Marine Construction and Welding

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Lecture No. # 36

FSW Metallurgy

Continuing with the friction stir welding, today we will look in to the little bit of FSW metallurgy, basic metallurgy of the friction stir welded joints. As we know, in fusion welding, we have essentially two distinct zones; that is, one is the fusion zone, another just surrounding the fusion zone, you have heat-affected zone, right?

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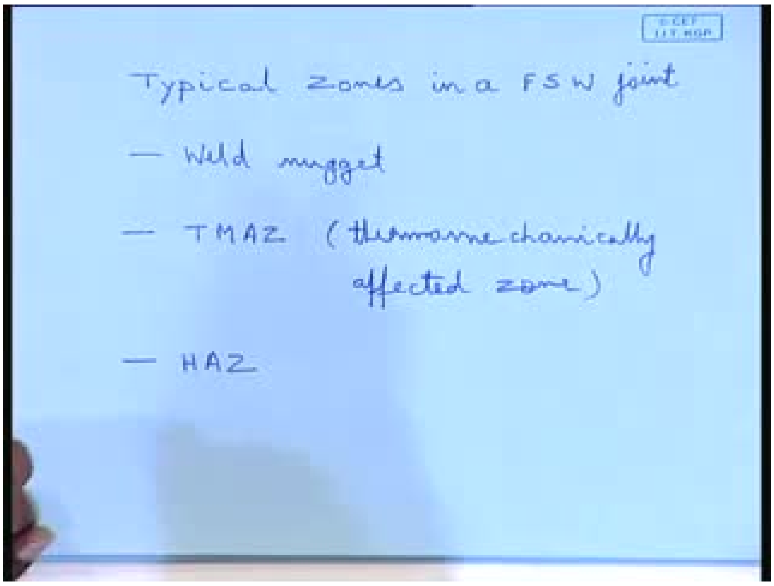

That is how the so-called basic metallurgy in case of in case of a fusion welding looks like; that means, because of the heat input, melting takes place. So, we have a typical microstructure there, which is a microstructure of the fusion zone, and just surrounding it where re-crystallization takes place, which does not go in to the so-called molten phase. There we have some re-crystallization and that is called heat effective zone. Here, in this case, we have typically three zones.

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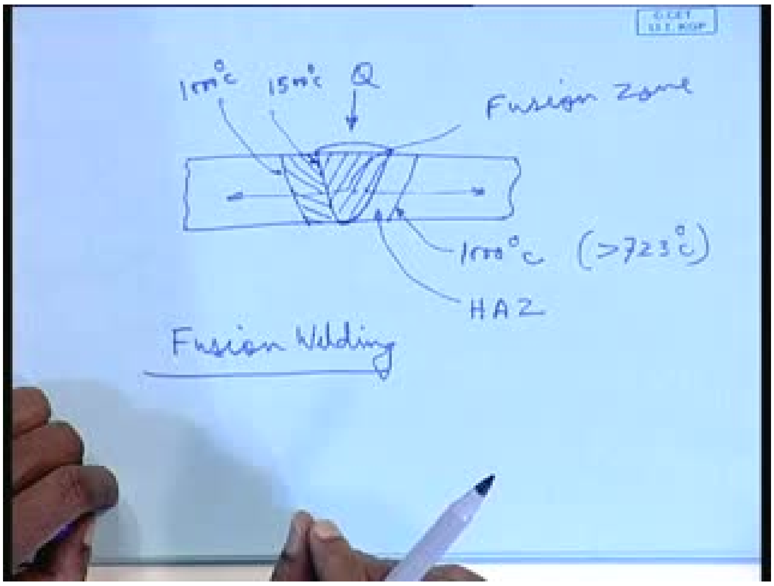

The central one, just below the tool which we have seen, the below the probe, that is referred to as the weld nugget weld nugget; that means, the zone where both plates were placed one after the another along the butt line, just along the butt line the metal there, as if has got as if it has got fused and formed the weld nugget, right? So, that portion you have a typical micro structural, I mean, the micro structure is somewhat different than the rest of the metal, and surrounding that we have a zone which is refer to as TMAZ; that is Thermo Mechanically Affected Zone, TMAZ - Thermo Mechanically Affected Zone; surrounding that, you have heat affected zone. That means, here, what you see? In case of fusion welding, if we go back to welding once again, just for the sake of analogy, what we see? Once the welding is done, the weld profile would look like this. This zone, this particular zone, is the fusion zone; fusion zone means, here, the entire material was in a molten state was in a molten state.

So, from the molten phase it has gone to the solid phase, so, it will develop certain kind of micro structural pattern, right? And, beyond that, a part of the material undergone a certain temperature cycle, a certain temperature cycle, that means, I am heat is being put in to the system and it will get conducted, right? Depending on this, they will be temperature raise; and, if we monitor the temperature and find out the line where it attend 1000 degree centigrade, that becomes the boundary of the zone where re-crystallization is absorbed, right? So, this zone is referred to as heat effective zone; all these we are talking about in case of fusion welding.

Why 1000 degree centigrade? Essentially, for steel re-crystallization to take place when it is subjected to a temperature greater than 723 degree centigrade, more than 723 degree, so, truly we should look in to the isotherm of 723. But, in any case, just for the sake of, I mean, simplifying the thing, it is said that the zone between 1500 degree centigrade and 1000 degree centigrade; what is this? That means, this part of this, this part of the plate was subjected to a temperature level in between that zone, 1500 to 1000, why? 1500, that is the melting temperature.

Right, so, that is how we see, that in case of fusion welding, we have two distinct zones; one is that of heat affected zone, another is fusion zone. What happens in the heat affective zone? Essentially, we see that, depending on the cooling rate, the sizes, the grain size, either they become bigger or they become smaller, right? Grain sizes means, when we see under a powerful microscope, the steel, it it, it looks like some some of the crystals, they, are placed one after the another. The sizes of those crystals are referred to as grain sizes, right?

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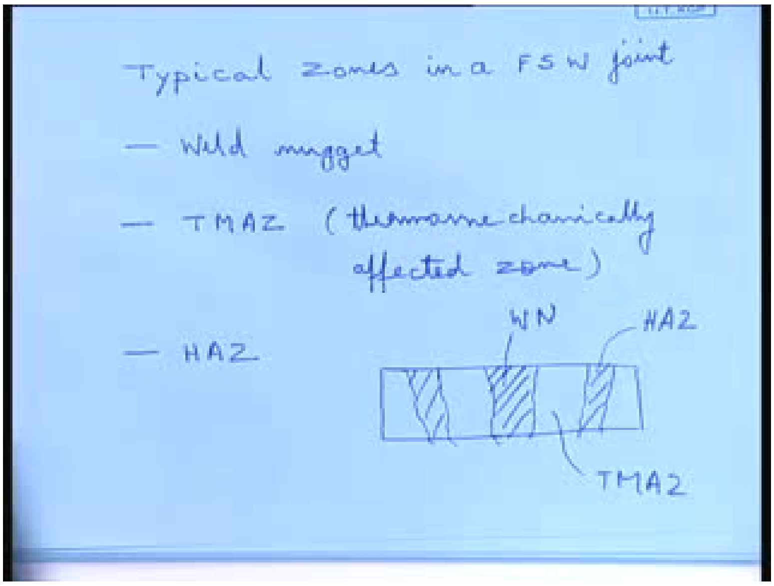

So, that is what is in the case of fusion welding. Whereas, in case of, in case of friction star welding, we have little different; little different means, here you will not have such a nice, this kind of fusion zone, right? Instead, you will you will have an area which will be the weld nugget; then, some zone which is the TMAZ, and then the fusion, so-called heat affected zone. These are not... Here, you have the heat affected zone; this is the

TMAZ, and this part is the so-called weld nugget. Now, not always this weld nugget and the TMAZ would be very clearly visible, very clearly visible.

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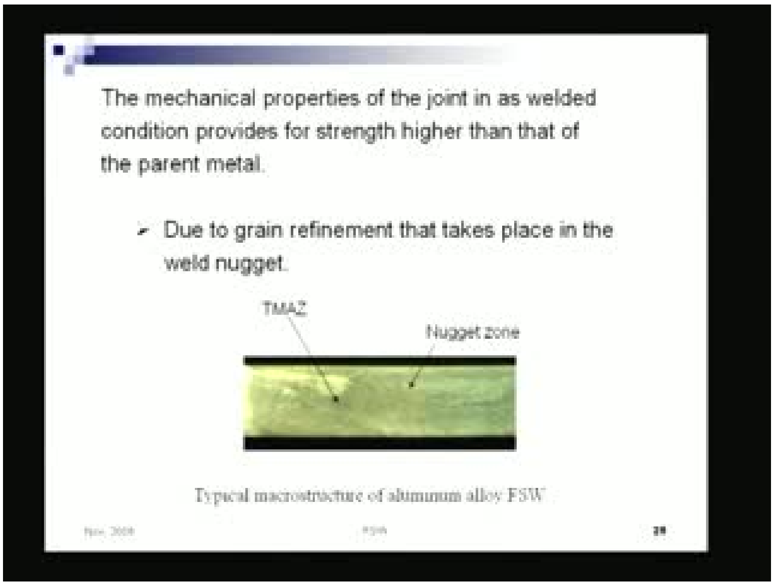

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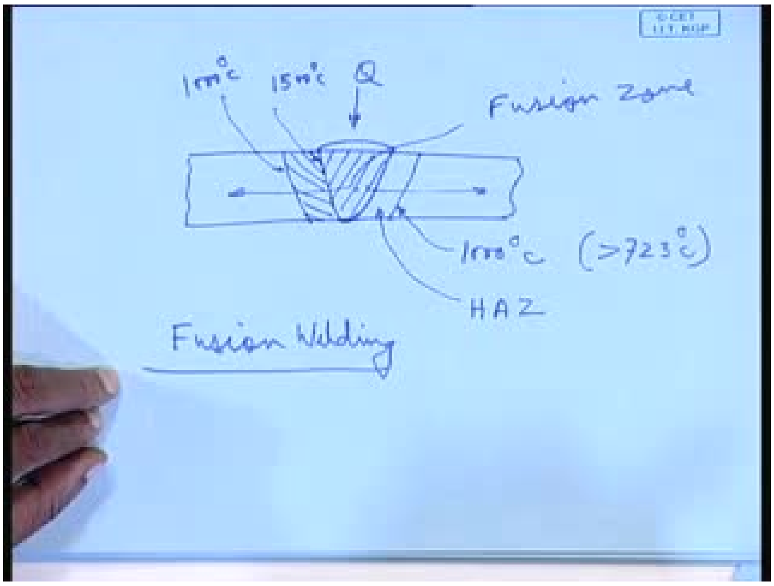

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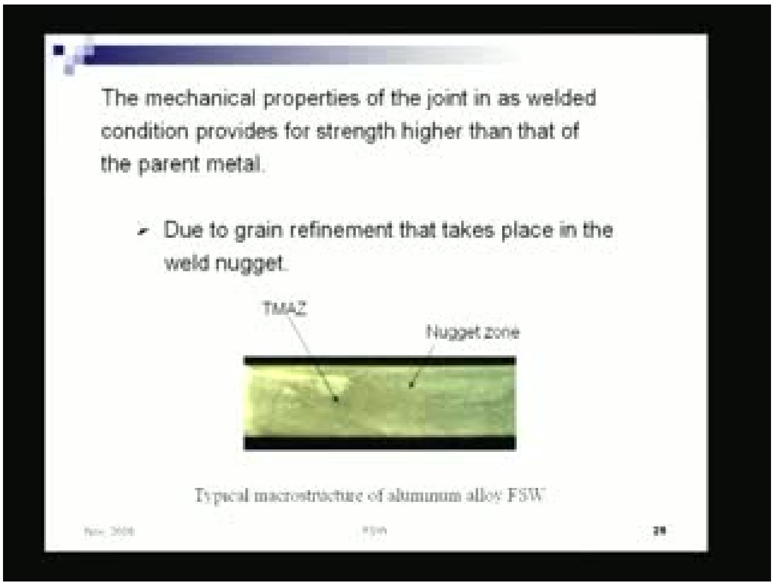

In fact, they are, I mean, in this section, it is not, not, very clearly visible as such. However, you can, anyway, this this picture is not that clear, so, that that also indicates, that, that also shows that in case of a fusion welding, if we take a section and do the proper etching, chemical etching and look in into the micro structure, I mean, the micro structures can be seen. And also, in the nugget eye, these distinct boundaries are very clearly visible, distinct boundaries are visible. Of course, this is a picture for a plate aluminum alloyed plate which has been friction stir welded.

