Joining Technologies of Commercial Importance

Dr. K. Dwivedi
Department of Mechanical and Industrial Engineering
Indian Institute of Technology – Roorkee

Lecture – 24
Ultrasonic Joining

Hello, I welcome you all in this presentation on the ultrasonic welding process related to the subject joining technology for the metal.

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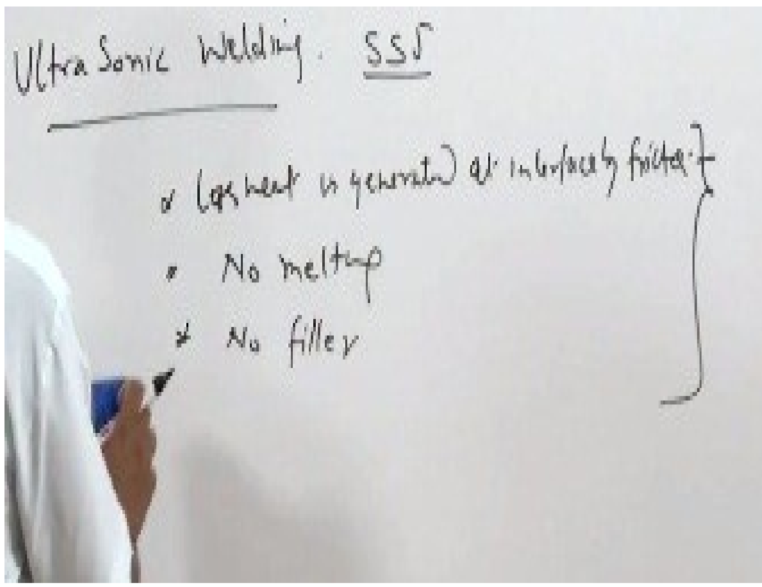

This ultrasonic welding process is one of the solid state joining process were very less heat is generated at the interface generated at interface by friction. And another important thing there is no melting or fusion, there is no filler use of filler so the mating surfaces are brought together in metal to metal contact and then using the vibratory energy, ultrasonic vibratory energy the joint is made through the localized plastic deformation at the interface.

So very less heat in is generated which at the most comes out to be like say 35 to 50% of the-- like say the temperature rise due to the heat generation is the temperature of a melting point in absolute scale. So point 35 to 50% of the melting point temperature in Kelvin of the metal that is the maximum temperature rise due to the frictional heat generated in course of the welding. And this heat helps to soften the metal, facilitate the plastic flow of the metal at the interface.

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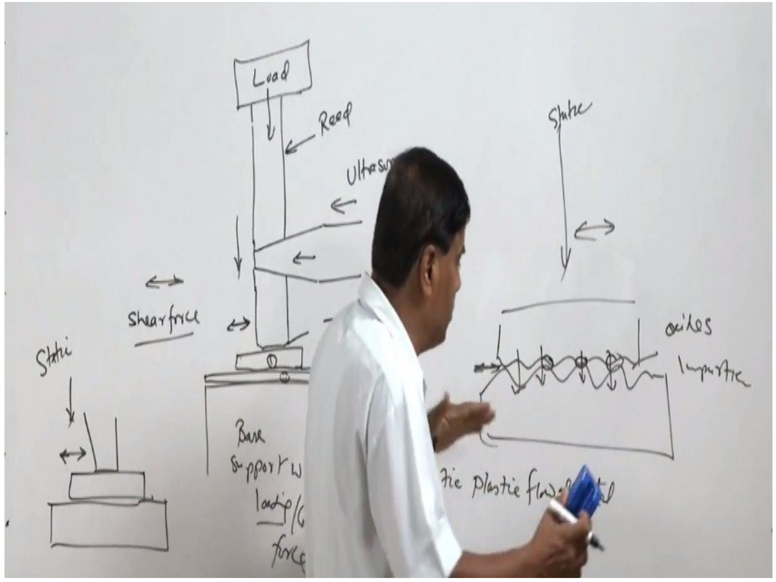

So sequentially we will see now that the what kind of system is used here. Let us say this is the base and the component to be joined is placed over the base, the base will support the work piece or the work pieces and the load which is applied, so loading or the clamping forces is supported by the base. Another component to be joined in very clean condition is placed over it like this. So there is a direct metal to metal contact between the two components.

