Advanced Manufacturing Processes
Prof. Dr. Apurbba Kumar Sharma
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 4
Advanced Welding Processes
Lecture - 4
Friction Welding Process

Welcome to this session on friction welding processes under the course advanced manufacturing processes. In the last sessions we have discussed about the solid state welding processes namely the ultrasonic and explosive welding processes. We have seen the various variant processes, their advantages, limitations and applications of these processes. In this session let us study a variant process in this category namely the friction welding process. Let us see its principle, features and applications as well. Let us see the principles of friction welding process.

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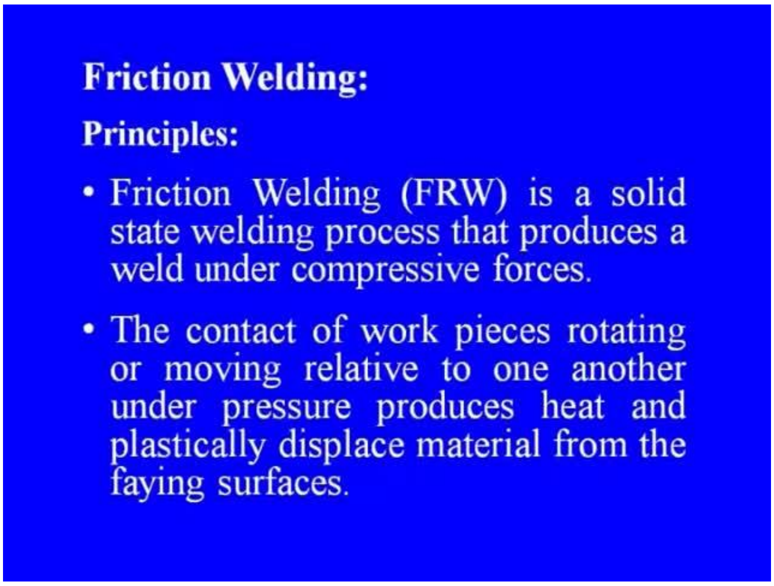

Friction welding process is also a solid state welding process that produces a weld under compressive forces. The contact of work pieces rotating or moving relative to one another under pressure produces heat and plastically displace material from the faying surfaces. So, this can be explained like this, the basic principle of friction welding is nothing but this is plastic deformation by means of applying pressure and creating a relative movement between two solid bodies, and then because of this there will be intense heat generated very locally, then that heat will plastically deformed two materials at the point of interaction and then upon cooling they will get welded together. So, this can be explained like this.

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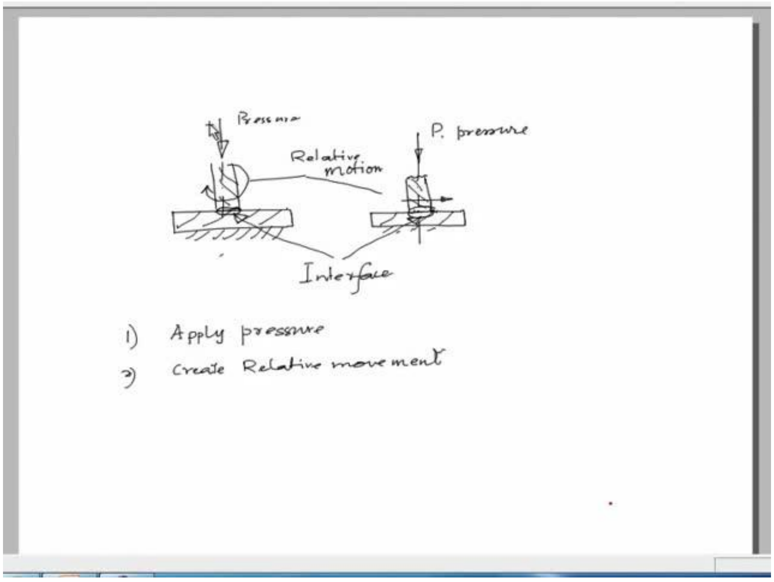

If I have one body like this, this is the surface of the material then another body which is in touch with this. So, this is another body. Now, if we apply some pressure on it say some pressure and this is say rigid. Now, this interface will be under intense pressure and now if we apply some rotation to this body or otherwise if we apply some relative motion to this body with respect to this. Say in this configuration, if we apply some movement to this with respect to the first body and which is already under some pressure P.

Therefore, the important important condition here will be applying some pressure and applying some relative motion. So, two, there are two criteria, apply pressure and create relative movement. Now, because of this in this interface so this will be the interface of this two bodies under relative movement will get heated up. So, they will get heated up and there will be a plastic deformation in the local locality where the pressure is applied. Because of this plastic deformation the material on the both the sides this as well as this will get deformed and get fused.

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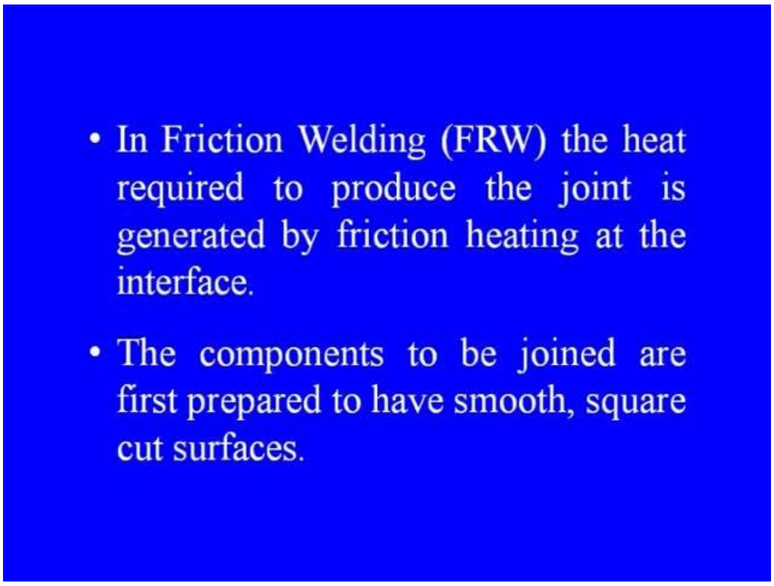

In friction welding the head required to produce the joint is generated by friction heating at the interface that we have already discussed. The components to be joined are first prepared to have smooth, square cut surfaces. Otherwise, this is another important thing otherwise what will happen if there are irregularities on the surface say for example…

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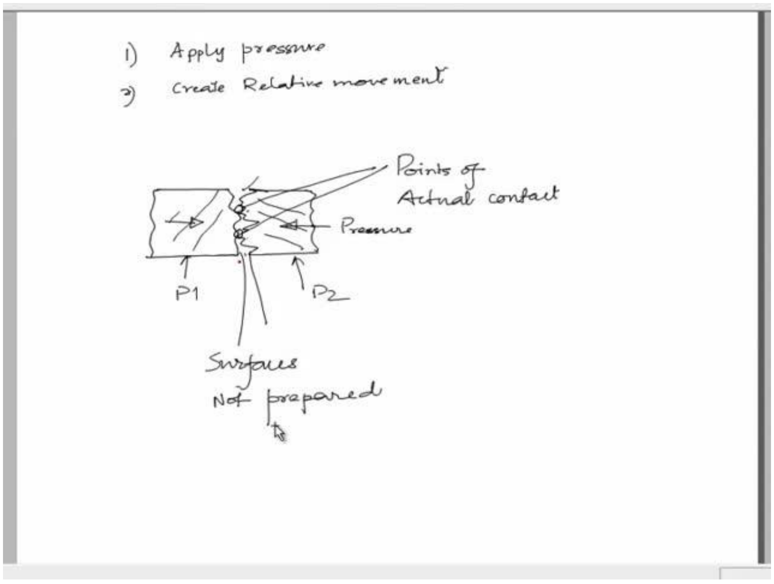

If the interacting or the traying surfaces have got something like this configuration and the other surface is also having something like this, this is body one. So, this is say piece 1 and this is piece 2 and they are, they are having contact only at few places that means their surfaces are not, surfaces not prepared prepared then what will happen the contact will be mostly through these points. So, this will be the points of actual contact. Therefore, upon application of pressure, now if you apply some pressure on these two say this is pressure then what will happen?

There will be deformations so locally only this these points where actual contact is there and these plastic deformations will cause bonding at this locally deformed portion only. Therefore, at the end of the day what you will find there, there will be joining, but only at those localized points where the plastic deformations and heat developed because of the applied pressure and relative motion was the maximum. And consequently some of the portions like say for here this point, this point; these points will remain as un bonded which will lead to some defects and failure of the joints.

Therefore, it is very important to prepare the surfaces of the objects to be joined to be prepared very finely, they should be parallel to each other and surface irregularity should be minimum to have a better joint to interface.