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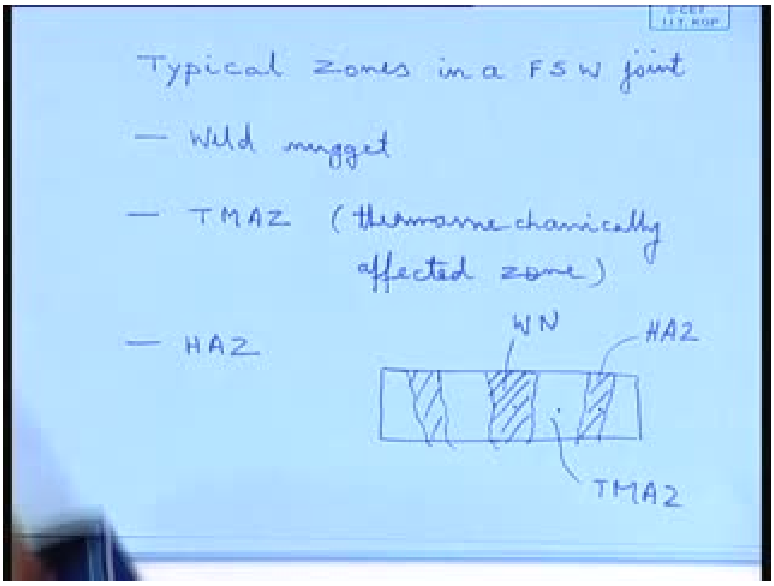

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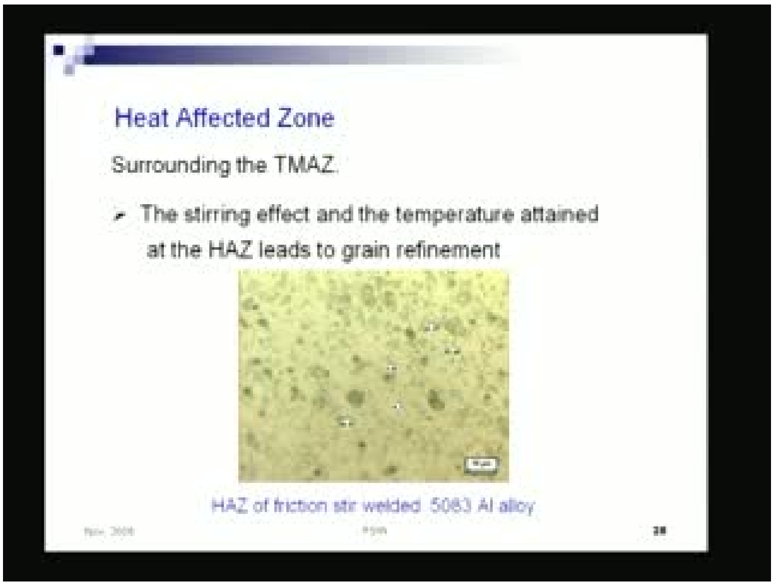

So, what happens, here, in the weld nugget, that there will be the grain structure, the variation in the grain structure of the weld nugget TMAZ and HAZ are observed; are not much absorbed in naked eyes, only when you go for under powerful optical microscope, only then one can see how the grain structure has formed. Like for example, this is a grain structure in case of a weld nugget, where in you can take rough measurement of these; these are the grains so, you can measure them; so, they are varying from 2.8 to roughly 3.4 micrometers, right, nugget. Similarly, if we look in to the grain structure in the heat affected zone, there we see the a grains sizes varied from 3.9 to 5.4 micron; that means, grain coarsening has taken place grain sizes are become bigger.

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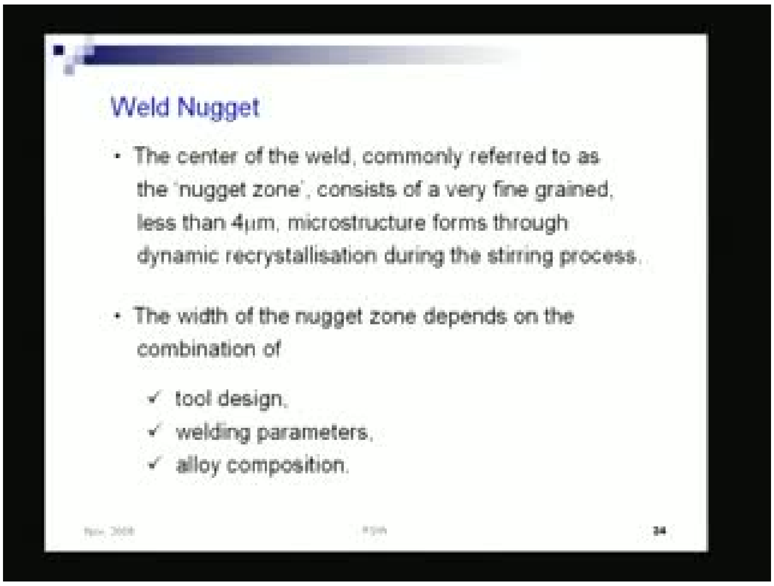

So, what we see? in in case of in in, in case of a friction stir welding, that the grain sizes, they increase, they increase from the weld nugget; as we move towards the heat affected zone in the weld nugget, the grain sizes are even smaller, finer, so, what we get from that? Once the grain sizes are finer, means, we get a superior mechanical property, we get a superior mechanical property. So anyway, that is what we see, that the weld nugget, this nugget is the center of the weld, center of the weld which is commonly refer to as weld nugget, and it consist of very fine grained structure less than 4 microns, right? Well nuggets consist of very fine grained structure, and that forms through dynamic re-crystallization during the stirring process.

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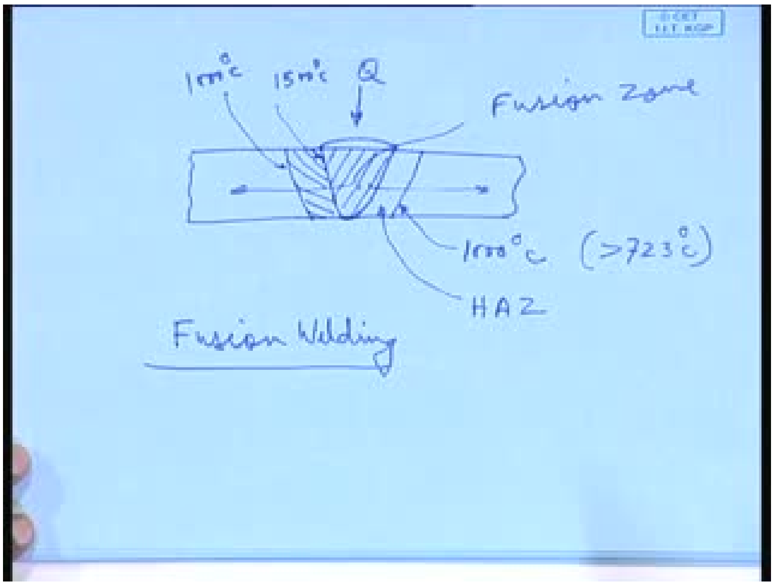

Because of the re-crystallization - that means, 4 microns, it is in fact, it is even less than the parent metal grain size in the...; that means, the original grain size, whatever was there, is even less than that; that happens because of the dynamic re-crystallization during the stirring process. Here, the changes in the grain is taking place; in case of fusion zone, whatever changes in grain size took place, whether it become finer or coarser or any other grain structure that got formed, that was because of the thermal cycle; because, the entire material here, underwent a certain thermal cycle.

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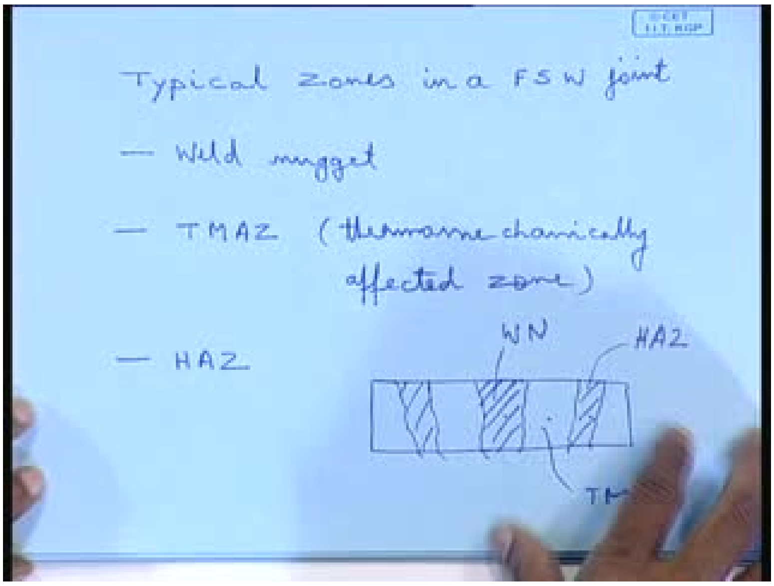

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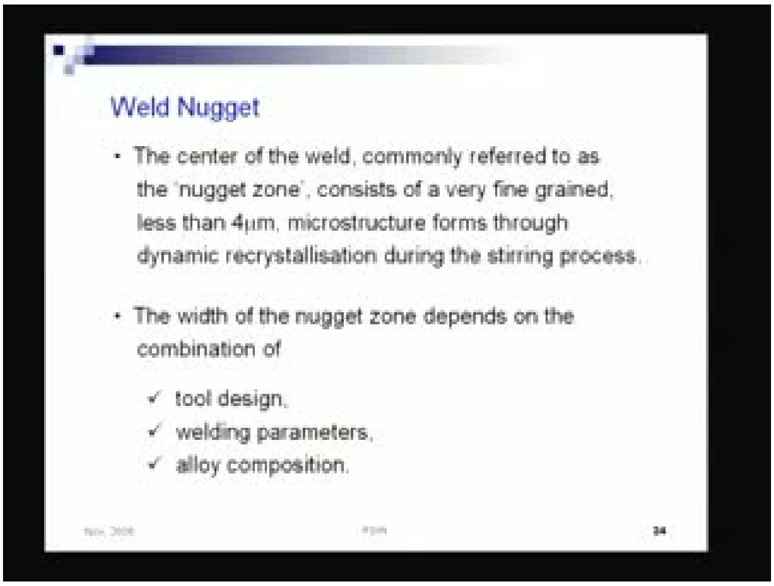

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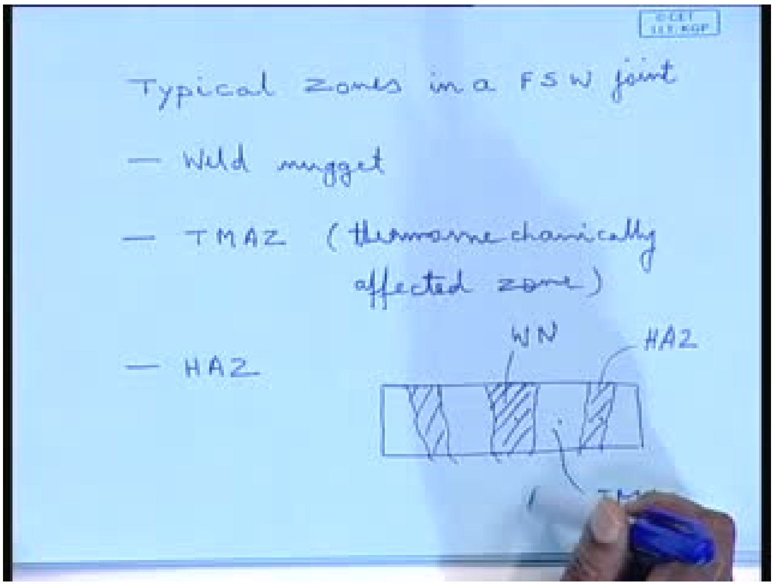

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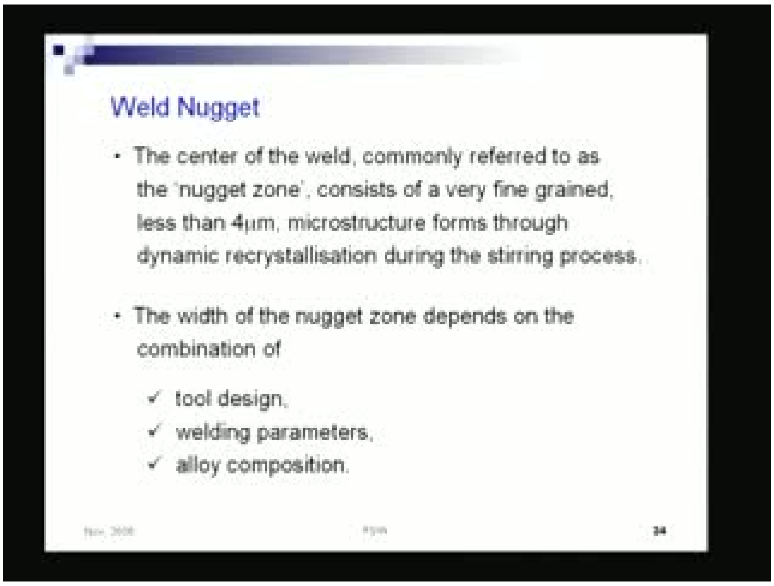

Whereas, in case of friction stir welding, it is not only thermal cycle, it is a thermo-mechanical cycle; that is why you have that thermo mechanically affected zone. Because, that extreme stirring effect what is taking place, that stirring effect is nothing but extreme mechanical deformation, right? Extreme mechanical deformation; like for example, you have a steel plate, if you cold roll, its grain structure changes, its property changes; like the steel, if you subject it to some tensile load and leave it, again if you taste it, you will find its strength as increased, which is known as strain hardening, right? Strain hardening or work hardening, what happens actually? The micro structure changes because of that mechanical work, because of that plastic work, because of that work which has been put in to beyond elastic limit. Same thing is happening here; here also it is extreme plastic deformation takes place in case of friction stir welding, the entire metal is being stirred. So, that is why it says that the, and, effect is the grain refinement takes place, because of that dynamic re-crystallization during the stirring process, right?