This is part one to be joined with the part two say. And then over this then one member is brought in contact with the surface of the one of the component which is placed at top. This is a tip, tip of the sonotrode, this transfers the vibratory energy to the plates the sheets being joined. And this is done with the help of one arrangement where in we will see that-- this is the transducer which will be supplying the ultrasonic vibrations like this.

This component is vertical and then applied load. So here the load is applied which will apply the necessary clamping force and this one is called Reed. Through the reed load is applied onto the work piece and this transducer will be supplying the necessary vibratory energy so, it will be at very frequency so this in turn will be causing the literal movement at the tip. So basically the force is applied through the reed.

And you can say the Shear force is applied through this vibrations, at very high frequency. So the tip basically applies both a combination of compressive force, clamping force and the Shear force. So Shear force, the clamping force is static in nature while the Shear force is a dynamic acting literally and acting at very high frequency. So when there is a direct metal to metal contact like say this is a real surface of the upper component.

And the real surface of the lower component having the contact at peaks and valleys under the constant static load and the literal shear force. Initially, the oxide impurities all these are flushed out or removed from the interface, so these impurities are removed and direct metal to metal contact is established in the initial stage under the effect of the static clamping force and the vibratory shear forces.

Once this contact is established metal to metal contact is established actual contact area starts to grow. And this growth is facilitated by Elastic-Plastic flow of the metal at the interface. So as the process continues Elastic-Plastic flow at the interface will continue to increase and this in turn will keep on increasing the direct metal to metal contact area and subsequently we will see that—

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The contact between contact between the two pieces to be joined is perfect and under this condition what we will see, we will see that due to the Elastic-Plastic flow of the material especially at the interface. So what are the things involved? The Friction and Elastic-Plastic flow, all these things will generate enough heat.

So heat generation will cause the temperature rise 0.3 to 0.5 times of the melting point of the metal in Kelvin, right. So this increase in temperature is high enough to cause the recrystallization and the formation of the new grain. And these things actually facilitate the refinement of the grains at the interface one and the second is cold or work hardening due to the plastic flow of the metal, work hardening although this is very mild or the moderate.

So the material which is formed at the interface is moderately cold work and the refined, why? Due to the Elastic-Plastic flow as well as the frictional heat generated causes the enough temperature rise for the recrystallization to take place.

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So if we measure the hardness at the interface we may find we refine that this is the interface then on approaching towards the interface we will refine the increase in bit hardness and this increase in hardness is attributed to the moderate work hardening which is taking place due to the Elastic-Plastic flow of the material at the interface and then additionally the grain refinement of the material at the interface due to the continues deformation in both the direction of the material in course of the ultrasonic welding process.

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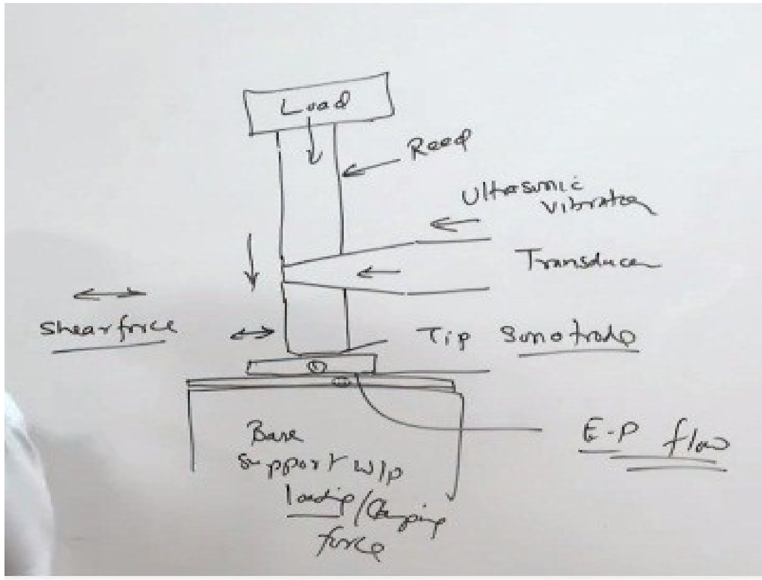

So in this case what we have seen we area applying the static load which will be basically holding the work pieces to be join and then literal force, literal shear force which will you apply through the – in form of vibratory energy through the transducer -- this combination of the two actually facilitates very Elastic-Plastic flow very dynamic conditions at the interface and facilitate the Elastic-Plastic flow of the material at the interface.