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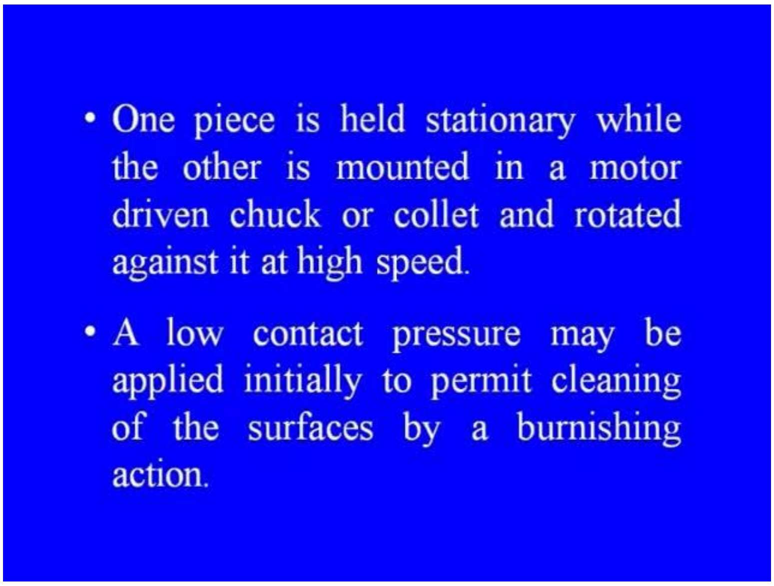

In this welding process one piece is held stationary while the other is mounted in a motor driven chuck or collet and rotated against it at a high speed. This is what we have discussed at the very beginning. A low contact pressure may be applied initially to permit cleaning of the surfaces by a burnishing action.

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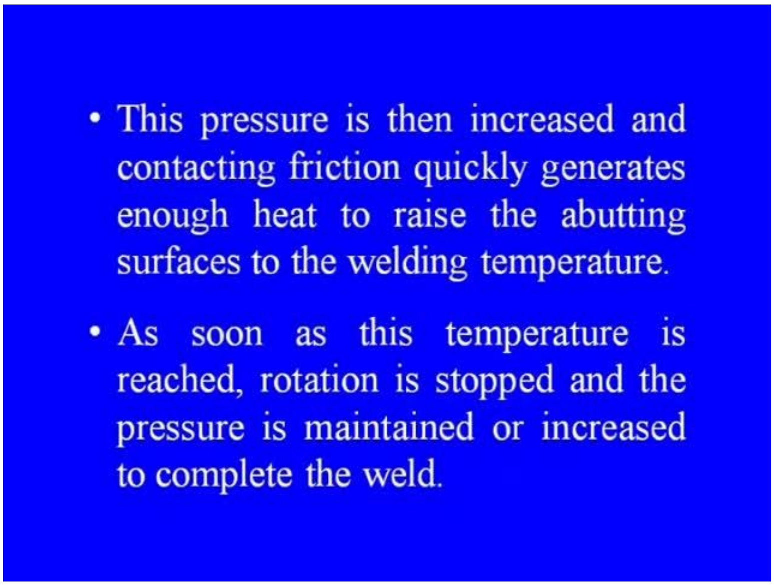

This pressure is then increased and contacting fiction quickly generates enough heat to raise the abutting surfaces to the welding temperature. As soon as this temperature is reached, rotation is stopped and the pressure is maintained or increased to complete the weld. This is another important condition. So, rotation or the relative motion will create to create the heat at the point of interface or point of contact. So, once sufficient temperature is developed the metal gets softened, metal gets plastically deformed, then the rotation on the relative motion should be stopped to enable the material to get solidified and thereby the joint will be formed.

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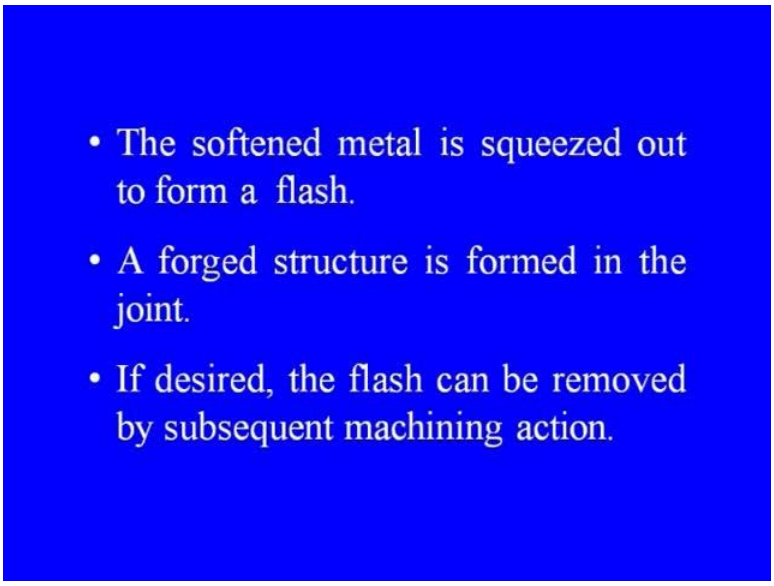

The softened metal is squeezed out to form a flash. The forged structure is formed in the joint. If desired, the flash can be removed by subsequent machining action also.

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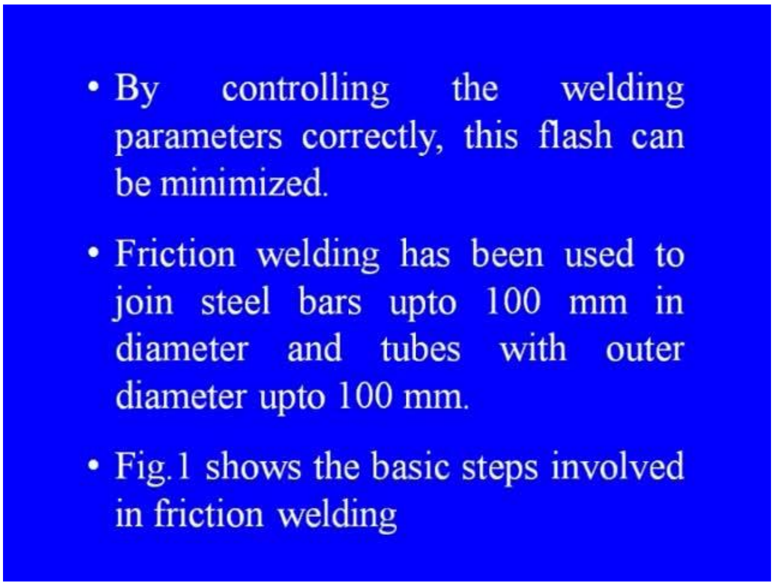

By controlling the welding parameters correctly, this flash can be minimized. Friction welding has been used to join steel bars up to 100 millimeter in diameter and tubes with cutter diameter up to, outer diameter up to 100 millimeter.

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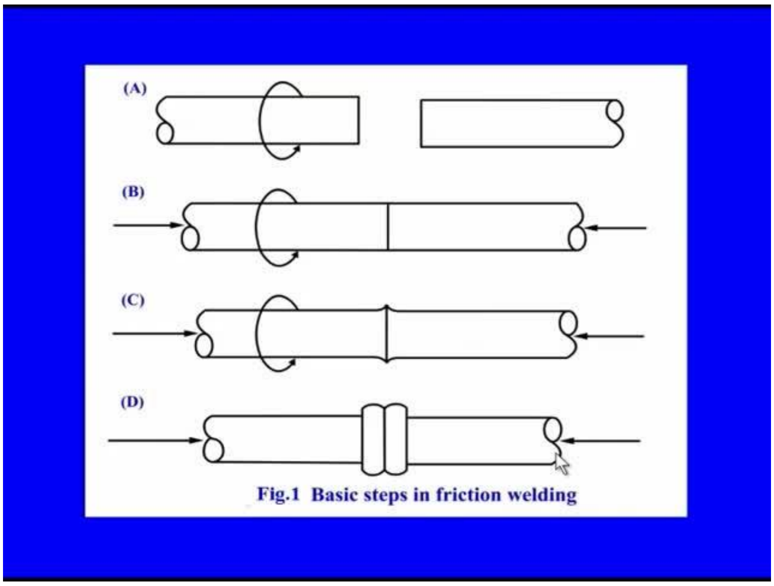

This can be seen in this figure as depicted in the screen. So, these are the two objects to be joined and these are the two faying surfaces. These surfaces need to be joined and here as can be seen one is kept stationary, the other is being given rotary motion with respect to its axis. Now, they will be put in contact with some light pressure initially from both the side and as this that contacting and moving then the pressure will be slowly increased to a higher level, and because of this the temperature will be developed at this surface because of the friction. And then this will cause the material on each side of this original objects to get softened, and since they are already under pressure like this so they will form some sort of flashes like this.

These are the signs of flashes being produced and once we continue the pressure and we stop this rotary motion then there will be a larger deformation at the point of contact and this will make the joint in between them. These flashes which is unwanted it as as can be seen from this figure so this is this is somewhat unwanted material and this is because of the plastic deformation of the two materials or the two parts under pressure. So, this can be machined out or suitable secondary operations can be applied to remove this flash, if we want this joint also to be at the same diameter of the original bodies or original objects. So, here some issues could be like how to maintain the axial similarity. We have to alignment is a problem here. So, the one has to be very much careful to make them aligned with the other body. Particularly, since one body will be under movement or the rotation therefore, the keeping the alignment can be a critical issue.

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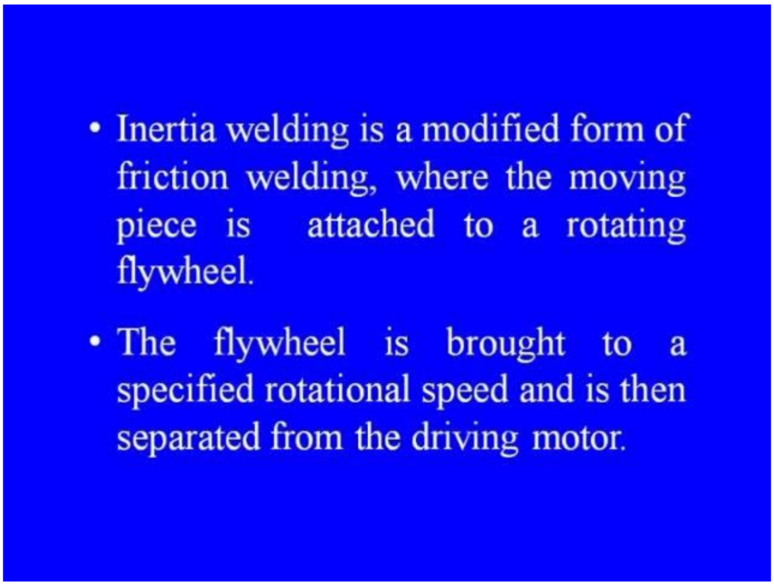

Inertia welding is a modified form of friction welding where the moving piece is attached to a rotating flywheel. The flywheel is brought to a specified rotational speed and is then separated from the driving motor.