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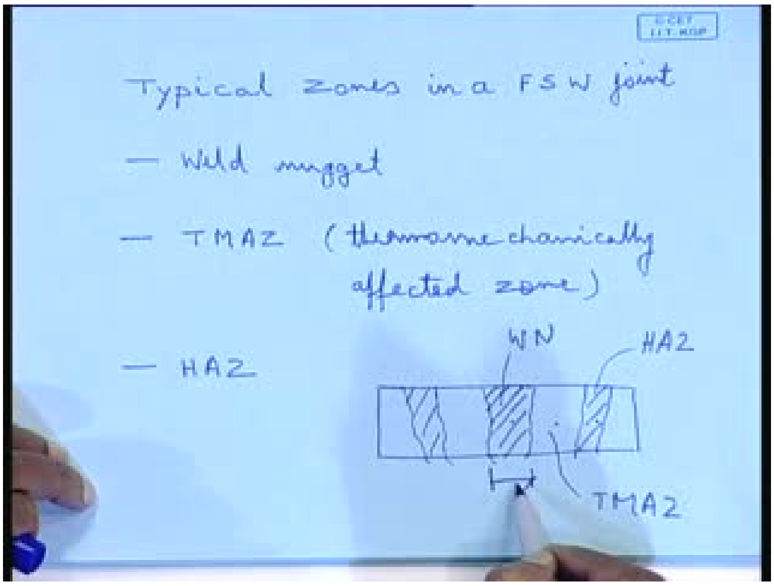

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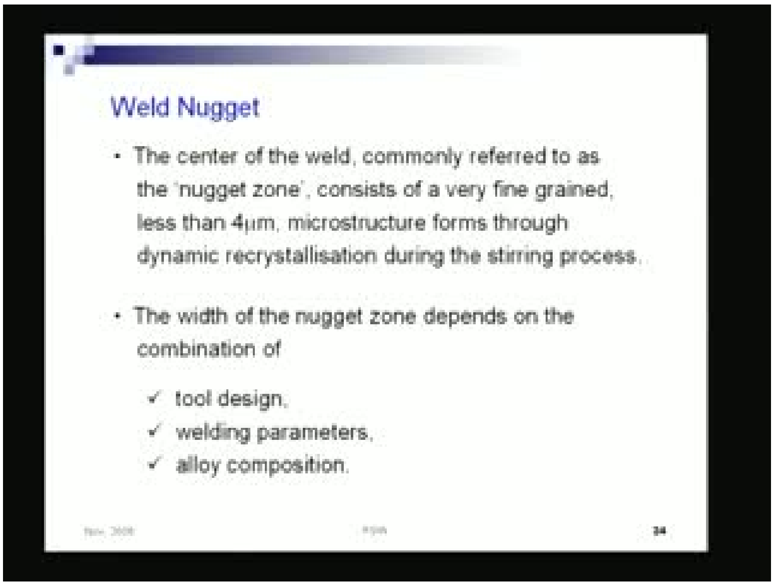

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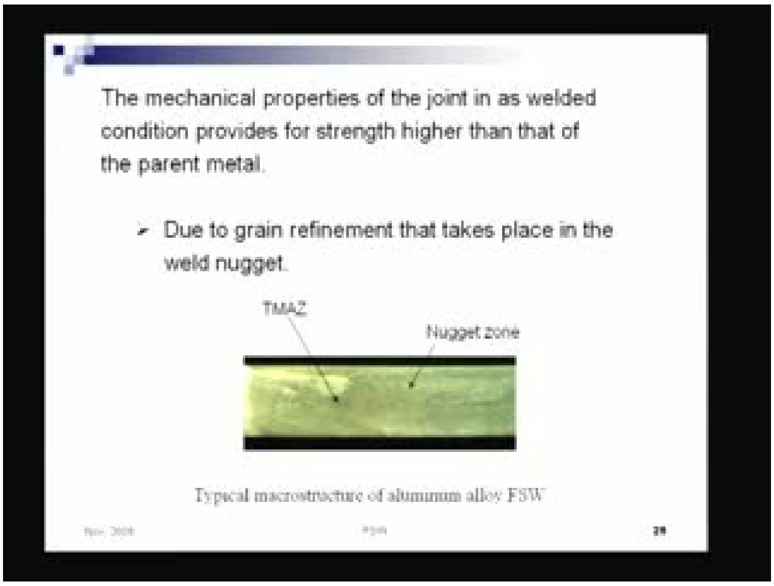

Now, how much would be the width, this width of the weld nugget? How much would be the width of this weld nugget? That will depend on depend on the tool design, depend on the welding parameters, depend on the average compositions, right? On these various aspects, it will depend. What is the width of the nugget, weld nugget? The mechanical properties of the joint in as welded condition provides for strength higher than that of parent metal; this is this is important and quite interesting, why? Because, when welding has been done, one may think that the welded joint is the weaker point; it is not so. In fact, along the welded joint, it shows, it exhibits a higher strength a strength higher than the parent metal, right? Higher than the parent metal.

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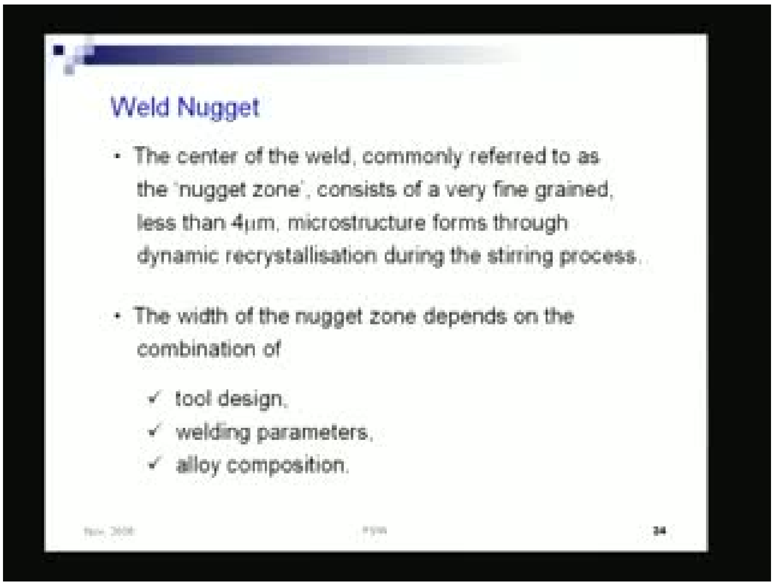

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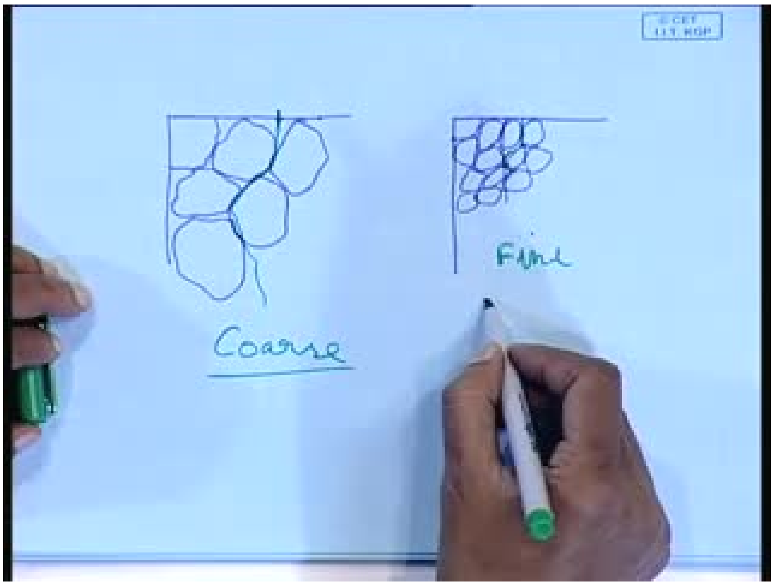

Why that is happening? Because of your grain refinement; I mean, without going much detail into the metallurgical aspects, certain simple simple rules are like this. That means, if the grain is refined means, the grain size becomes smaller, you have higher strength; if the grain sizes are bigger, you have lesser strength, right? Little bit if you see, suppose these are two samples, now say, these are my grains as we can see in the in a powerful optical microscope.

Right, in another sample, that grains we are seeing are, say, something like this; so, this is what a fine grain structure, a core grain structure, right? So, what happens is, when it becomes a fine grain structure, it exhibits higher strength; higher strength against what? Against, say, tensile failure; what is a tensile failure? It is nothing but a rapture proceeding through the grains. A tensile failure means what? That means, the, say a piece of bar, if you subjected to tensile load, say it breaks after some time; breaking means what? That means, it is getting, some crack is developing and it is progressing along the along the width or whatever, right?

Now, what happens, when you have bigger grains, then grain boundaries also want bigger, right? So, generally a dislocation, I mean, where the failure will get initiated, where it is the weakest point, right? From the weakest point, the failure will get initiated. Now, from the weakest some, say this is my weakest point, is the plate, so here, the failure gets initiated, and then how it will get propagate? It will propagate through places of list resistance; what are the places of list list resistance? Well, one is the boundary, grain boundary; it is easier to break through the grain boundaries, right? And here, you have bigger grains; so, I have wider grain boundary, right? So, it becomes easier to break through the bigger grain boundaries than a smaller grain boundary.

Because, in smaller grain boundary, what will happen? It will progress, then it will heat the grain, it will have to take a detour as if, again heat a grain, so, it will have a much more, a longer path as if; this is a simplest explanation, why? A fine grains structure gives you higher strength than a coarse grain structure, right? A fine grain structure has exhibits a higher strength; so, or in other words, any process which leads to a fine grain structure is good for the material, why? Because, that will, that same material with same chemical composition will give you additional strength.

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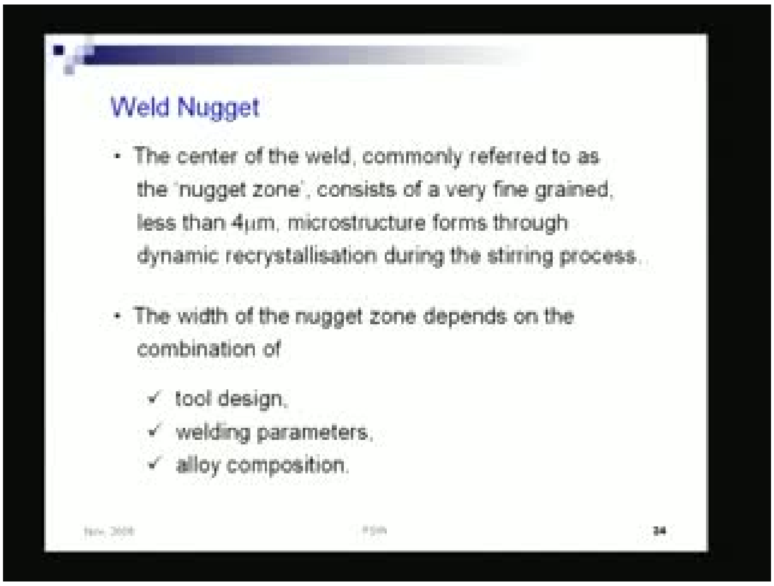

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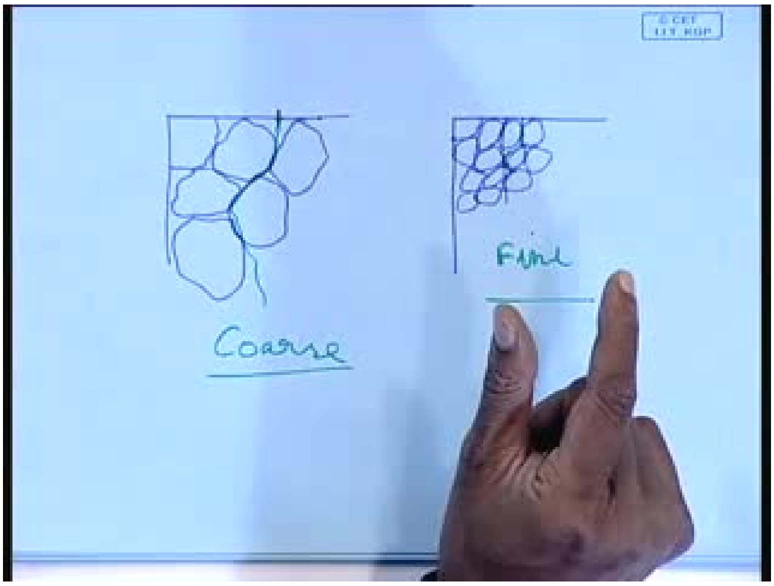