And that in turn helps in development of the joint at the interface. So keeping this principle in mind if we see that no external heat was supplied and only-

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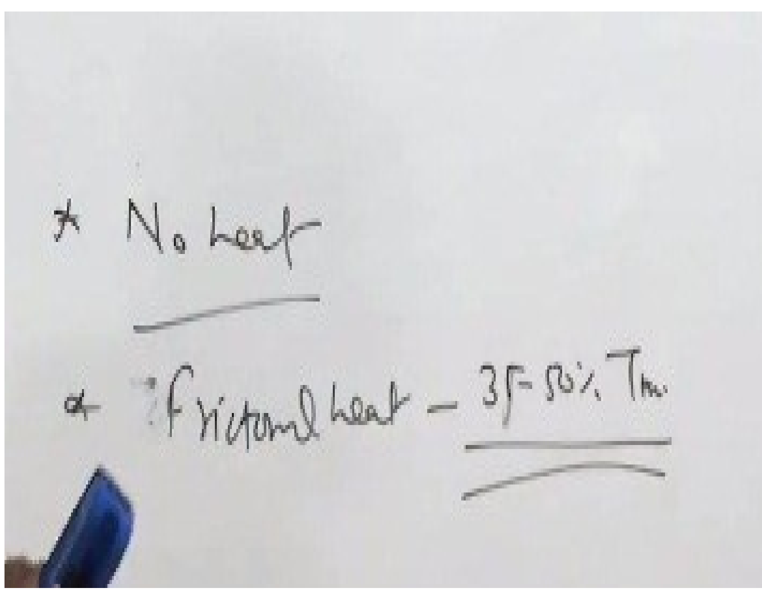

So we did not supplied heat from the outside and despite of this without any supply of heat only the frictional heat frictional heat caused enough temperature rise like say 35 to 50% of the melting point of the metal in Kelvin scale which is found to be enough for recrystallization of the material and the plastic deformation coupled with the recrystallization results in the refinement of the grain structure also.

So since there has been no melting so not cost structure, no heat and the heat being generated at very small area at the interface and therefore the issues related with the heat are extremely limited.

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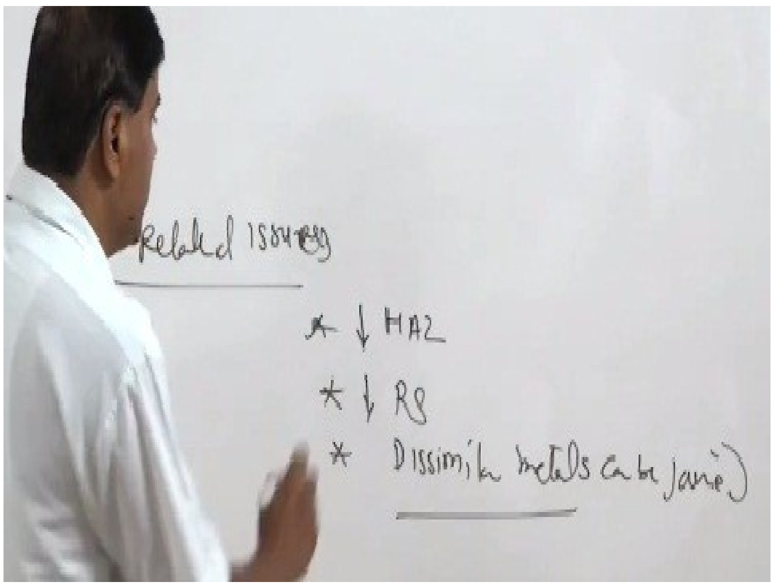

So no heat related issues in case of the ultrasonic welding, and because of this we will since is no melting cost structure and the heat being generated over a very small volume of the metal so what we will see very less HAZ, very reduced residual stresses. And any dissimilar systems, dissimilar metals which are metallurgical incompatible metals can be joined by this process, okay. So these are some of the benefits. Additionally, due to the inherent nature of the process itself.

