is, it has a limitation in the penetrating power of the magnetic field, penetrating power of the magnetic field, it generally, it penetrates up to 6 millimeters; that means, any track beyond 6 millimeter.

Suppose, a discontinuity beyond 6 millimeter below, say you have done a, you are checking a plate of 20 millimeter, thick crack is there on the bottom half below 10 millimeter; that will not be visible it. It generally penetrates up to 6 millimeter, so that is the limitation of magnetic particle testing.

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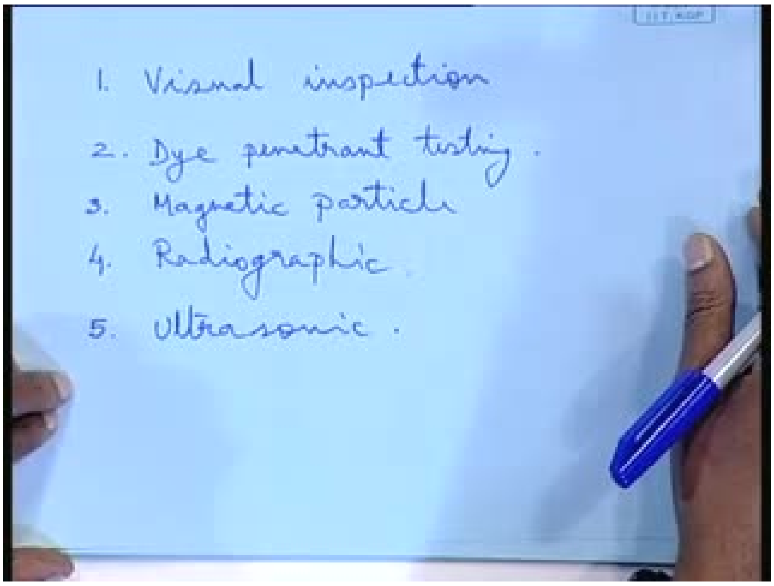

Well, next is the Radiographic Testing; Radiographic Testing is nothing but the conventional X-ray. As we do similar to that, it will be more powerful X-ray basically, right? So, the X-ray you are all are aware of, in the same method, you will have to put a photographic material below and over, you expose it with X-ray.

So, whatever defect is inside, will get an image there; and again, a trained eye has to read that film; something like your lung X-ray is done; doctor will know whether things are all, right? Or, not same way, a welding doctor will know by checking the X-rays. Whether there is any, I mean, the spots whatever will come, whether it relates to a crack or relates to a slag inclusion or relates to porosity, right? Similarly, you have ultra Ultrasonic Testing; Ultrasonic Testing is again, well, with Radiographic Testing, the biggest advantage is, you can literally see through the entire weld fusion zone through the material; all defects you can see.

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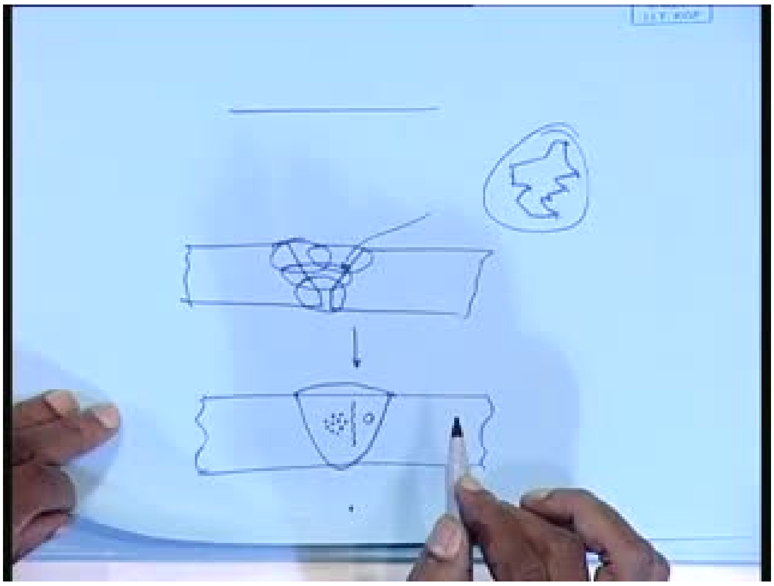