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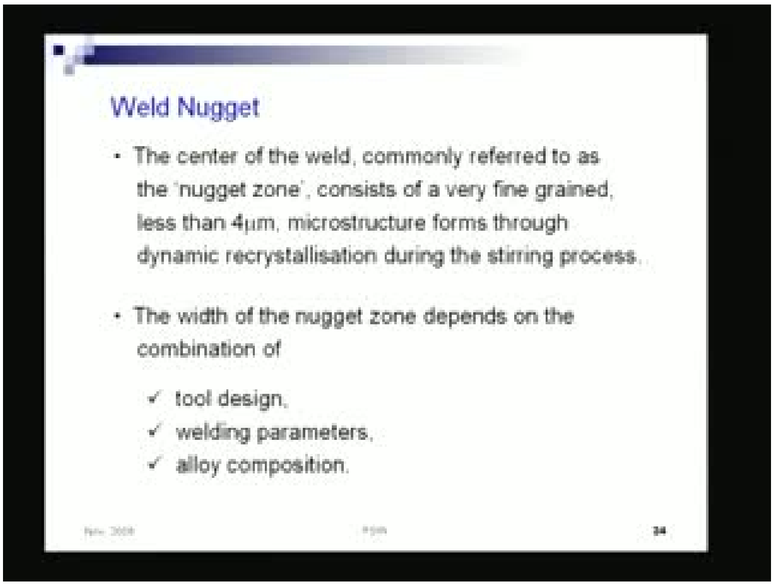

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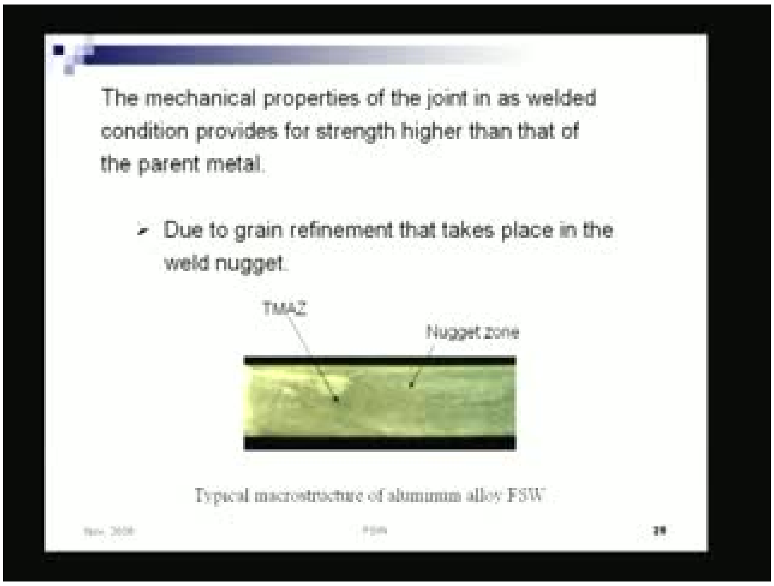

Same thing is happening here. As we can see, because of the re-crystallization taking place; that means, originally the crystal were bigger; because of the friction star welding it, has become even finer, how? Re-crystallization as taken place, the crystals got re-crystallized because of this mechanical action, primarily mechanical action; because the heat involve was not much, right? So, thereby, we see the mechanical properties of the joint provides for strength higher than that of the parent metal; so, that shows that if friction stir welding is done, then it will satisfy your all strength requirement. Obviously, this, this, this will hold good, that means, the joint will provide for strength higher than parent metal, provided there are no flow in it, no defect in it.

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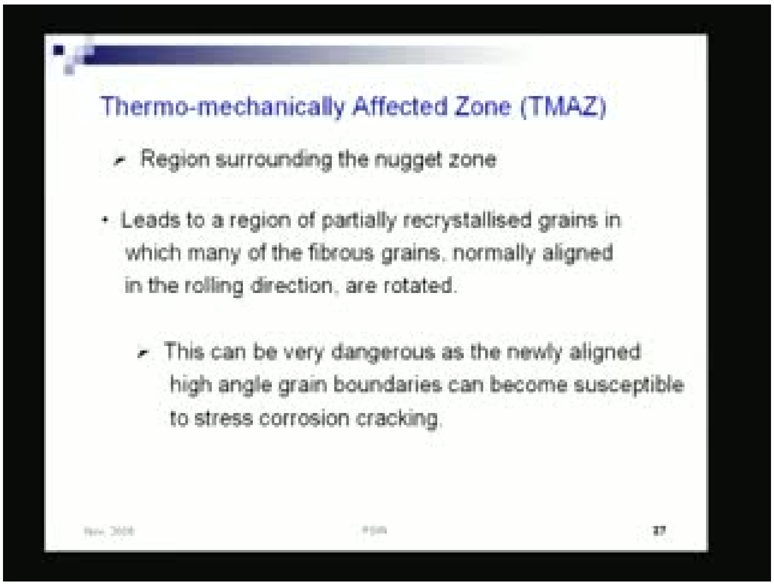

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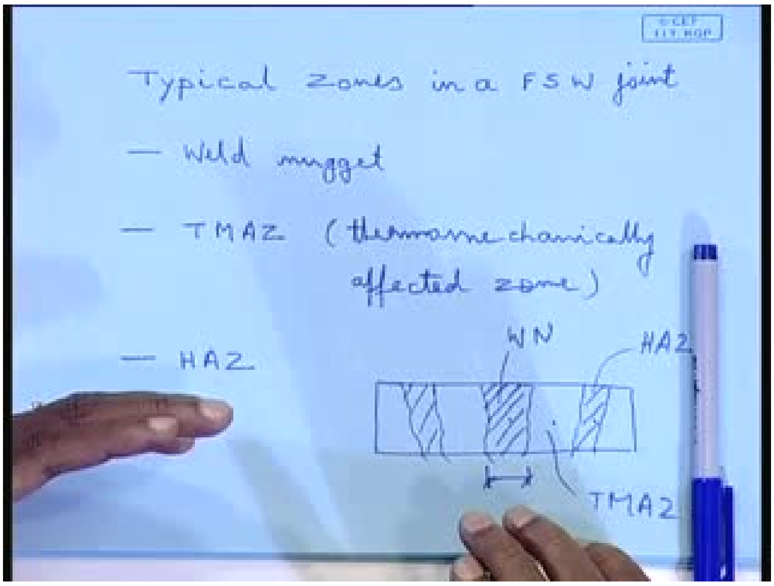

So, due to grain refinement that takes place in the weld nugget we get the strength higher than the parent metal. So, this is here of course, this aluminum it is not very clearly visible; anyway, so, here we see the fine grain micro structure of the weld nugget, it has gone as below as low as 2.5 microns. Then, the thermo mechanical is just adjacent to your weld nugget; you have the thermo mechanical affected zone. Why thermo mechanical effected is being termed as? Because, it is subjected to a certain temperature rise; because of the friction, some heat was generated; over this, you had that, what do you call, the shoulder; the shoulder was rubbing against the plate, so, in the periphery of the shoulder because of friction additional heat was generated.

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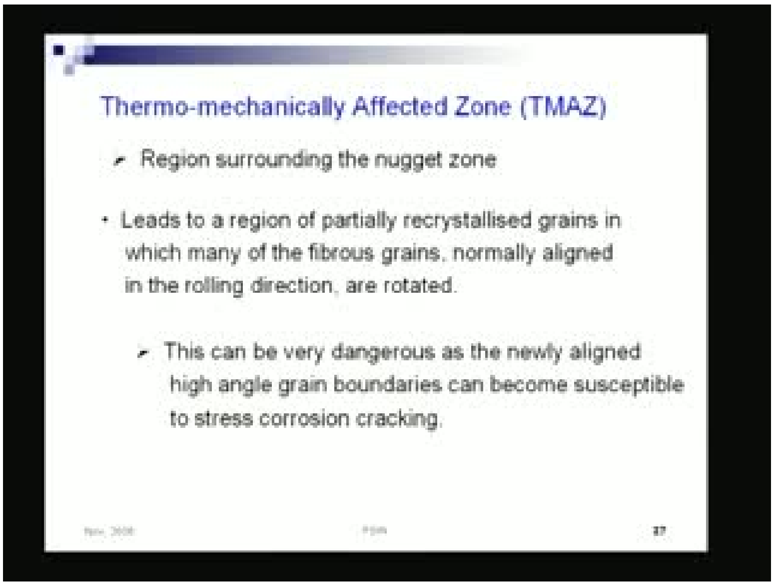

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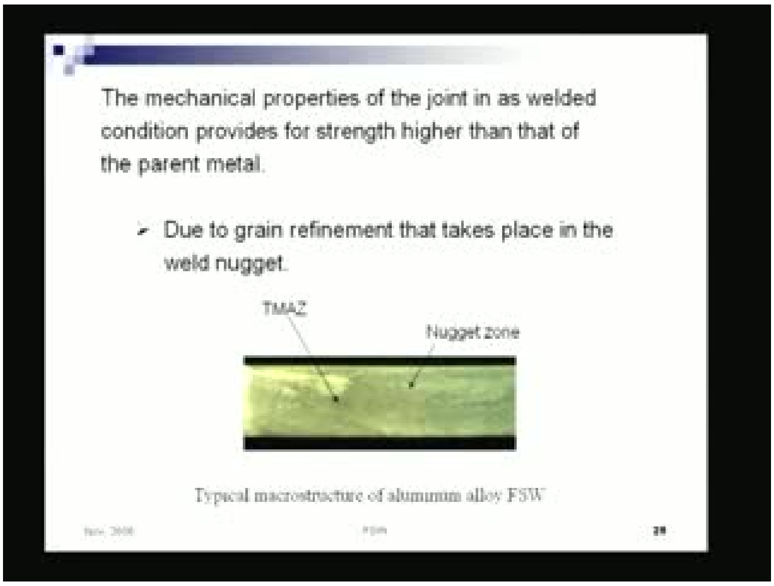

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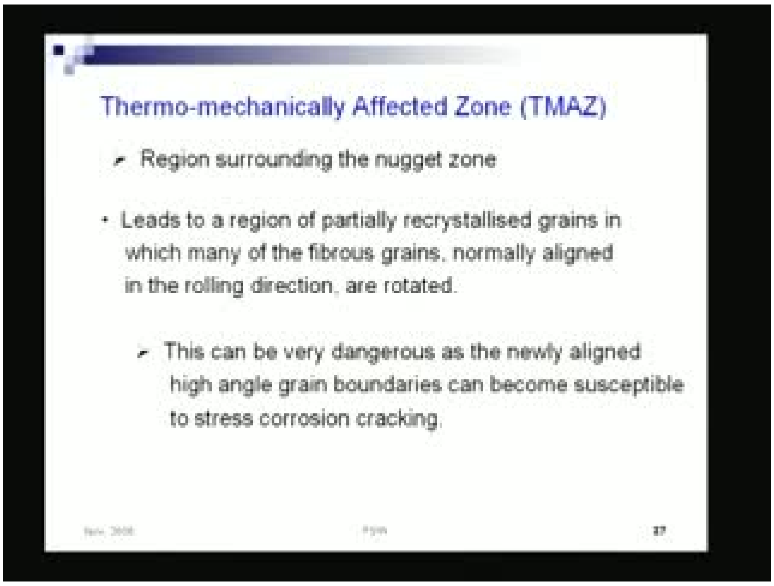

So, this plate around the weld nugget, the nugget is forming below the probe, below the nib of the tool friction stir tool, right? There, the weld nugget found, and around that you have the thermo mechanically affected zone; that was some temperature rise was there, as well, as it got mechanical deformations, mechanical deformations because of the stunning action which is taken place in the weld nugget; so, this is the region surrounded surrounding the nugget zone. It leads to a region region of partially re-crystallized grains; here, the re-crystallization is partial, which many of the partial re-crystalized grains, in which many of the fibrous grains normally aligned in the rolling direction are rotated; that means, you will see it is not very clearly visible here; here, one can see that, I mean, that the grains have got, as if twisted, the grains have got twisted; the metal have got twisted; that becomes somewhat visible in in in a better micrograph.

So, here, because of this, this can be because of this fibrous grains which gets aligned in that rolling direction which are getting rotated; this can be dangerous as the newly aligned high angle grain; boundaries can become susceptible to stress, corrosion, cracking; it is some other aspect is coming in to the picture. Because, as you know, here we are primarily talking about aluminum alloy; all these metallurgical aspect, whatever talk about are that of aluminum alloy, high magnesium aluminum alloy; they are the marine grade alloy, right?

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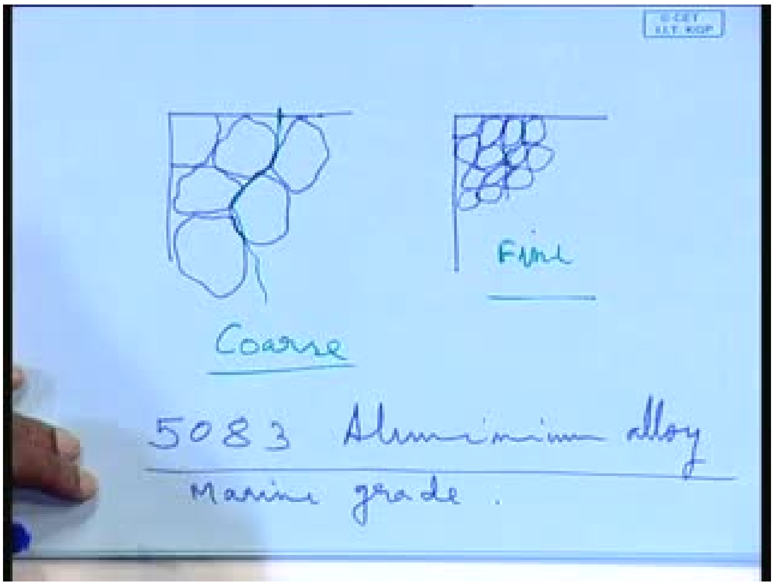

That is, it is referred to as 5083 Aluminum alloy, this is a this is of marine grade. By marine grade, you mean, they are used in marine environment, right? This 5000 series alloy, they are they have a high magnesium percentage, high magnesium content of the order of 4 and a half percent magnesium which provides for the corrosion resistance in marine environment, this particular aluminum alloy.