Now we will see the things which actually matter in a development of the sound and perfect weld joint. So for that what we need to see.

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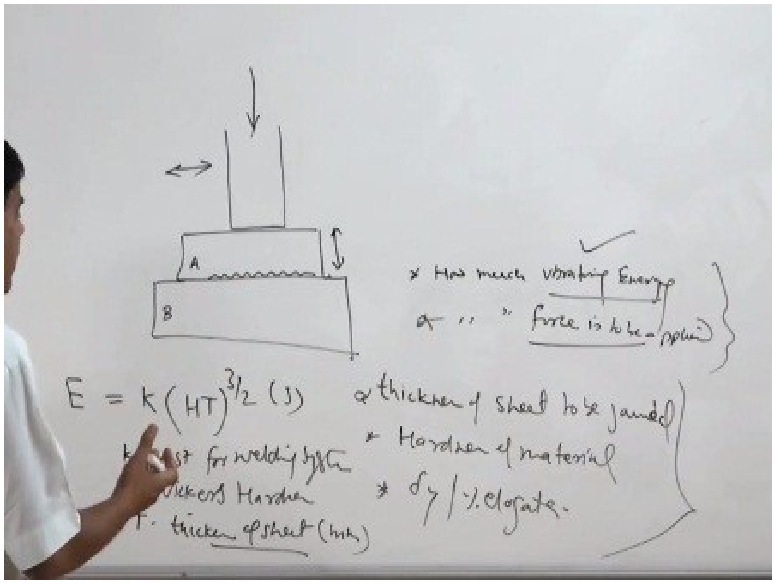

Like this is the upper component and this is sonotrode transferring the vibratory energy, supplying the literal shear force through the vibrations and the static clamping force and this is the another member with which it is to be joined, so part A and the part B. So how much vibrate energy is to be supplied? There are some aspects like how much vibratory energy is to be supplied.

This is one thing and the second is how much force, force is to be applied for development of the sound weld joint. So what is important here, the kind of surface conditions. Like surface roughness, presence of the impurities, hardness of the material so the factors that affect these two vibratory energy, and the clamping force which is to be applied is influenced by thickness of the sheets to be joined.

This is one thickness of the sheets to be joined then hardness of the material. Then we will see under the percentage elongation also to some extent determined up the plastic flow behavior of the material at the interface during the process. So these factors also affect the amount of energy that it will take before development of the sound weld joined apart from the presence of the impurities and the oxides etcetera.

So since the thickness and the factor that is governing the ability for the plastic flow influence the success of the process significantly and that is why these two parameters significantly determine the energy which is required for development of the ultrasonic joints and which his given by say the vibratory energy need to be supplied say in Joule is found the function of the K multiplied by H into T raise to the power 3 by 2.

So this is the energy in Joules or K is constant for welding system being used for development of the weld joint, H is the weakest hardness of the material which is being joints—so higher is the--so this because hardness number will come, higher is the hardness greater will higher will be resistance for the plastic flow and so greater will energy it will take for development of the joint and similarly the thickness T thickness of the sheets being joined in MM.

S the thicker is the plate greater will be the energy requirement for development of the weld joints. Because these needs to be transferred across to the interface and then so the thickness of this top sheet will definitely be mattering here definitely be important. So greater the thickness of this plate greater will be the energy requirement to be welded and similarly higher is the yield strength higher is the hardness lower is the ductility greater requirement of the energy for developing sound weld joint.

So considering this points materials having low sigma y, low hardness they will be easier to be welded and similarly less in thickness they will be easier to be welded. So thin sheet and soft metals, soft metals can be easily soft—easily ultrasonically welded as compare to the harder high strength materials of the higher sections due to the energy requirement.