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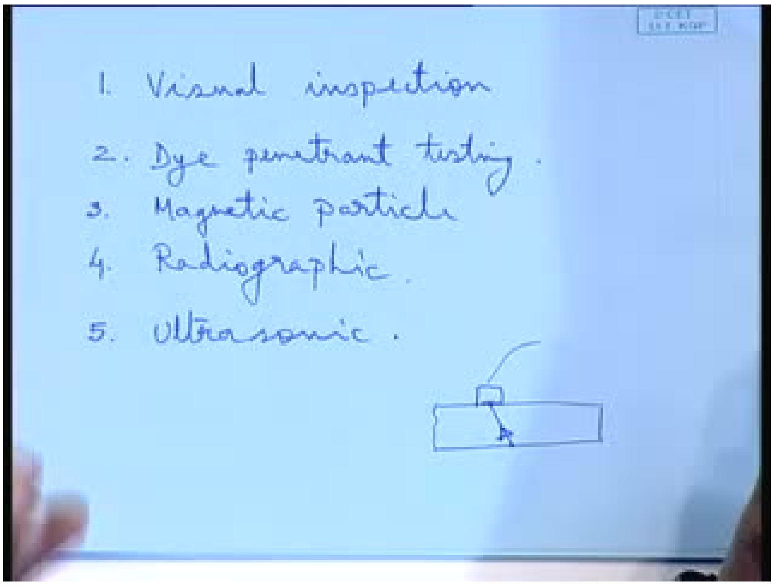

But, at the same time, it has limitations; that supposingly, your defect falls in line with the, falls in line with the crack; suppose, assume a theoretical crack like this, a vertical crack, and your X-rays are coming vertically down; so, it will give a spot in the film. You will not realize that this is a such a long crack is there; you will find it is a small, possibly some defects, small small, though that is hypothetically, it is possible; but, such a coincident can be rare. Other disadvantages of Radiographic are, these hazards, that is number 1 very much hazards; and second, it is a bulk equipment. So, not every nook and corner, you cannot test.

Whereas, ultrasonic testing, it uses the principle of sound, sound wave, you know; wherever you put a sound wave, whenever it meets a interface, it gets reflected; that is how? In that principle, even these probes can be used as a thickness gauge; I put it it this these probes, small probes which can be held in the just by the fingers. So, it is small, potable, so, you can take it out anywhere within the nook and corner or a complex complicated structural geometry is there; it can be taken there.

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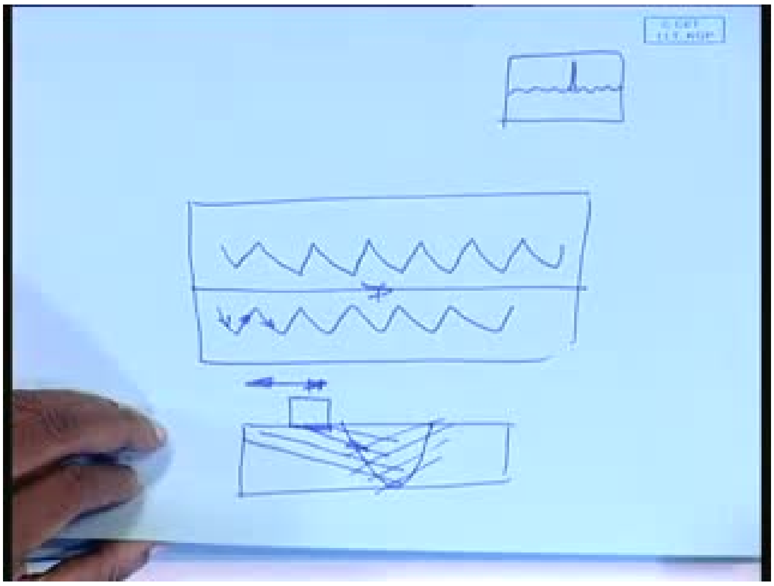

So, this ultrasound probes are used in a zigzag fashion. This is the weld line, the ultrasound probe is moved in in such a fashion on both the sides of the weld zone. This is the welding line; this is the movement of the... Why is it done that way? Because, these probes have a capability of transmitting ultrasound in a oblique fashion, right? In a oblique direction, so, if the weld zone is this, you go on moving this; it scans the entire depth you make; this movement of the probe. So, it scans the entire depth, again on the other side, it will scan the entire depth. So, thereby, it goes on scanning the entire depth so, any any discontinuity it is meeting within the weld zone in the form of a crack or a slag inclusion or porosity, it will be reflected in the monitor. Because, otherwise, the monitor signal will be something uniform; wherever there is some discontinuity, may, there will be some spike; again, the same thing, what this spike means.

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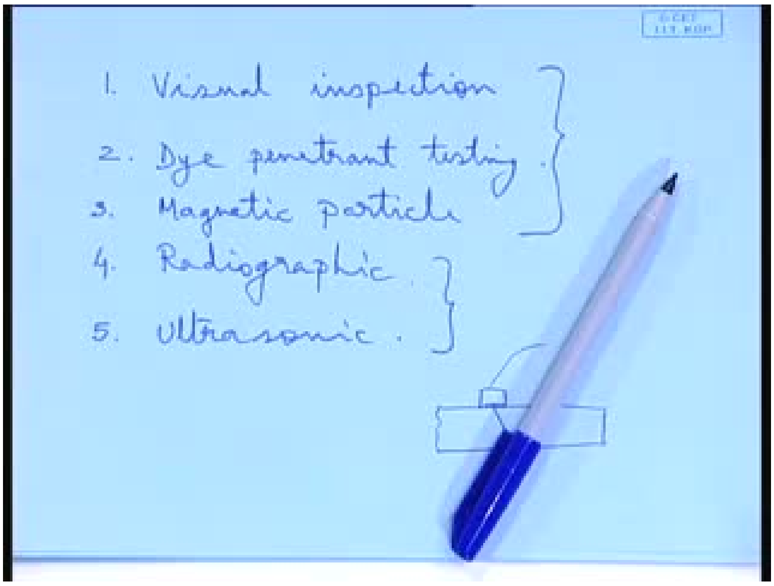