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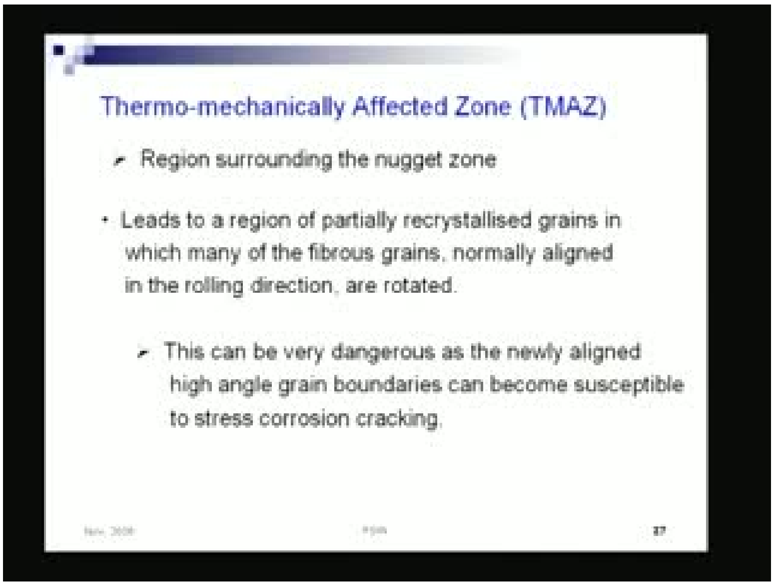

So, because of this, the partial re-crystallization of the grains, and that to they are getting mechanical deformed, that leads to a situation that leads to a situation wherein, which may cause may make the material susceptible to stress, corrosion, cracking; stress, corrosion, cracking means, it will make the material susceptible to corrosion, and under stress, the cracks will form, right?

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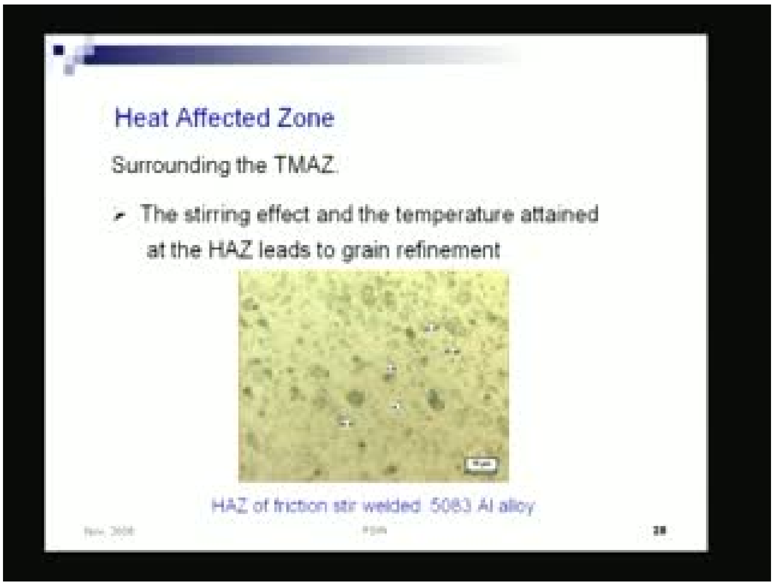

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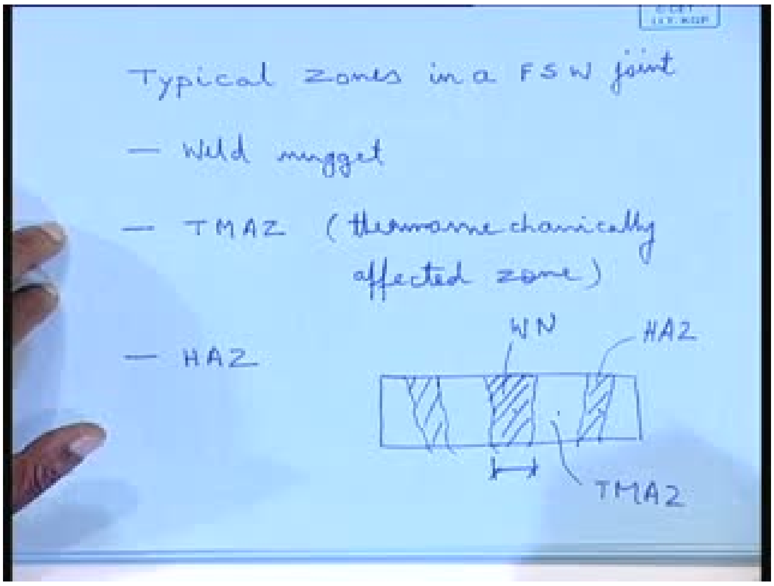

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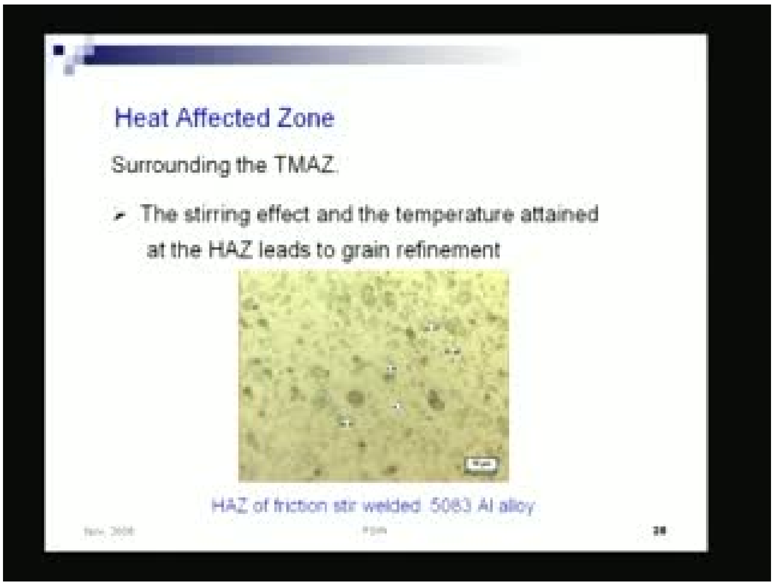

So, that is how we can see that there are thermo mechanical effected zone or the TMAZ zone becomes the weaker zone. Like in fusion welding, the heat affected zone is the weaker zone, because, there you have the grain coarsening taking place. The grain sizes increase in case of fusion welding in the heat affected zone; in case of, well here, and then we have the heat affected zone. This is again surrounding the TMAZ as schematically, we have shown here the surrounding the TMAZ. This zone is the heat affected zone; that is somewhat similar to that of, as we saw, in case of fusion welding, here the stirring effect and temperature attend at the heat effected zone, leads to again grain refinement; here, it leads to grain refinement means, grain refinement from that of the parent metal.

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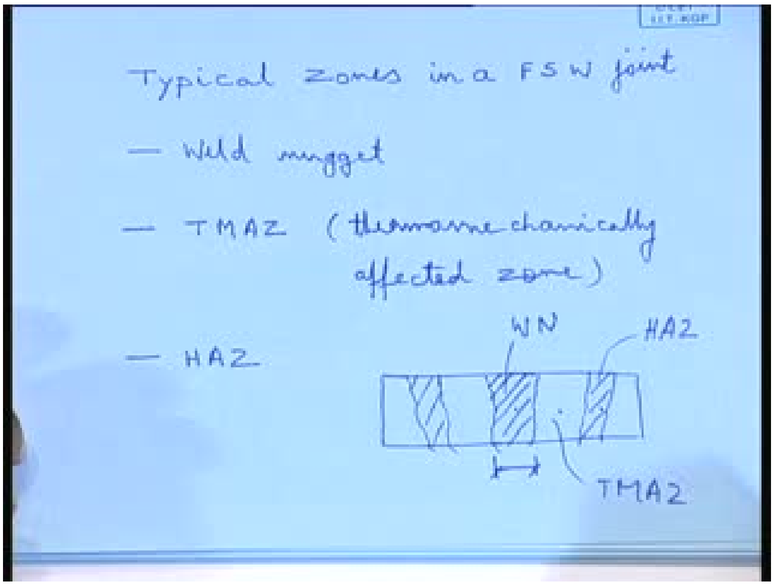

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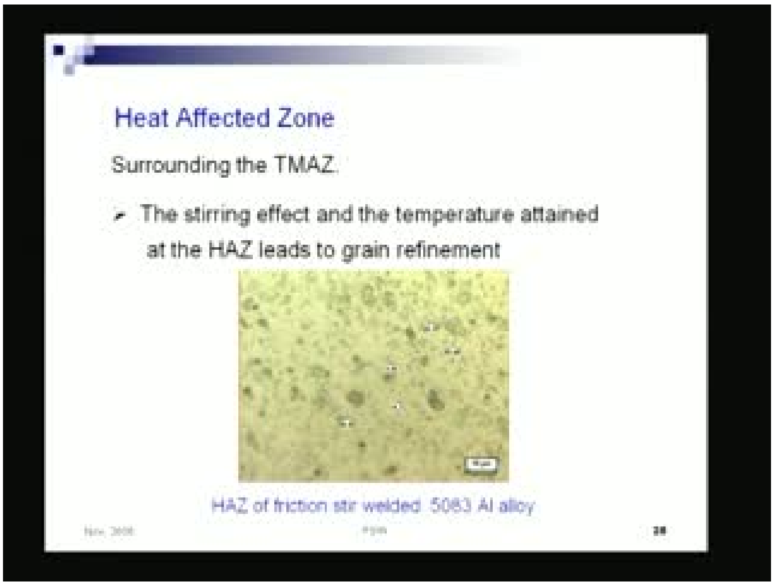

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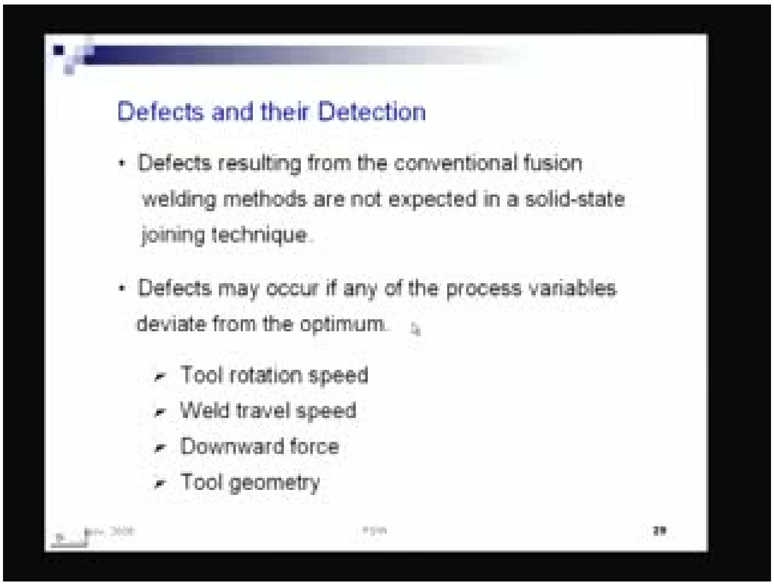

Though we see here, a particular given case, wherein, we see that the grain sizes are varying from 3.9 to 5.4 microns, right? Whereas, in weld nugget, it was even smaller, much smaller than this; so, what do you see? That the grain sizes become smaller, I mean, grain sizes becomes smallest in the weld nugget and then they gradually increase as you go to our heat affected zone. But still, within the heat affected zone also, it remains in a refined condition; refined condition means, lesser than that of the parent metal there. By overall aspect is that, you you have a, I mean, by doing friction stir welding in aluminum alloy, one can expect, have a superior joint; that means, joint without any flow, welding flow, as well as superior mechanical property; because of the; because of the thermo mechanical action which is the material, is being subjected to the grain structure, is forming the micro structure, is forming such that which which is leading to a superior mechanical property, right?

Whereas, in case of fusion welding of aluminum alloy, one of the primary problem is a primary, primary so-called difficulty is that, formation of various welding defects, formation of various welding defects because of fusion. Since fusion is taking place, that chances of porosity, they increase very much. In case of aluminum welding, that happens more because of the aluminum layer present over it, right?

Whereas, in friction stir welding, since there is no melting taking place, so, all those difficulties due to fusion are not there at all, right? And, at the same time, for one also, there is no problem of deformations, thermal deformations, which which is which is a severe; one can say difficulty in case of fusion welding, because of the high rate of heat input. Well, now we will look in to the defects and the detection; because, it being a different kind of welding method, we will look in to its defects and detection separately. So, defects what we have seen, that generally the level of defects are less in case of friction stir welding in compression to fusion welding process. Here, the defects resulting from the conventional fusion welding methods are not expected; there is a first thing in a solid state joining technique.