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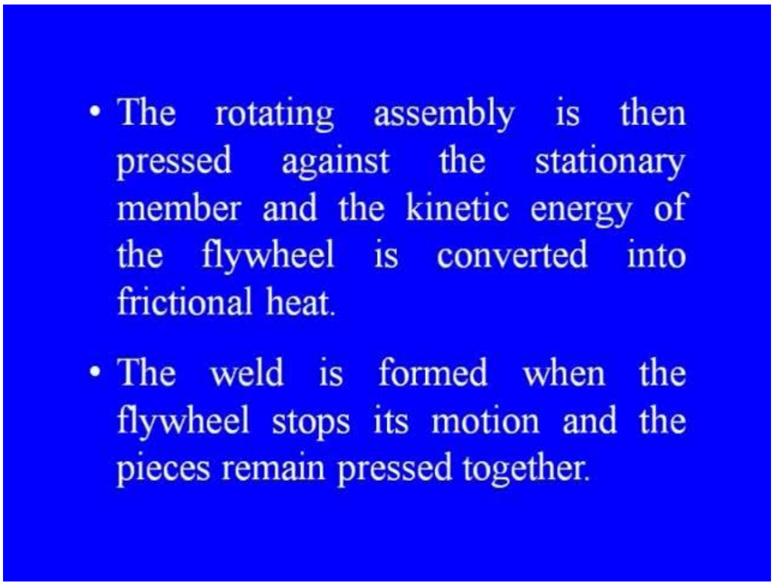

The rotating assembly is then pressed against the stationary member and the kinetic energy of the flywheel is converted into frictional heat. The weld is formed when the flywheel stops and the process remain pressed together.

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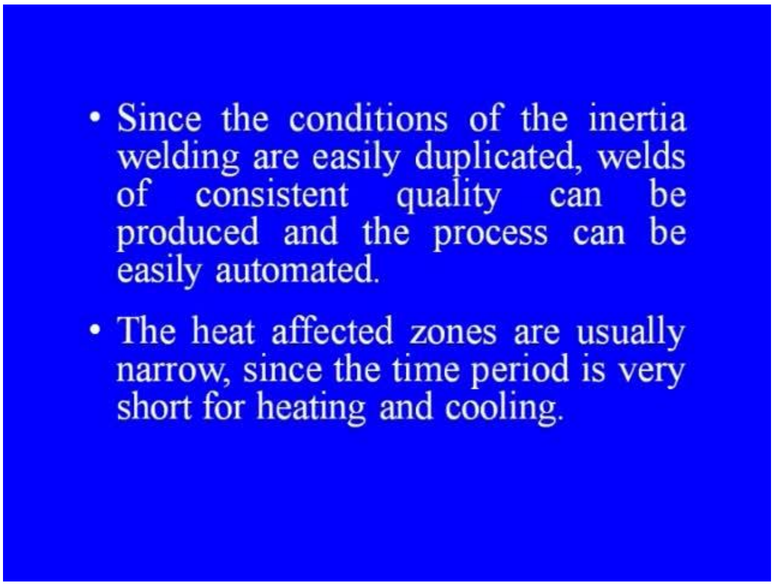

Since, the conditions of the inertia welding are easily duplicated welds of consistent quality can be produced and the processes can be easily automated. The heat affected zones are usually narrow, since the time period is very short for heating as well as cooling. This is an important aspect of this joining technique where almost nil heat affected zone we can expect. Now, let us see few variants in friction welding process.

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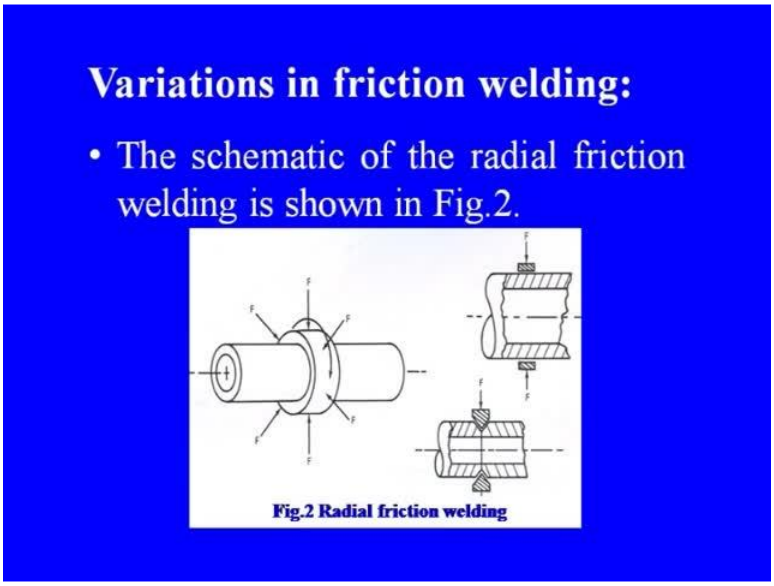

Here is a schematic of radial friction welding process which is shown in the screen. So, here this is, these two are the parts. So, they are under pressure and this is this is under body which will provide the rotation. This is another variant namely orbital friction welding.

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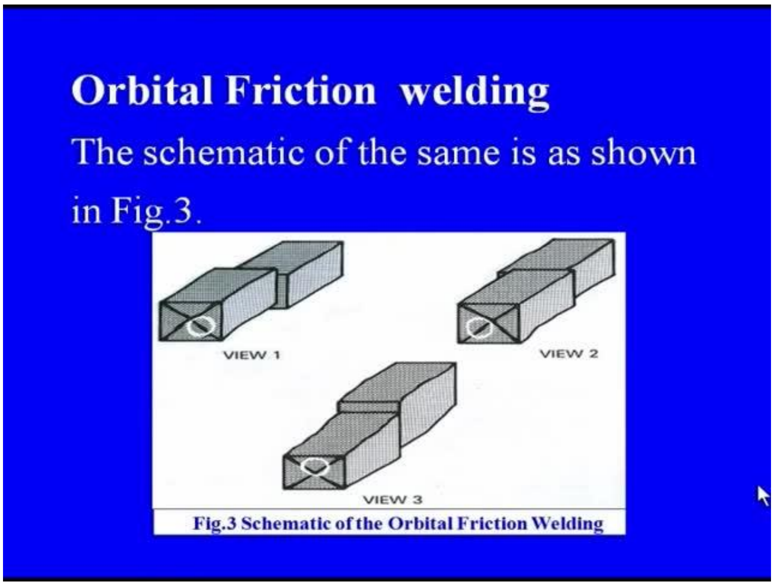

So, this is shown in the screen again. So, these are the two parts to be joined and these are the interfaces. So, they are brought together, then applied pressure and then this is another view of this in which the, these pieces are seen to be in perfect alignment and they are joined by using that friction welding technology. Now, let us have a look at the distinct advantages of this friction welding processes. So, this is basically a green process we can say where no gas is burnt or no fumes will be produced, no toxic fumes will be produced, no chemical will be used and even no arcs are produced, arcs could be at times harmful for the operators eye etcetera or for controlling the arc itself needs some other mechanism, but this is a purely mechanical process which does not have these type of problems.

More over one of the important aspect of this process is here the two pieces to be joined are joined as such. No third piece or the third material is required here and added this third material sometimes causes problem as far as the joint properties are concerned, it may reduce the joint strength or it may change the metallurgy of the joint or other mechanical properties or electrical properties of the joint.

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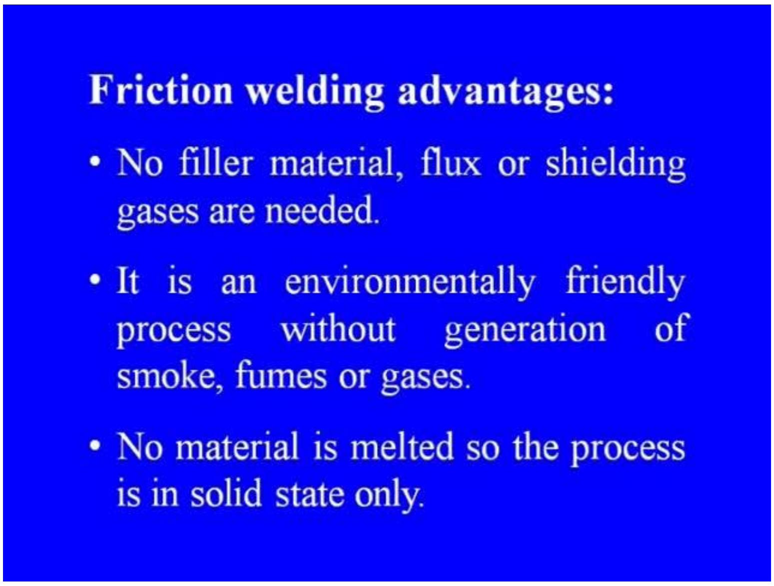

Therefore, here no filler material we use so the material properties, the strength properties etcetera will remain to that of the original materials are being used, then no flux or shielding gases are needed, they are not used so that brings down the cost of the process also to some extent because shielding gases are sometimes costly and more over they have got some environmental implications as well. Then flux as we know managing the flux on the welding zone itself needs some other arrangements. It is an environment friendly process without generation of smoke, fumes and gases that I have already indicated. No material is melted so the process is in solid state only.