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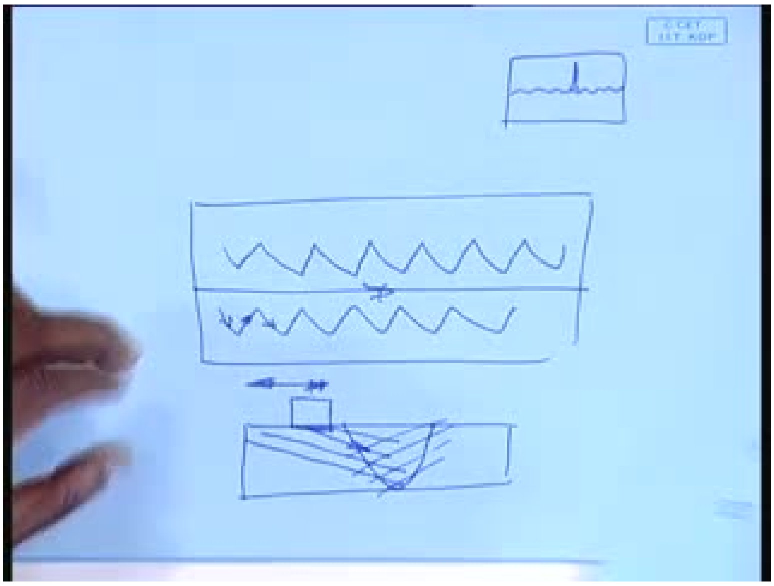

What extent of crack, etcetera? Again, it needs a very trained interpretation, right? Something similar to that of... You see, the ECG plots again something similar, you will have to be trained in that. But, the logic is, point is, through this, you can very easily see what is there inside; and the same thing can also be recorded; that is another biggest advantage of Radiographic and Ultrasonic Testing; that you can produce a record of the tests; that is very very important from legal point of view; because, you know, what happens? All these becomes assumes an immense importance; if an accident takes place in the service, life; some accidents take take place, then you start digging out, start postmortem and all that. So there, these things become very important; that, well these welding were tested, and these are my reports. But, all these, visual dye penetrant, magnetic particle, no report report is man- made means, after the after you have seen, after done, you can write it down. But, this is in the process of... testing reports are generated; the photographic films or the prints of those from the ultrasound probes, right?

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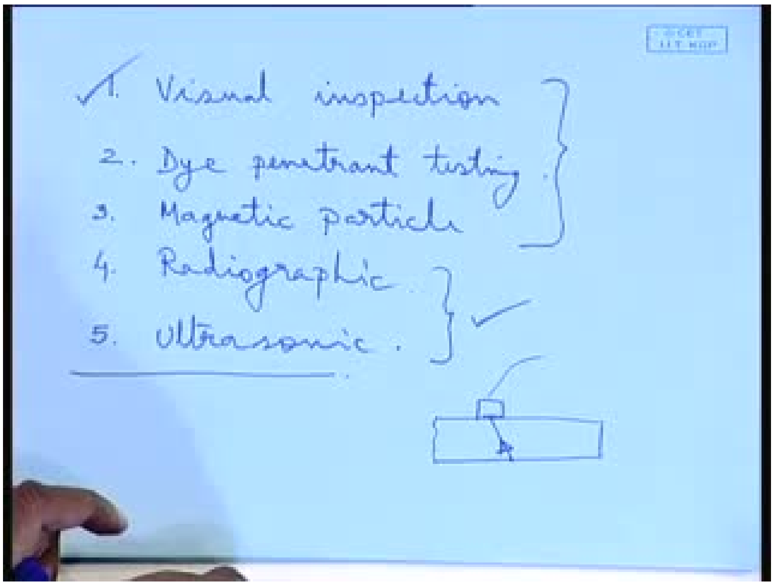

So, these are so, that is how we see; they are the basic five techniques which are used, which are used extensible extensible. What is done is, the vulnerable parts, say, the bilge plate, that welding of the bridged plate and the slide plate, the sheer strake and the side shell plate, so, such vulnerable joints, they are 100 percent Radiographic tested. These are all specified by classification society rules that where, what type of testing is a must visual; its inspection is a must for entire weld length, very vulnerable places Radiographic or Ultrasonic Testing is a must, right? So, that is how we see that these are the entities which are primarily used in ship building; there are many more, but in shipbuilding, these are the most relevant and these are the ones which are used.