As we are saying, the first and foremost conventional defects which we refer to as welding defects are not there; however, some defects may occur if any of the process variables deviate from optimum, right? So, what are the process variables? There, the two rotation speed weld, travel speed, downward force and tool geometry. These are the basic four process variables; of course, these are the fundamental three process available for a given tool geometry, right? Because, tool geometry is not a not a not a kind of dependent variable; for a given tool geometry, these are the three basic process variables, right? So, if any one of them goes wrong, then some kind of defects may arise. Essentially, the defect what arises is, that is that is what is called, I mean, will see some of the defects; prime one of the primary defect is that. A kind of a continuous discontinuity may form within the welded joint; continuous discontinuity, that means, the metal stirrings assume a situation. The metal stirring is not taking place uniformly, so, there is a place; a void is remaining all through, right?

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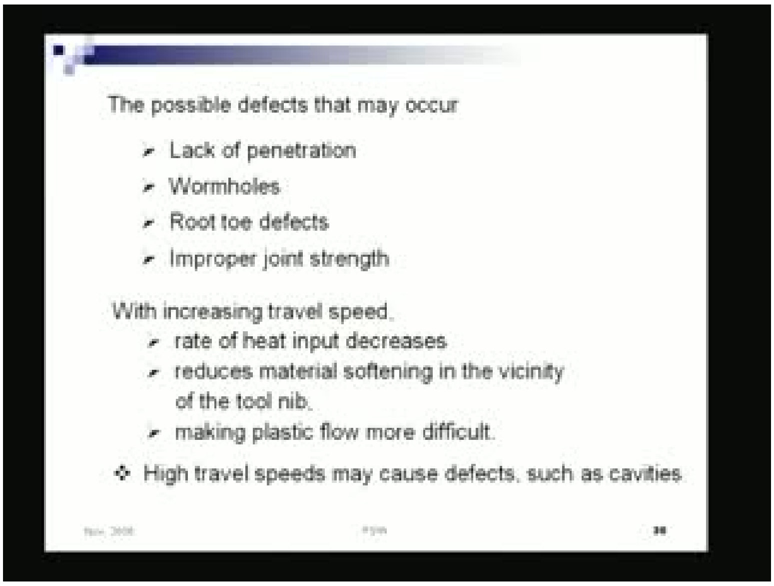

That is the one of the severe defects; but of course, that that will happen only the reason is simple. If any one of them is not is is not near the optimum, then such kind of defect may happen. Well, otherwise, the possible defects that may occur are the lack of penetration; that lack of penetration, that lack of penetration what I was saying. Then, the wormholes root two defects improper joint strength; improper joint strength means, the proper mixing, proper stirring; and proper mixing of the material has not taken place; so, what we see is that, with increasing travels speed, the rate of heat input decreases, right? So, these are the type of defects one can one can expect or one one may observe in a faulty welding, right? One one of these defects may be observed in a faulty welding.

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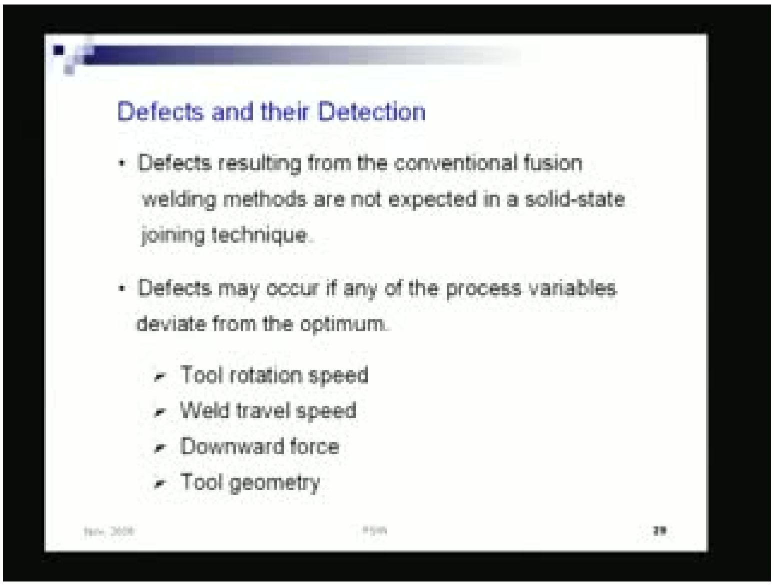

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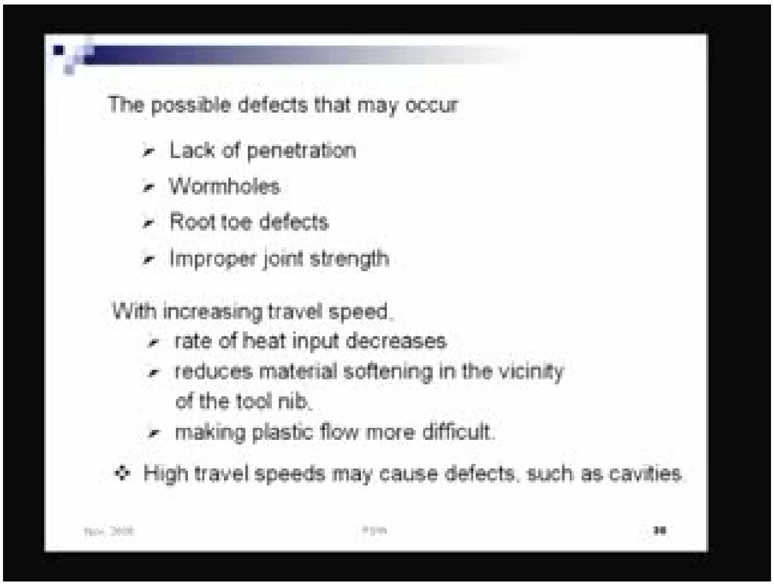

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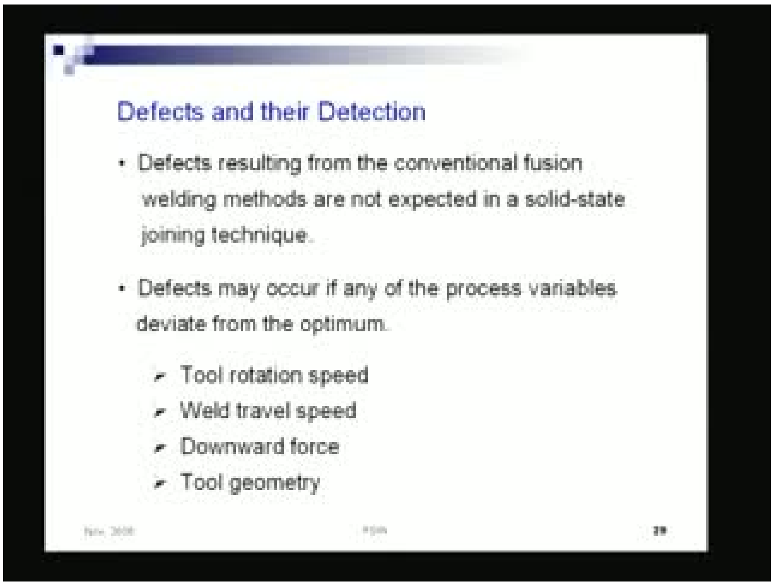

So, as we said that this, whether defect will occur or not or what type of defect will take place will depend on depend on on these process variables, deviation from this process variables, right? So, we see what are the what happens when travel speed is increased. Travel speed means, essentially, traveling speed of the tool, or in other words, welding speed, the rate of obviously, if that happens, the rate of heat input will decrease; if travel speed increases, rate of heat input decreases; if rate of heat input decreases, what will lead to reduces material softening in the vicinity of tool nib.

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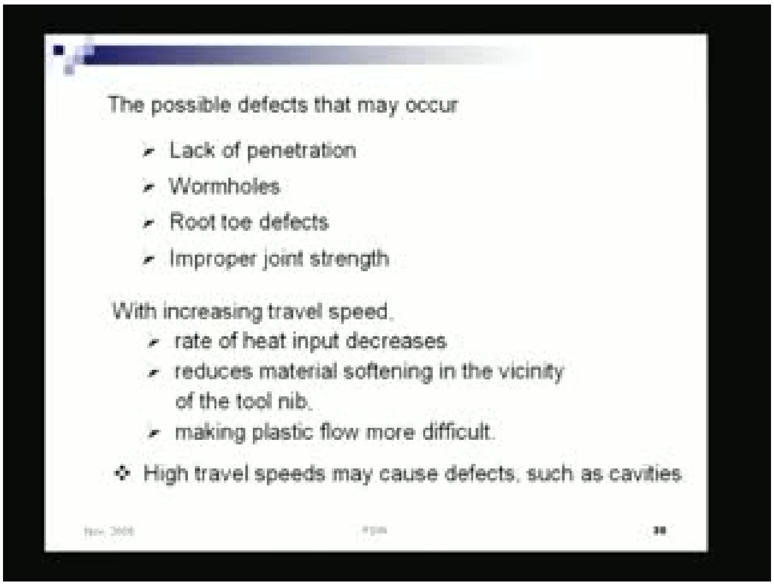

Sufficient heat is not there, it is something analogous to fusion welding; that means, where, if I move the torch very fast, so, what has happening? Metal was getting solidified very fast, right? And that lead to different defects there; and here, what will happen? The material softening will not take place; because here, the material should attend a soft stage; it should become soft enough, such that, it can be mixed properly, because the material is being stirred. So, that will not happen if the travel speed is more; so, making plastic flow more difficult, so, material flow will become difficult, and that may cause a defect such as cavities, right? Such as cavities, even lack of penetration, right?

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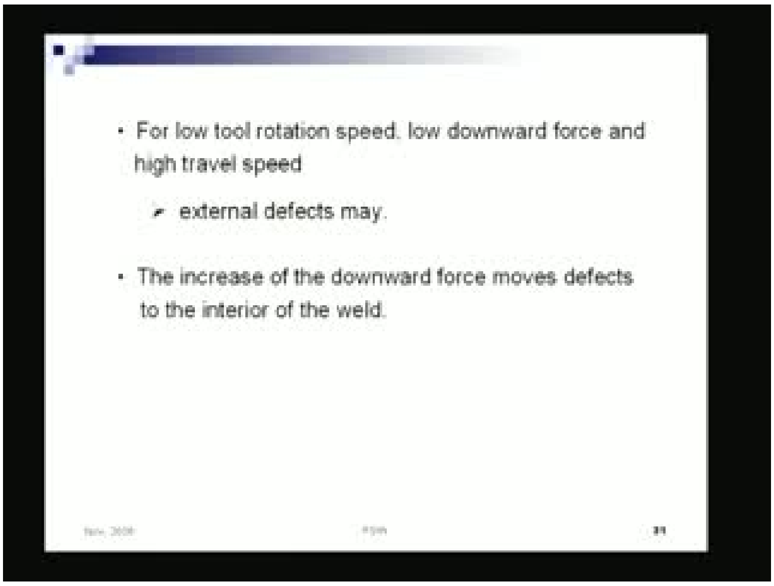

And obviously, improper joint strength, all these will happen if we have too high a traveling speed; and for low tool tool rotation speed, there we are talking about the travel speed, is the tool rotation speed for low tool rotation speed and low downward force, right? And high travel speed, what will happen? It will give rise to all kinds of external defects; low tool rotation speed means what? Heat generation will be less; because, heat generation, as we have seen, is directly proportional to the RPM; if RPM is less, heat generation will be less, less down ward force; less down ward force means, it may not fully penetrate, right? As well as, I mean, even if it fully penetrates less downward force means, the frictional force along the shoulder will be less, right? So, the additional heat which it was supplementing from the shoulder, that will not take place, that will not be available. So, there will be both; this low rotation speed and low downward force, will give you less amount of heat, right?