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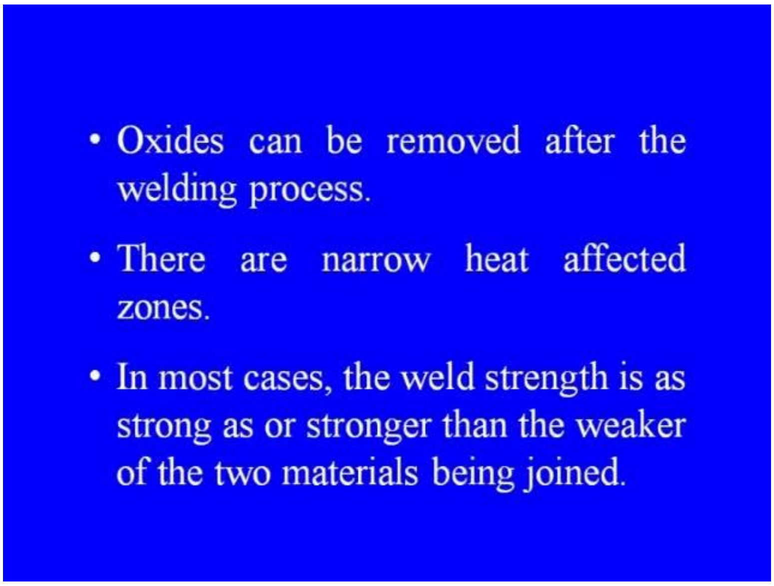

Oxides can be removed after the welding process if at all they rely at the temperature that this friction welding will be carried out oxide formation may not be very, very prevalent. However, even if there are oxide formations that can be removed afterwards, there are very narrow heat affected zones that is what we have already discussed, that is how this process is very attractive for the metallurgist or for the the processes where very good strength and the uniform micro structure is needed. This is very important aspect as we know heat affected zone changes the micro structures in that zone and change in micro structure automatically implies changes in properties. In most cases the weld strength is as strong as that of the weaker of the two materials being joined, this is another important aspect.

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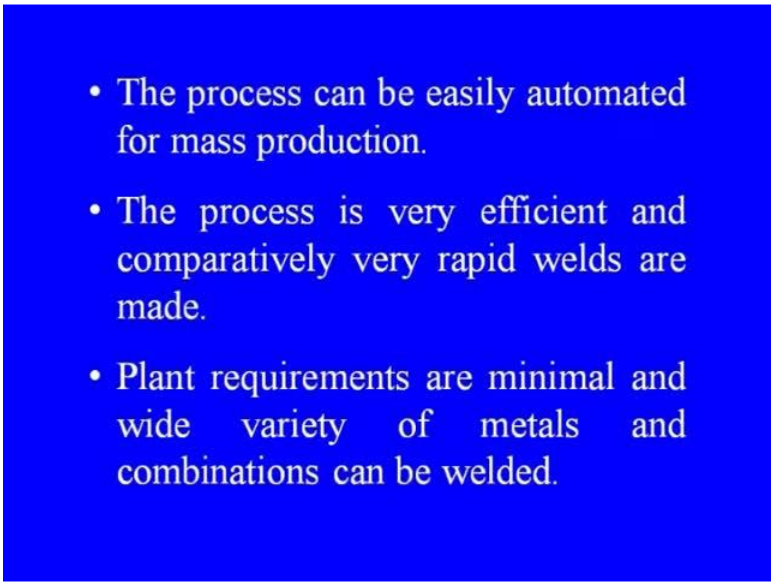

The process can be easily automated for mass production. The process is very efficient and comparatively very rapid welds are made. Plant requirements are minimal and wide variety of metals and combinations of them can be welded.

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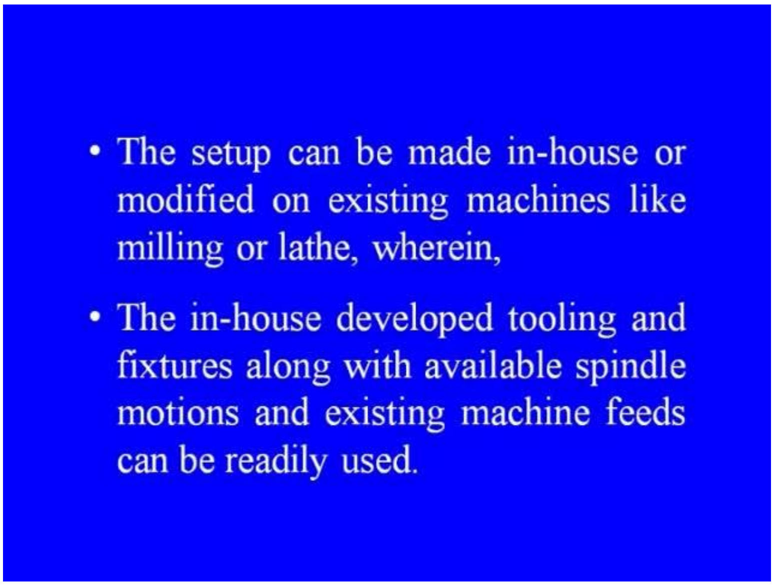

The set up can be made in house or modified on existing machines like milling or lathe. The in house developed tooling, and fixtures can also be used along with available spindle motions and existing machine feeds can be readily used. That means there is no very sophisticated arrangements are required for to carry out this welding process.

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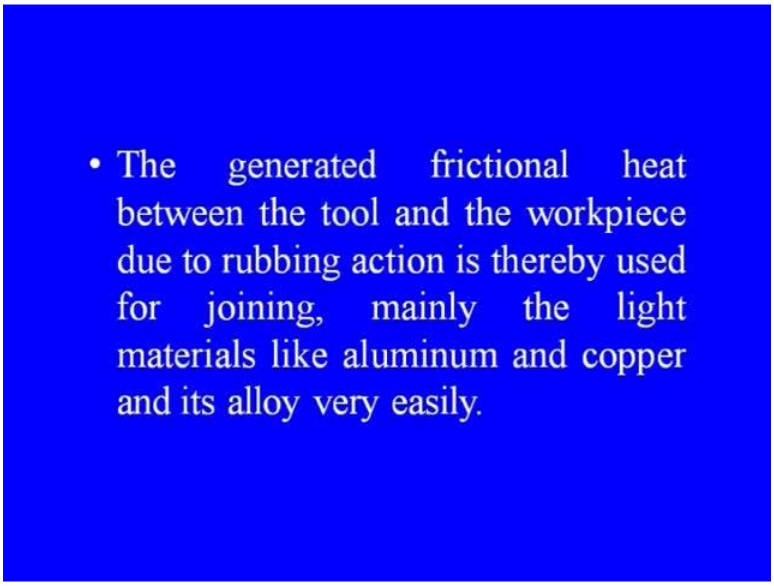

The generated frictional heat between the tool and the work piece due to rubbing action is thereby used for joining mainly the light materials like aluminum and copper and its alloy can very well be welded. Now, let us look at some of the limitations of this process.

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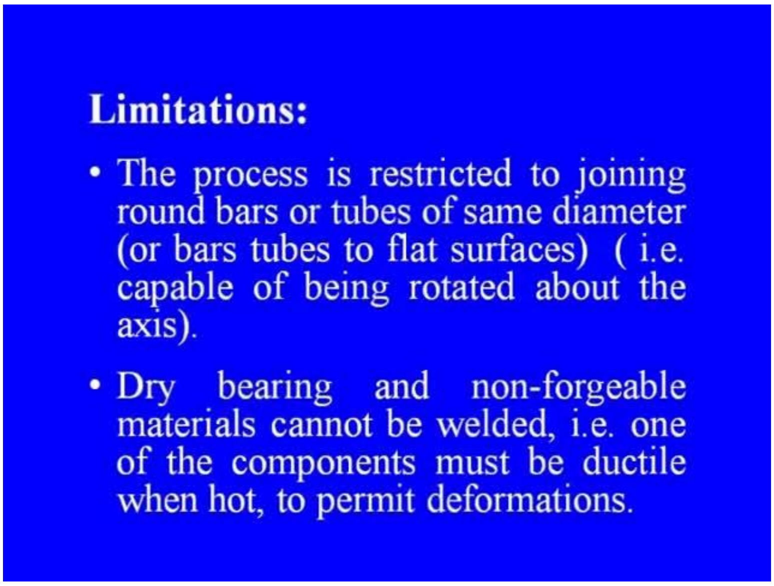

The process is restricted to joining round bars or tubes of square diameter or bars or tubes to flat surfaces that is capable of being rotated about its axis that is what we have already seen. Dry bearing and non forgeable materials cannot be welded that is one of the components must be ductile when hot to permit deformations. This is a kind of prerequisite one should be ductile so that there will be material flow that will take place once we soften it and that will ultimately help in getting them joint.