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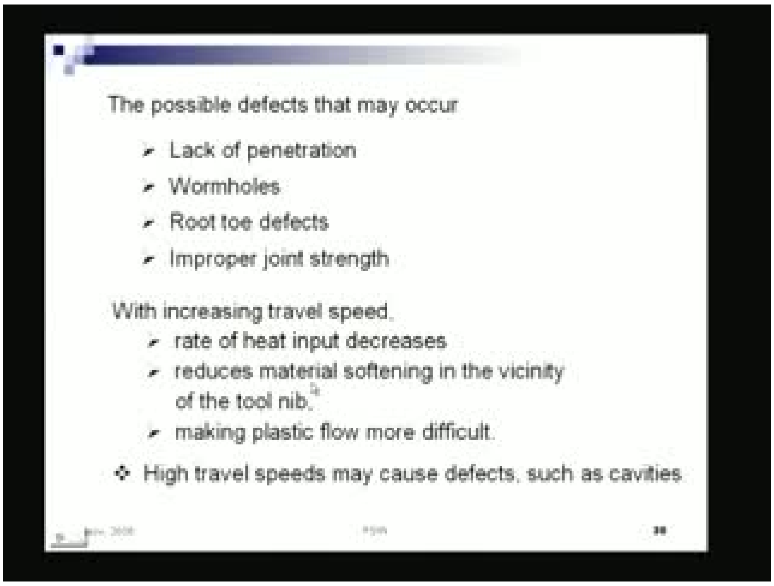

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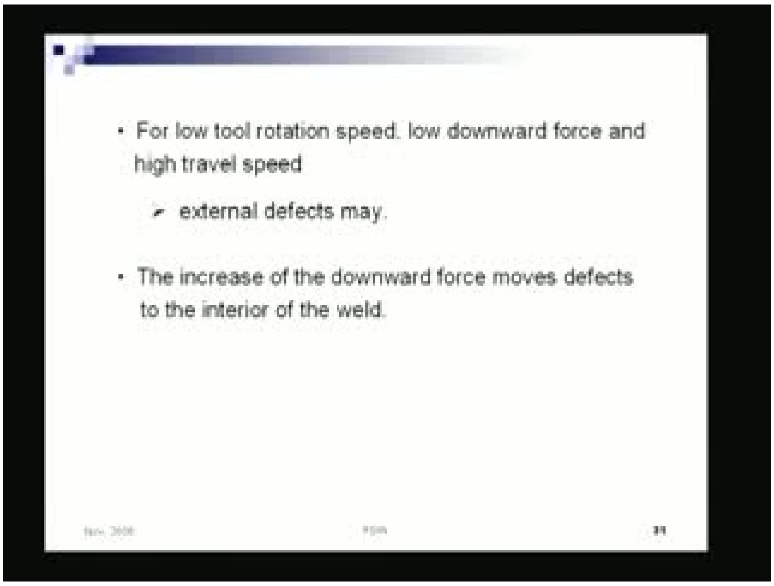

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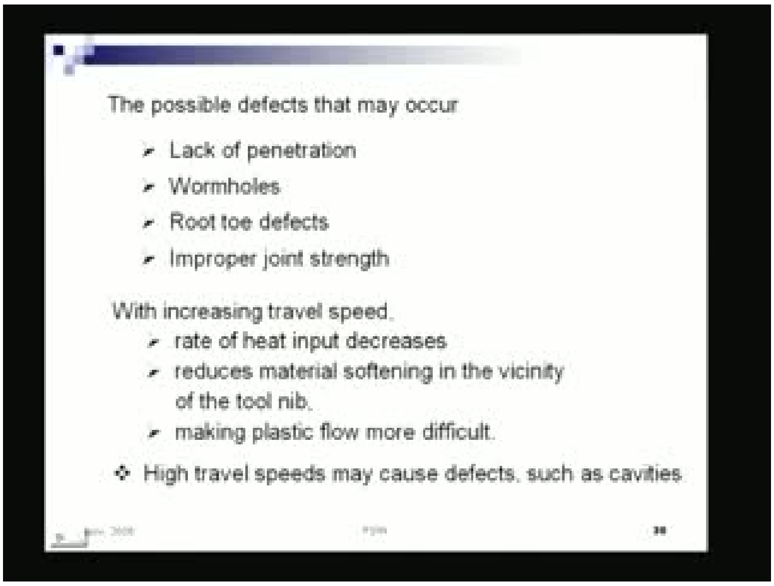

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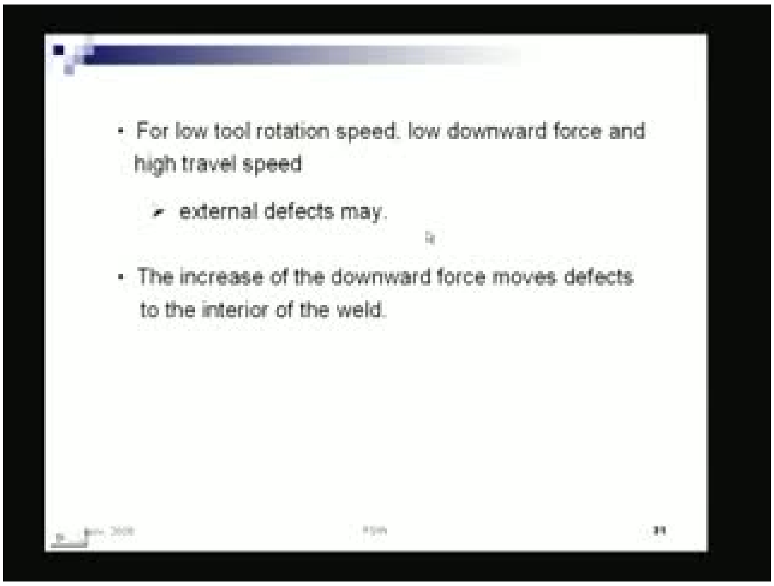

Along with that, you have high travel speed; so here, also your rate of heat input is decreasing. So, as it is less heat is being generated, and that too is being moved away very fast, so, it will lead to all kinds of these defects; and primary, the defects would be external; the increase of the downward force moves defects to the interior of the weld. Again, too much of downward force, if it is applied, then again it means, this those wormholes and improper joint strength and lack of fusion inside all those thing may happen with increasing downward force and as well as this. I have mentioned here, along with increase in downward force, there will be tendency of cutting of the plate from the surface; because, the shoulder will be rubbing too hard against the plate, so, it will try to cut through the plate; that means, on the edges, along the shoulder, the plate will get cut. So, that also will be kind of a defect; because, that will be a place for stress concentration, that will be a place for, if the structure is subjected to fatigue, is a place for stress concentration leading to crack initiation, right?

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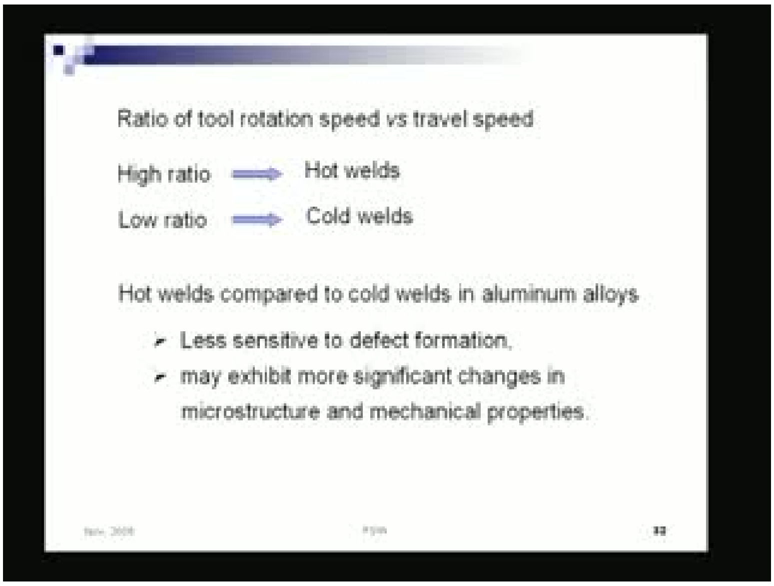

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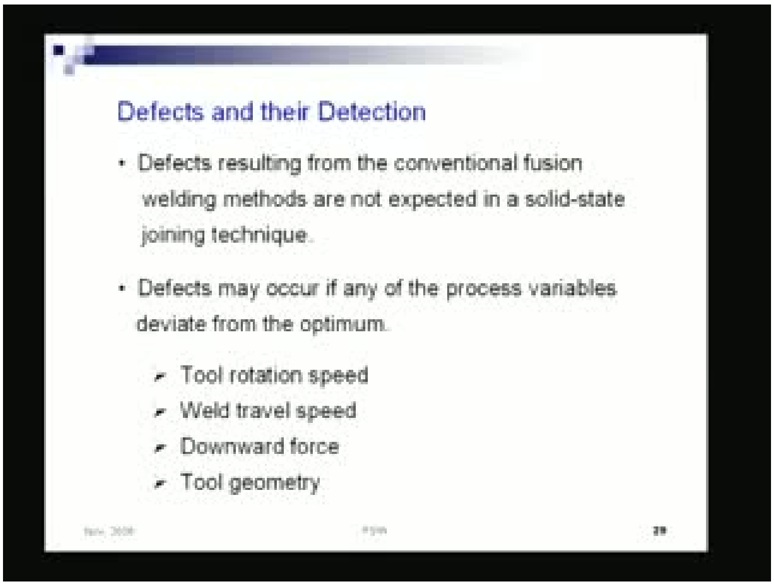

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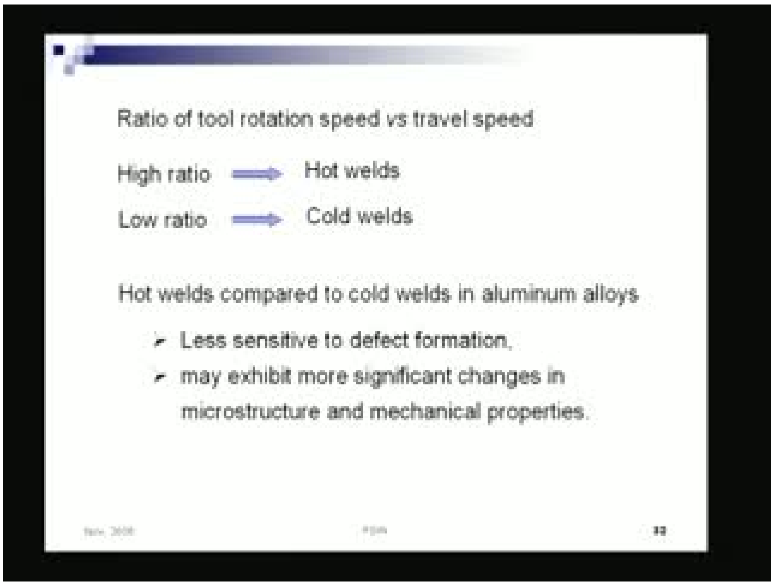

So, what we see is that, in this friction stir welding, this tool rotation speed and weld travel speed, there are the two aspects which are very important. Tool rotation speed and travel travel speed, so, there is a so-called this tool rotation speed verses travel speed. If the ratio is high, it is said that it leads to so-called hot welds. If the ratio is low, that leads to cold welds; ratio is high means high rotation speed; but low travel speed, high rotation speed with low travel speed means what? Too much of heat input, both are giving with higher rotation, more amount of heat is generated with slower travel speed, more is the rate of heat input; that means, at a given instant, more heat is going in to the plate, so, that is referred to as, will give rise to so-called hot welds; the reverse of that would be cold welds. So, hot welds and cold welds, what are they? Hot welds compare to cold weld in aluminum alloys: less sensitive to defect formations; that hot welds are less sensitive to defect formation, right? May exhibit more significant changes in micro structure mechanical properties; obviously, when it is a hot weld, means what? Essentially, more heat is going in to the system; if more heat goes in to the system, straight away, what do we get? The benefit is, that metal become much softer; because, if more heat is there, material becomes much softer; and here, we have a lower travel speed, so for a longer time, it remains softer. So, in that case, it is expected that the defect formation will be less. Once the metal is, the whole process of welding is based on the fact that metal is soft and I am stirring the metal.

So, once the metal is softer, then I can stir it better; so, the chances of defect formation will be less, so, a hot weld condition is rather preferable; a hot weld condition, that means, the ratio of two rotation speed to the travel speed expected to be higher, right? That is the advantageous part of it, and other is it may exhibit more significant changes in micro structure and mechanical properties, obviously; because, the heat treatment it is undergoing will be different; the annealing effect will be more, because, for a longer time the heat is being retained; the speed is slower, so, rate of heat input is more; so, resistance time of the heat is more, so, cooling rate will be less; so, there will be a significant change in the microstructure can be observe. And, once there is a change in micro structure and also the mechanical effect is also there, it is, better stirring is taking place. So, the micro structure will get affected more significantly; and if that happens, that will have an effect on mechanical properties as well.

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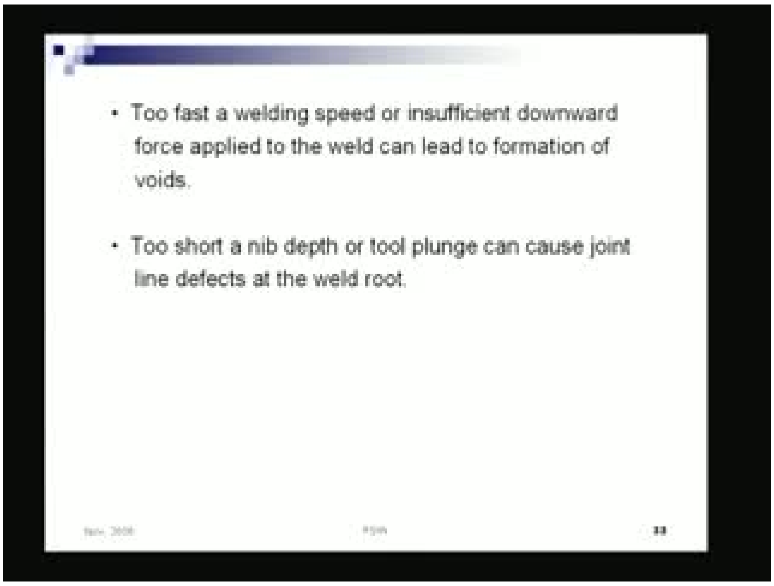

So, too fast a welding speed or insufficient downward force can lead to formation of voids. Here, we are seeing again, the effect of the downward force. If if the downward force is less and the speed of welding faster, then it can be to formation of voids; these are the voids that we are talking about, which may be an internal defect also; that means, from both the top and bottom, visually you will see it has been welded very nicely; but internally, there will be a continuous void remaining between in the joint.

Why that happens? Because of less downward force and faster speed; then, too short a nib depth or tool plunge can cause joint line defect at the weld root; that is also obvious. Because here, what what we see is that, as we said that the deep depth, the height of the nib or the height of the probe which plunges inside the metal for doing the welding should be near equal to the thickness of the metal being welded. So, if that height becomes less, that means, if I weld a plate whose thickness is more than the more than that of the probe height, the nib height of the FSW tool, then you will have a defect at the weld root. That means, there will be lack of fusion in the root, will take place, a lack of fusion will take place at the root.

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So, this is just a picture which shows an experimental setup of a friction stir welding process. This is how it looks like; the welding has been done here; here, you can see, that means, this particular width, what what is visible here, this is not the entire heat of the weld nugget. No. The weld nugget would be somewhere at the center only; this is the entire width of the shoulder diameter, basically. So, the TMAZ, the thermo mechanical affected zone is expected to be having this kind of width, because this much width has got directly affected by the pressure as well as the heat generated; beyond that, whatever heat got generated and the whatever the metal got effected will be because of the heat flow taking place from the heat which got generated in this region.

So, the heat affected zone will be beyond this boundary; it is expected heat effect zone will be beyond this boundary and that is only heat effected zone. But here, it will be thermo mechanical affected zone; because here, the mechanical pressure, downward force is also there as well as the frictional heat is also going in directly.

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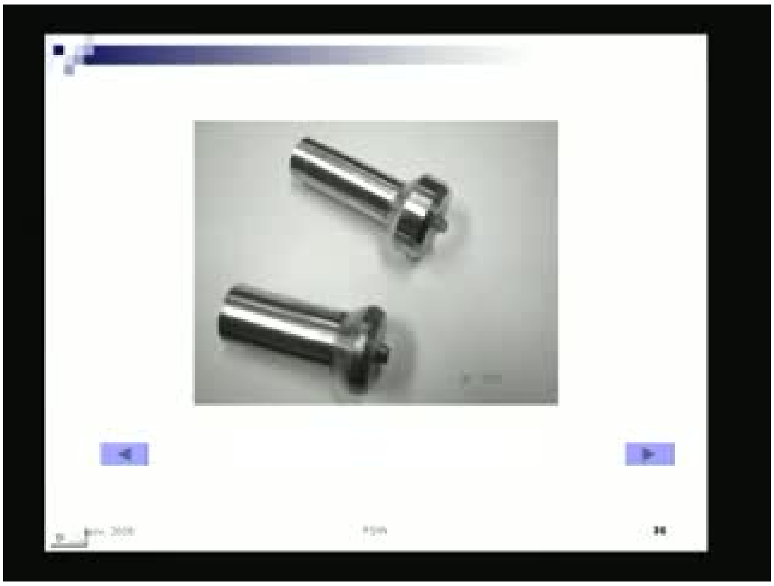

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So, this is this is what; so here, you can see, in the process what happens? You achieve a welded plate which is having one flat surface; there is no reinforcement bead or any such thing; one smooth flat surface is achieved in case of friction stir welding. So, these are tools; you can see, the this this is your shoulder, right? Shoulder diameter, and you have a small tool here, of course, a tool of trapezoid, I mean, not trapezoid, pyramid kind of pyramidal; a first term of a pyramid has been made the tool geometry which has been tested and this this this welding square done.

So, that is how we see that this friction stir welding, as you can see, is a process which is suitable for, primarily, to start with suitable for material which is which has a lesser melting point, which is softer, right? So, as far as structural material is concerned for, and that too with relevant to main structure, we have steel, aluminum, titanium composites, right? So, there this aluminum, it fixes in well for as far as friction stir welding is concerned, right? So, a friction star welding can be implemented, then you have the primary benefit, primary benefit of your... Because, when when you do fusion welding of aluminum, the defects leading to, primary defects of porosity, right? Porosity and crack formation, those defects can be all together avoided, right?

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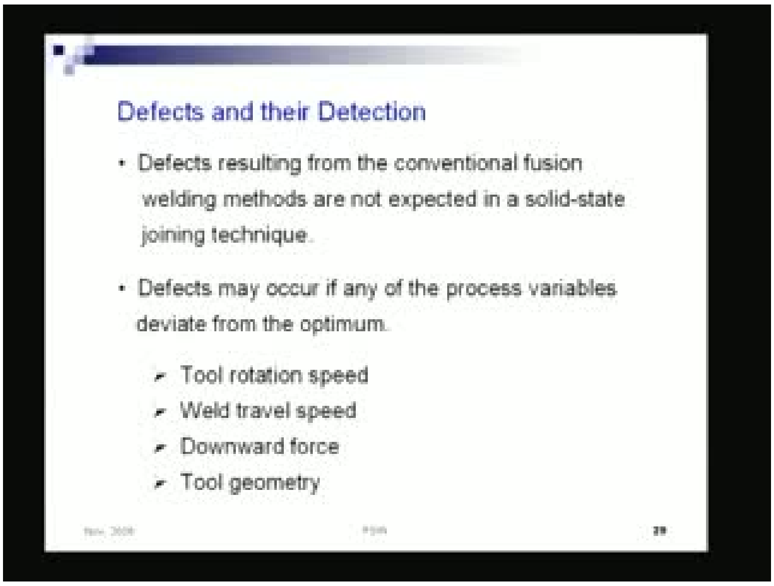

Well, so, that is what is the friction stir welding. And next, will look in to… Well, here, once again we are going back; as we can see, in the friction star, we have talked about defects and the detection. We have already talked about this; defects and detection as far as friction stir welding is concerned. Now, however, the welding which has already been done, say the fusion welding processes which we have already discussed about; because, the whole process of welding is what? I mean, when do we say that the welding has been done properly? When there is no defect in it, defect in the structure. Or in other words, the whole process of welding is nothing but a tool which translates the material to the final product, a tool with whose help we can translate the material to the final product. Well, there are many other tools are also involved in the process; for example, a cutting tool, a bending tool; this is a joining tool, right? So, unless the joining is done properly, your final product also will not be proper, right? So, how to do? That means, when you are using this tool, you should have a mechanism through which you should be able to ensure that the joining has been done properly.

We should be able to ensure that the joining has been done properly. Because, if it is not if it is not done properly, that amounts to, that in in in in coarse of usage of the product, it might cause failure; it might lead to a failure at that place where this joining has not been done properly, right? The failure could be in the form of a, I mean, if it has not done properly means, there can be an improper joint. By improper joint, what we may mean is that, strength in that part will be, strength bearing capacity might be less; so, during under the service load, it may get overstressed and fracture may develop. So, there can be a breakage of the structure.

Other type of defects could be that the structure means, suppose two plates are being welded and we expect a flat surface; two flat plates are being welded so, the final surface is also a bigger flat surface. Instead of that, if I have geometrically different because of deformation taken place, like, the plates are to be like this, instead, if I have like this, that means, a deformation, angular deformation has taken place; so, that is also not a correct joint. Physically, the two plates are being joined, but led to a product which is not accurate, right? There is a defect in it. So, in any case, we will be talking about the defects which are only visible or are there within the weld zone, within the weld zone.

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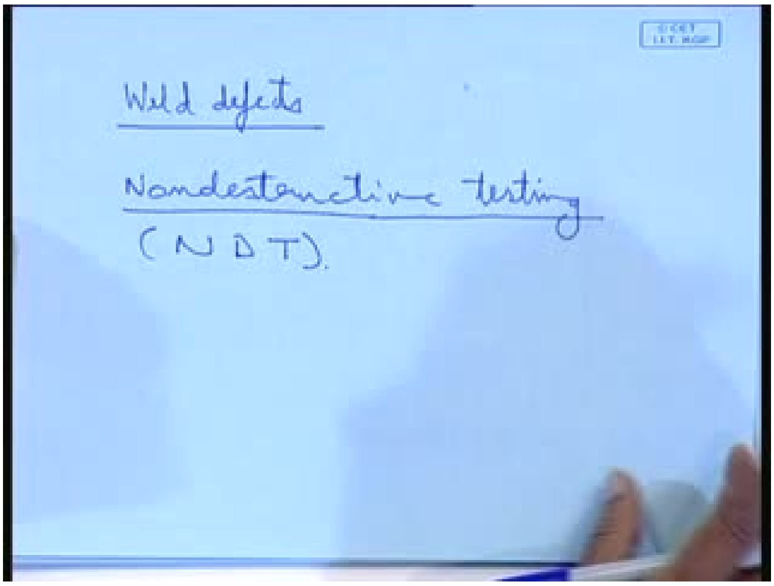

So, we should have, that means, firstly, we should know what are those weld defects, right, which are termed as defects or when a when we will say that. Well, there is a defect, so, that is one aspect to know about the defects; other aspect is to know about that they are there; that the defect is present; how do we know that? Because, if the defect is present, if it goes unnoticed, if we cannot detect it, then what will happen? We will come to know about it much later in the stage but, in a very bad way means, some certain failure will take place which may lead to loss of property, loss of life, anything may happen, right?

So, definitely, that is not expected; so, at the construction stage itself we should be able to assure ourselves that the structure which has been fabricated, that is defect free, right? So, that is done through what? Through some testing, Non-destructive testing; Non-destructive testing, that means, whether they have been done properly or not, one always can find out through means of destructive testing; that means, two plates have been joined, welded, so, cut out a sample subject it to tensile test, impact test, bending test and you can say well the joint is correct.

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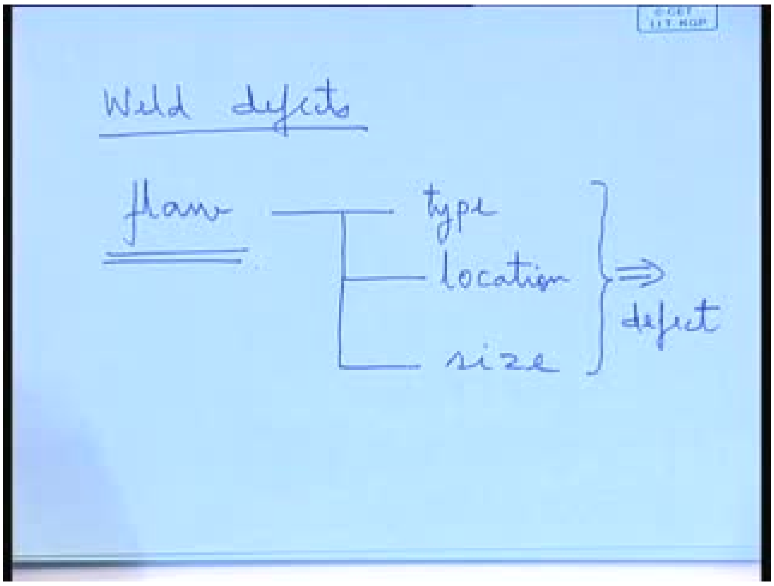

But when you are actually doing a fabrication work, you cannot cut out a sample; so, you will have to have a means of Non-Destructive Testing which is also refer to as NDT, right? So, well, let us first look in to the type of defects. What are the types of weld defects? Now, this is what defect? Because, what happens, the welding is such a process, it is really very difficult to ensure that it can be a, a welded joint can be 100 percent defect free, right?

So, now, if there is a defect, I cannot accept that product; it has to be rejected. So, another term is used, which is referred to as flow; so, instead of saying 100 percent defect free, I mean, well, so what do you say, that the... when you do a welded joint, it may remain, some some flow may creep in, some flow may occur in the process. Now, depending on the type of the flow, what type is kept in, what type of flow has taken place, where it has taken place; the location, right? What is the size of the flow, right? Through these three parameters, we will say whether this flow qualifies to be a defect or not, right? Whether this flow qualifies to be a defect or not?

So, what we are trying to do is, we are trying to, sort of, find out a mechanism through which we will try to classify the flows, such that, if they fall in within the boundaries or within the limits of type, location, size, then, if they are within that, then, we say these are the defects. Now, I will have to make the structure defect free, means, those flow are to be removed; that means, you will have to either redo the structure or make or implement some corrective measure, whatever; something has to be done. If they are beyond that; that means, they are, well, in other words, I mean, they are they are within the permissible limits, then we say they are not defects. There is a certain flow in the mechanism with which are permissible; permissible means, we accept them. This comes from the logic of that you can never make anything 100 percent perfect; you cannot do, right?

So, then, which one I say that, well, if this much I say is perfect and beyond that I say its imperfect; so, to find out that definition or to find out that boundaries beyond which I will say, that will unacceptable within which acceptable. So, that will be drawn through this; with the help of looking into what type; that is why the differentiation between flow and defect we are trying to make, we will try to look in to the type of the flow, where it has taken place and what is the size of it. So, if they, if they are for falling within a with within a boundary, we say, that is acceptable; if it is beyond that, more than that or whatever, it is a defect, right?

So, little more in detail we will see in the next class; and once we know the defects, then we look for what are the mechanisms for finding them out; that means, the non-destructive testing methods.