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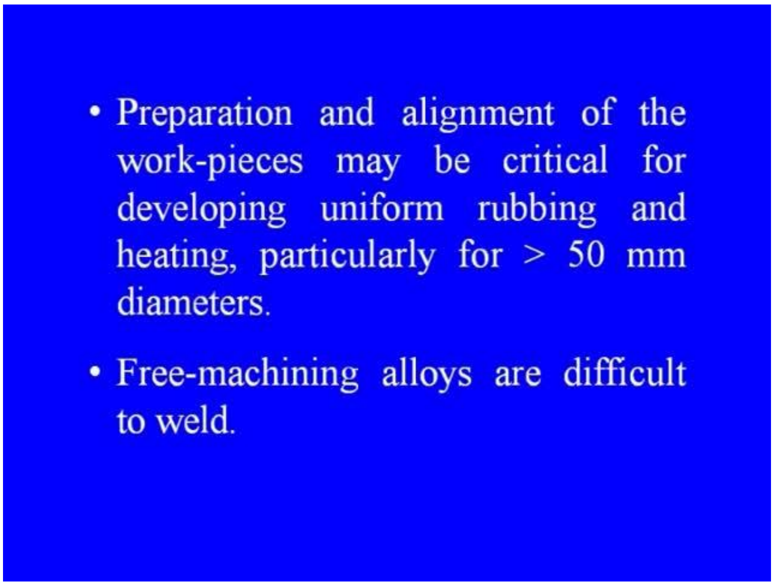

Preparation and alignment of the work pieces may be critical for developing uniform rubbing and heating, particularly for pieces having diameter more than 50 millimeters. Free machining alloys are difficult to weld by this process.

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Capital equipment and tooling cost are high. This happens generally if we desire large capacities and then better process capabilities and specialized machines. Let us note the applications of this process.

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Friction welded parts in production applications span over wide products for aerospace industries, agricultural industries, automotive industries…

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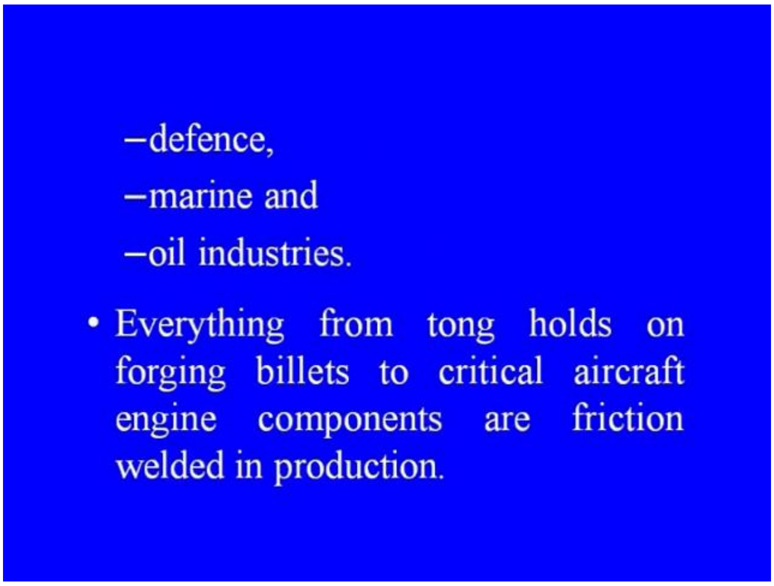

In defense applications, marine applications, oil industries and so on. Everything from tong holds on forging billets to critical aircraft engine components are friction welded in production shops, that shows the versatility of this particular process.

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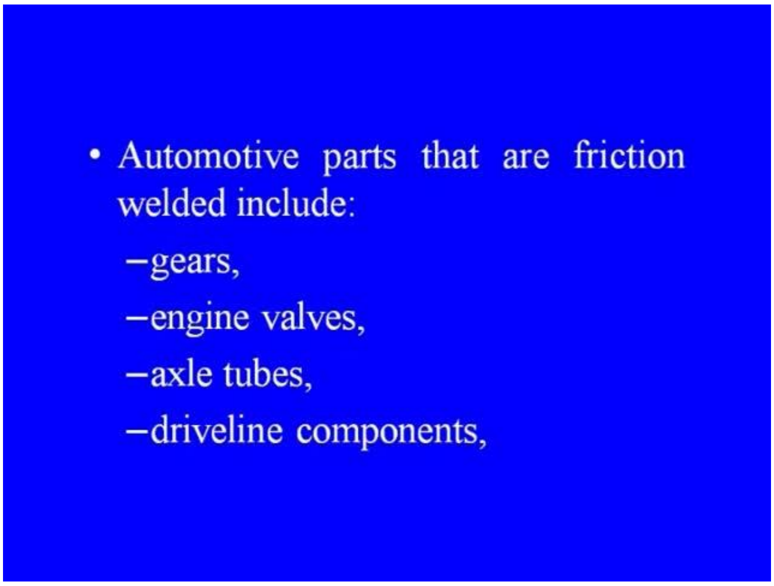

Automotive parts that are friction welded include gears, engine valves, axle tubes, driveline components…

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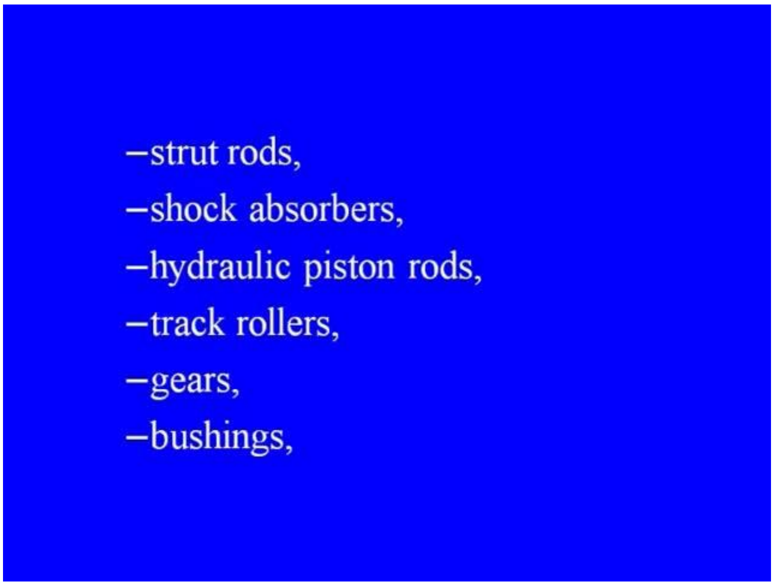

Strut rods, shock absorbers, hydraulic piston rods, track rollers, gears, bushings…

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Axles and friction welded parts are also used for welding common components which are used for manufacturing agricultural equipments.

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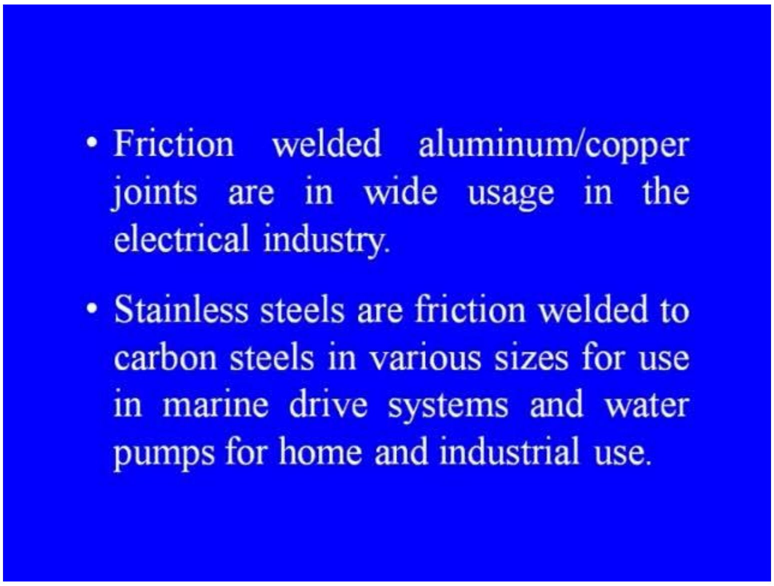

Friction welded aluminum or copper joints are in wide usage in the electrical industries. As we know electrical industries the electrical conduction of current is one of the important aspects of the materials in most of the components where current carrying capacity is considered and aluminum and copper are two materials that are considered to be best in current conducting capabilities, in their current conducting capabilities. And since there are very negligible heat affected zone. Therefore, the current carrying capability does not get much affected if we join these type of materials through friction welding as we have already discussed. Stainless steels are friction welded to carbon steels in various sizes for use in marine drive systems and water pumps for home and industrial use.

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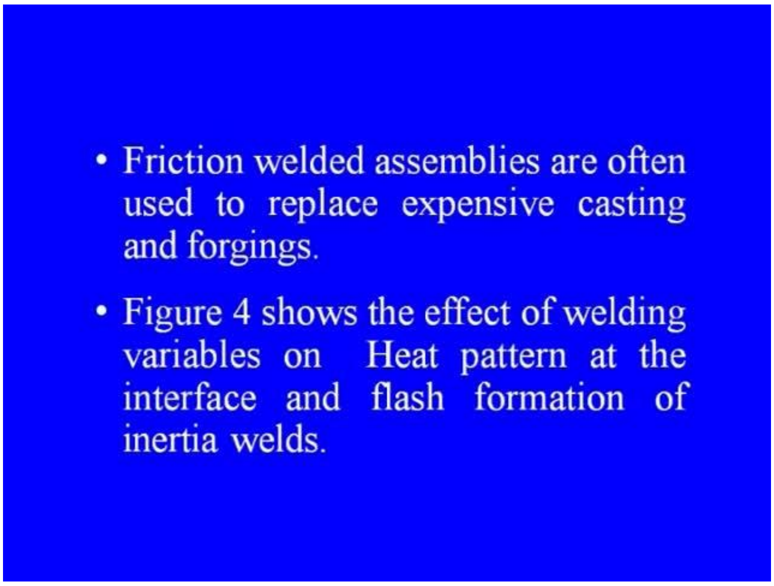

Friction welded assemblies are often used to replace expensive castings and forgings. The next figure shows the effect of welding variables on heat pattern at the interface and flash formation of inertia welds.

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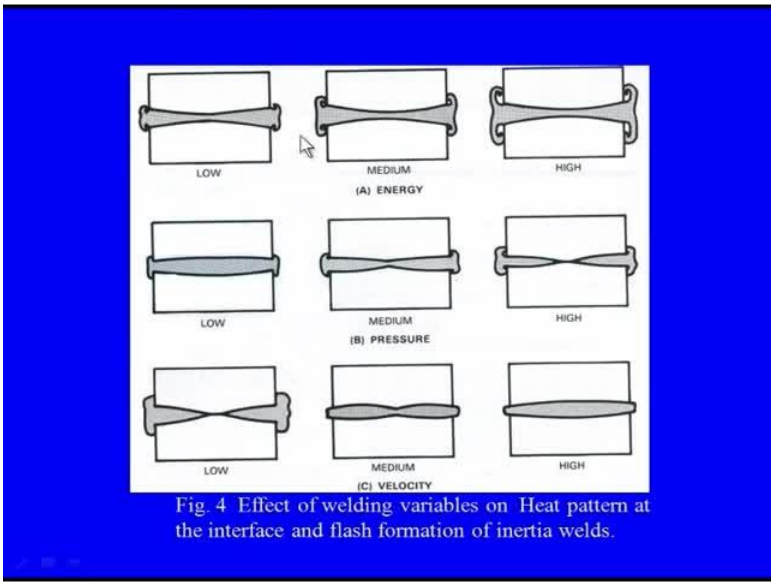

Fig. 4 Effect of welding variables on Heat pattern at the interface and flash formation of inertia welds.

So, this figure is in the screen. So, this is where the low energy being used and medium and high that we have, we have seen. If we use high energy high amount of flashes will be used will be produced as a result of this process. Medium energy means considerably less and at low energy there will be minimal flashes being produced and higher the size of the flashes the choosing of the corresponding processes to remove this flashes will be different as we have already seen there.

For minimal flashes probably we can go for some some polishing kind of processes, but if the flashes are bigger like this then we have to go for some serious measuring processes. Similarly, as far as the applied pressure is concerned for low pressure there will be low flashes or smaller flashes will be produced and at high pressure flashes produced will be much larger. Similarly, as far as the velocity is concerned if low velocity, at low velocity this will not be, joint will not be proper medium velocity and at high velocity this will be proper. Now, let us move on to another process that is friction stir welding.

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This is in fact a variant process of the friction welding and we can see the schematic of this process in the screen.

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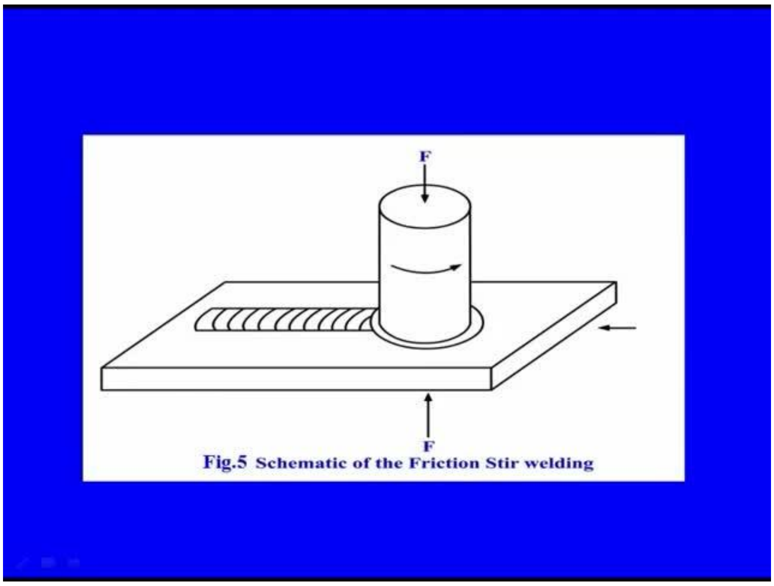

Fig.5 Schematic of the Friction Stir welding

So, this process as I have already spoken about this. So, this is the schematic, this is the plate and this is we can say this is a tool which will be kept on rotating and the area which it will touch will get heated up, softened and softened. Now, instead of one plate if we keep two plates here both the plates will get softened, heated up and then finally, they will be joined. So, this is a very basic process of friction welding schematic. So, this can be seen like this if two plates are there.

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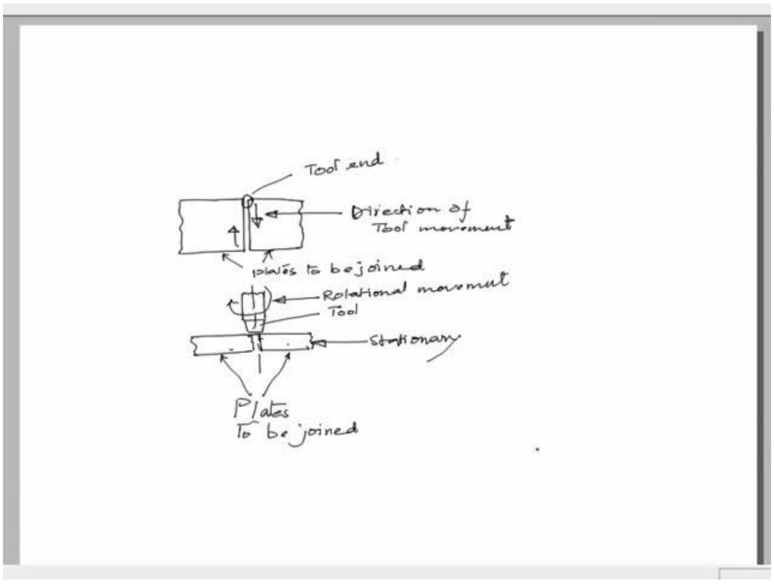

If two plates are there say these two plates are there, they needs to be joined. Now, I can use one tool so this is the top view. So, this will be the pin. So, this will be something like this, the side view will be or the elevation will be like this. These are the two plates to be joined and this is the tool we can use and this tool can have different configuration, this can be, this we can say this is the tool and these two are the plates to be joined, plates to be joined. So, these two are the plates to be joined and this is the tool end.

This will be given a rotational movement or this is rotation to the rotational movement to the tool and these two plates they will be held stationery. This plate will be held stationery. Now, along with this rotational movement to the tool, the tool will also be moved in this direction or vice versa, it can be if we start from this point, this can be moved in this direction as well. So, this is this we can say direction of direction of tool movement tool movement. This is of course, I am talking about the relative movement.

Therefore, it is not necessary that only tool should be moved, we can make arrangements for, so for that purpose that the plates, both the plates can also be moved, but that has to be the movement has to be integrated movement of the both the tools. Now, this will cause the intense heat generation at this joint because of the frictional heating, that is what we have discussed in the, in the previous you know mechanism also when we discussed about friction welding process.

So, because of the friction there will be heat generation and because of the applied pressure this will cause the materials to plastically deform and joint is made. So, the same procedure does take place in this case also. Here, these two surfaces to be joined gets heated up, they deform plastically and gets joined. Let us see the necessity and advent for this friction stir welding process.

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The basic problems with fusion of or welding of few materials say namely the aluminum alloys 2024, 7050, 7075 are like the cast brittle dendritic structure. They posses this brittle structure and brittle structure is always difficult to handle as we know from our previous experiences, then they possess micro porosity.

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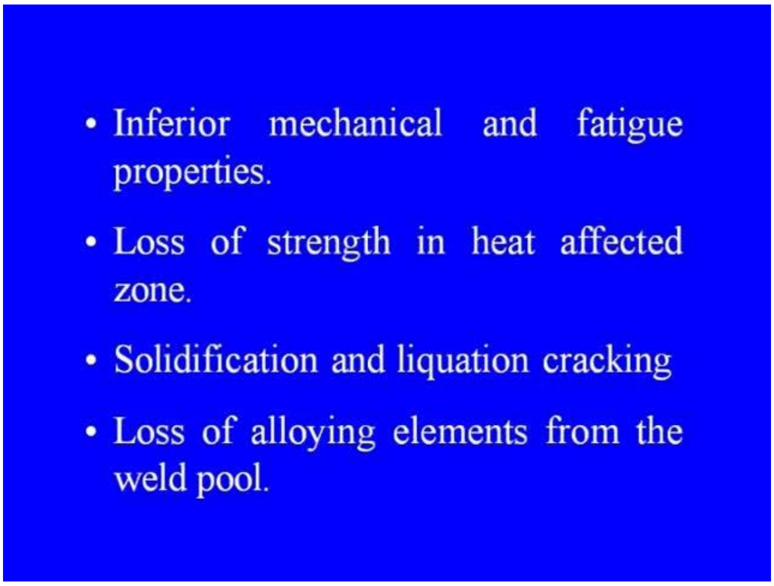

Inferior mechanical and fatigue properties, then loss of strength in heat affected zones, then solidification and liquation cracking, loss of alloying elements from the weld pool. So, these are some of the common problems of very important materials. These are aluminum alloy metals as we have seen 7075, etcetera. So, these series are very, very popular as they are having light weight and their strength wise they are quite good therefore, in industries in many industries like auto and aero industries they are very, very popular.

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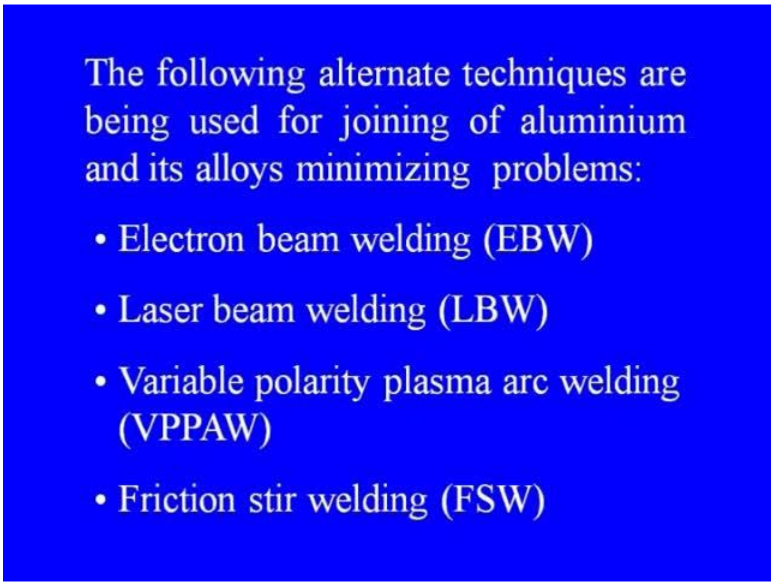

Therefore, to make them joined effectively the following alternate techniques are being usually used. One is electron beam welding EBW, another is laser beam welding which we will be discussing shortly in the another session, then variable polarity plasma arc welding VPPAW and one process which is frequently being applied is the friction stir welding. So, this is the schematic of a friction stir welding process. This is what I was talking about just few minutes ago.

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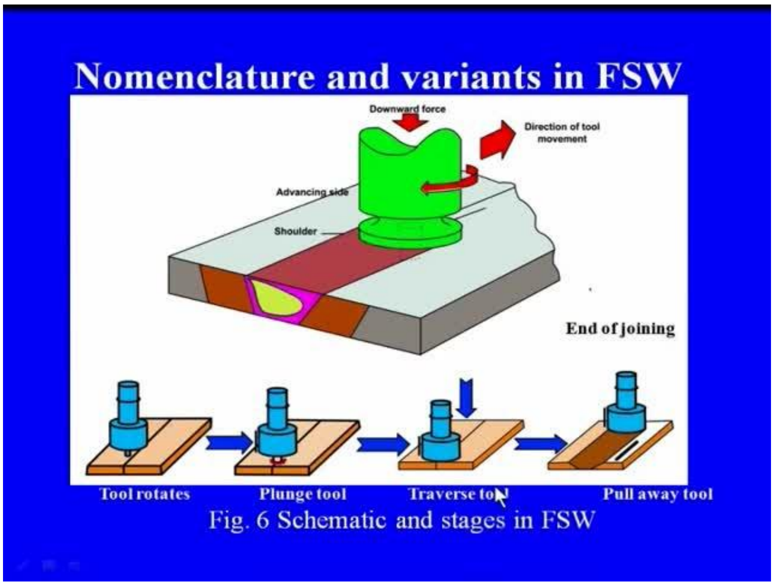

So, on the screen the schematic is there. So, these are the two plates to be joined these two plates, basic plates and this is the interface. This interface is being acted upon by the tool. So, this is actually this is the basic tool that will be responsible for making contact with the base plates base plates and this is the mechanism you can say which will provide the rotation. Rotation to this tool, this tool will be braced or fastened to this mechanism very tightly. So, that there will be any, there will not be any relative moment between this and the tool. The relative moment will be between the base plates need that needs to be jointed and this tool.

And as I said already so this will be given rotational movement with respect to its axis as well as this tool will be moved along the joint to be produced where the both the plates that we can see this is the interface of the plates to be joined. Therefore, the tool needs to be moved along this joint to be produced. So, this is how the sequence of events we can say and this bottom diagram shows the sequence of events. First both the, both the plates together bring the tool near to this then align this tool end point that I have already explained, this end point with that of the joint to be produced, apply pressure as well as rotation and then then move the tool from one end to the other end where the joint is to be produced.

So, here there are number of other parameters involved that will ultimately determine the efficiency of the joint or the performance of the joint. These parameters could be what is the RPM we are giving to this tool? This is an important aspect of this process. Then what is the pressure we are applying to this tool. What are, what are the materials we are joining whether they are similar kind of materials or dissimilar materials? Then at what speed we are advancing the tool. This is another very, very important aspects of this joining process which will affect the process efficiency as we know in case of conventional welding process also.

The speed of speed of moment of the welding gun is one of the important parameters that determines many factors as far as the joint is concerned. So, here also this is no different this RPM as well as the rate at which the tool is being advanced these two are very important factors as far as the joint efficiency is concerned. Then the configuration of this tool also might affect to someone extent, what kind of tool configuration we are using and the material of the tool.

This is another important aspect because this tool will be under intense pressure and severe condition as far as the speed is concerned, as far as temperature is concerned. So, this will have to face a severe conditions at the interface. Therefore, the material has to be selected accordingly so that it the tool itself do not get softened and do not get deformed while the process is in progress. Otherwise the very basic intention of attaining the joint will be failed. So, these are some of the important aspects while going for friction stir welding process. Now, let us look at some of the unique advantages of this friction stir welding process.

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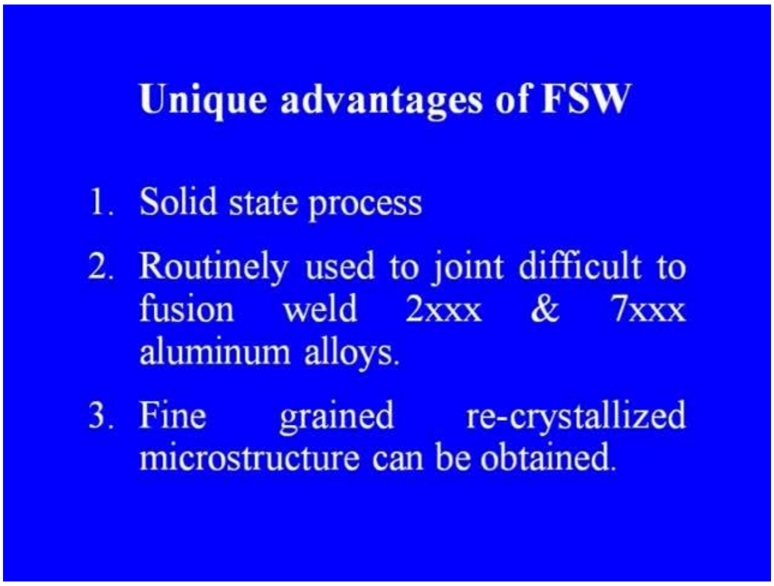

First of all this is a solid state process where no melting is there, no meltful management is required and therefore, the heat management is also not that much rigorous. Since, this will not come to the complete melting point of the melting point of the metals being used. It will be some intermediate temperature. Routinely used, this process is routinely used to joint difficult to fusion weld materials like 2000 series, 7000 series of aluminum alloys, then fine grained re-crystallized microstructure can be obtained as a result of this joint.

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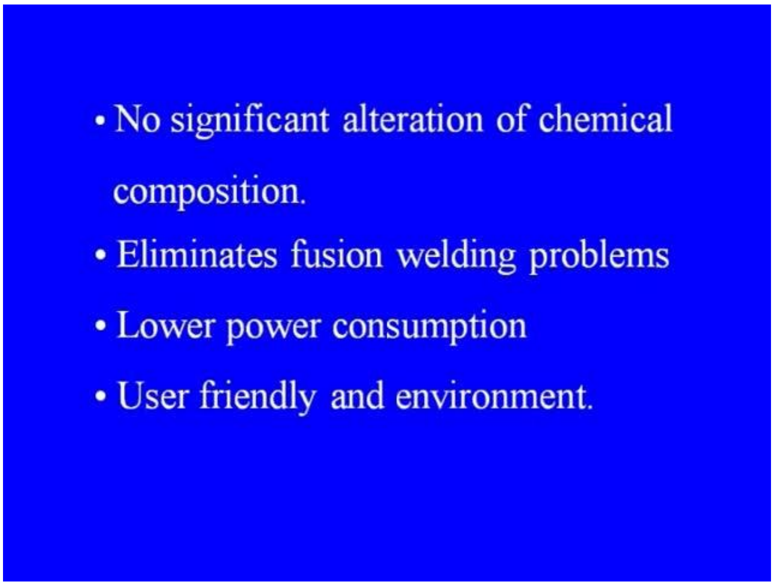

Then no significant alteration of chemical composition since this is purely a mechanical process and the heat developed will be much lower than that of the melting temperature. This eliminates fusion welding problems. Then lower power consumption and we can expect a user friendly environment as there is no smoke being produced, no toxic gases being produced and no additional gas environment is used for this process.

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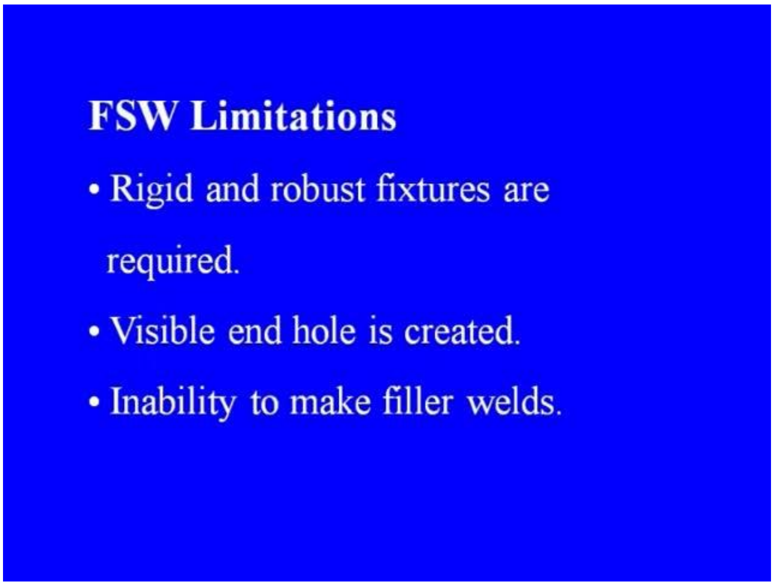

Now, at the same time let us note few limitations of this process as well. This is a process where rigid and robust fixtures are required as we have already spoken about. The process involves rotation at very high speed, high RPM is involved as well as, as well as there will be some translatory motions also involved to the tool, moreover to withstand these conditions the plates, those are to be produced need to be produced should be fixed with a very high force.

Therefore, very good clamping arrangements should be needed and during the rotational movement as well as the translatory movement so that there will not be any relative displacement or any movement to the plates or misalignment that causes to the plate should take place, we should take or one should take very robust fixtures for making this arrangement. Then visible end hole is created at the end of the building, then inability to make filler welds this is another limitation of this process.

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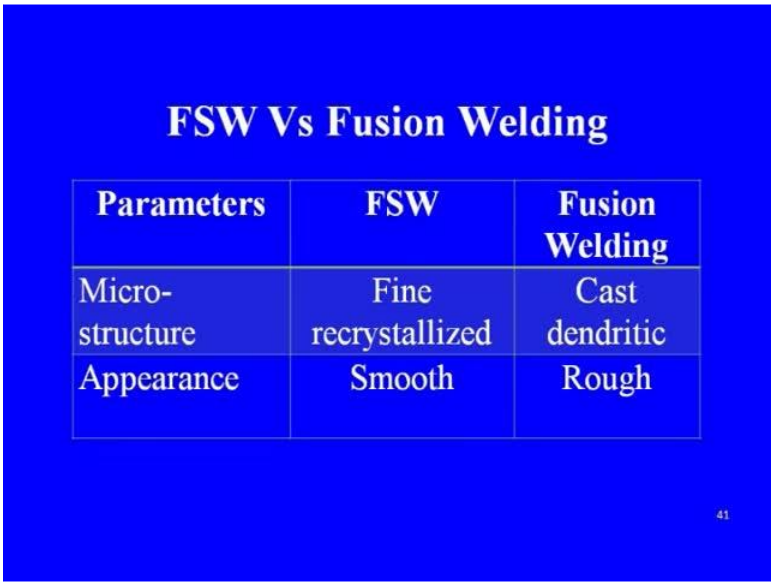

FSW and fusion welding process if we try to compare then micro structure wise FSW or friction stir welding process produces very fine re crystallized micro structure whereas in fusion welding process usually gives cast and dendritic structure. Then appearance wise friction stir welding gives very smooth appearance of the joint, whereas the fusion welding process gives a rough surface.

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Then if we see the consumable of shielding shielding gases then there is no shielding gases as we have already discussed in friction welding process, stir welding process, but fusion welding process the gases shielding gases are required. Then distortion is negligible in friction stir welding whereas highly significant in fusion welding. Mechanical properties obtained in friction stir welding are usually superior than that of the fusion welding process.

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Parameters	FSW	Fusion Welding
Fatigue lives	Excellent	Inferior
Corrosion behaviour	Excellent	Inferior
Impact on environment	Negligible	Significant
Running cost	Less	High

Fatigue lives are excellent in friction stir welding, welded joints. Corrosion behavior are excellent whereas in both the cases fusion welding gives inferior properties, impact on environment is negligible in case of friction stir welding which is we can say a environment friendly process, but fusion welding is not. Running cost is also less.

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Now, have, let us have a quick look at the friction stir welding applications. Number one is aerospace industry in which wings, fuselage, cryogenic fuel tanks, aviation fuel tanks, aircraft structure and external aircraft throwaway away tanks are being producing used this welding technique.

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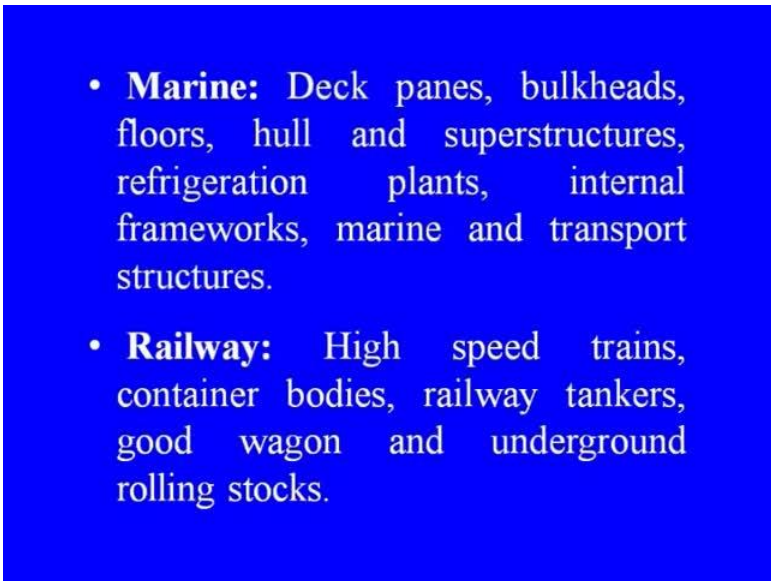

Then in marine applications deck panes, bulkheads, floors, hull and superstructures, refrigeration plants, internal frameworks, marine and transport structures these are being welded in using FSW. In railway FSW finds application in high speed trains, container bodies, railway track tankers, goods wagon and underground rolling stocks etcetera.

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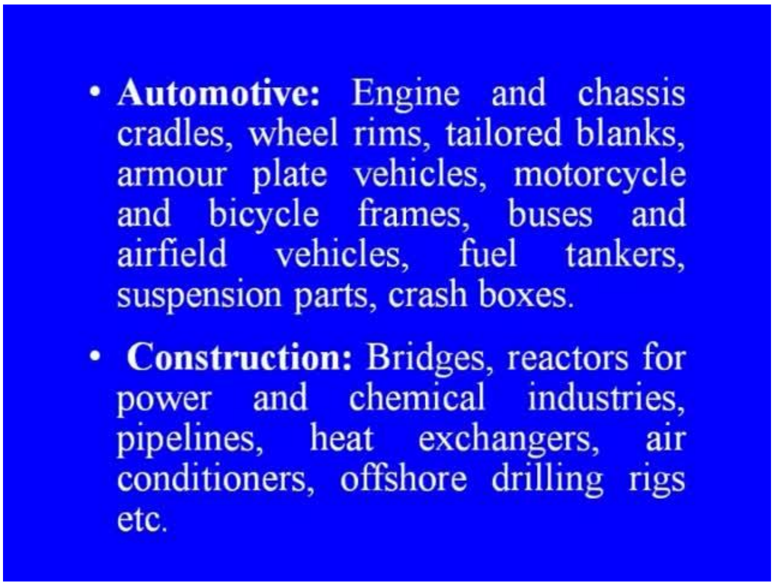

Then in automotive industries engine and chassis cradles, wheel rims, tailored blanks, armour plate vehicles, motorcycle and bicycle frames, buses and airfield vehicles, fuel tankers, suspension parts, crash boxes etcetera, etcetera. In construction industries bridges, reactors for power and chemical industries, pipelines, heat exchangers, air conditioners, offshore drilling rigs etcetera, etcetera.

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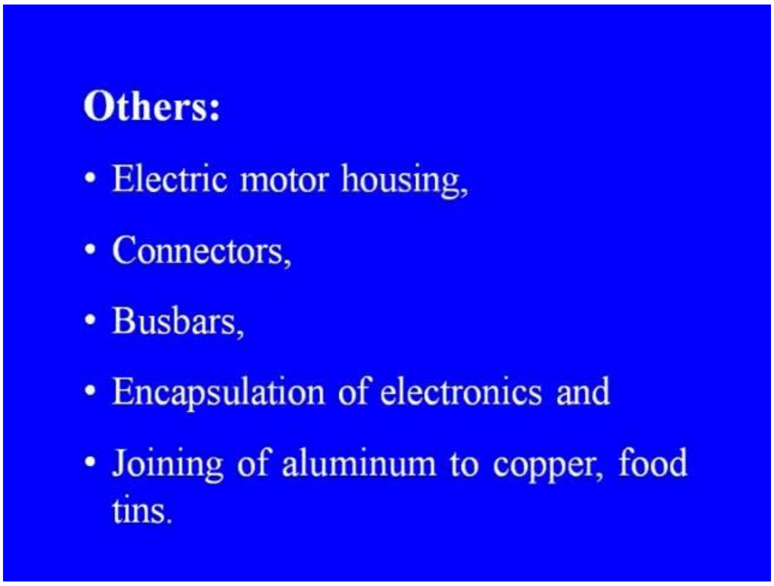

Other applications includes electric motor housing, connectors, bus bars, encapsulation of electronics and joining of aluminum to copper, food tins etcetera. Now, let us summarize what we have studied in this particular session. We have studied the friction welding process, its features, variant processes like the orbital friction welding, their advantages and applications. We have discussed the friction stir welding process in details, then unique advantages of this friction stir welding process, its features, advantages and then the applications of this process were also discussed. We hope this session was interesting and informative.

Thank you.