And it is the capacity of the ultrasonic welding systems that actually limits the maximum thickness which can be welded using this process, since not very high energy ultrasonic welding systems are available. So the process is basically limited to the thin sheet or very thin gages sheets.

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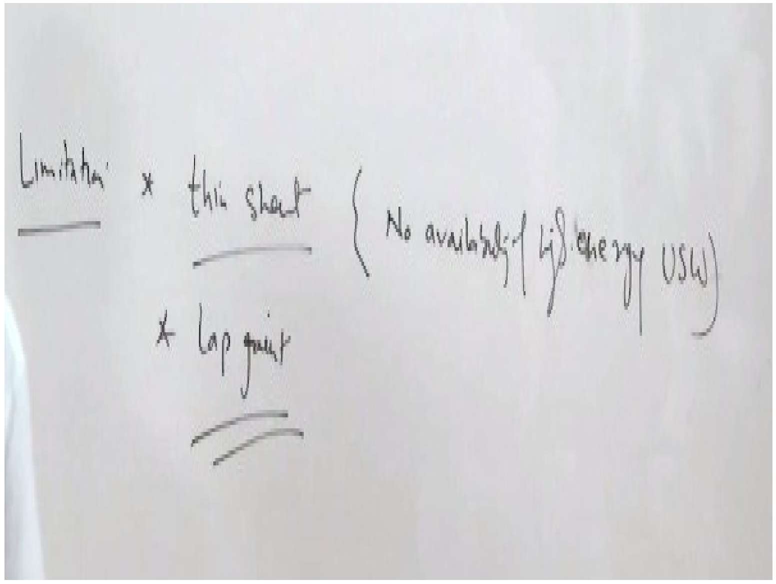

And therefore, what we will see limitation wise as far as the limitation the process is limited to very thin sheets. And this limitation comes primarily from the non-availability of high energy, high energy ultrasonic welding systems. So if we have high energy ultrasonic – high energy ultrasonic welding systems then definitely it is possible to join even the sheets of the greater thickness.

Another one is that this is limited for the Lap Joint configurations only. In other configuration joints are not so easily possible, so therefore the two major things can say associated with this processes in form of the limitations.

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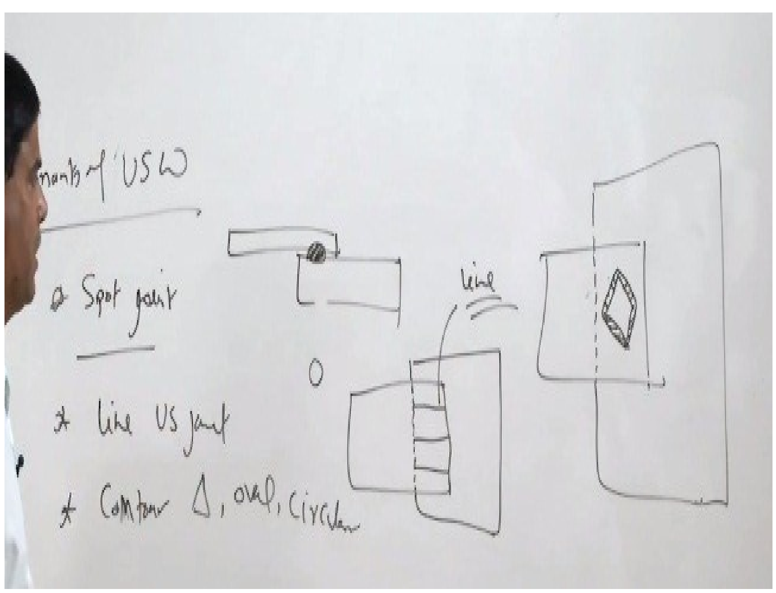

Now the kind of joints which can be made using the ultrasonic welding processes if we have to see the ultrasonic welding process very common that Spot joints are made wherein one sheet is placed over the another and one spot kind of joint is made at the interface so section will be circular in this case, and its area will determine the shear strength load carrying capacity of the joint.

So this is most common form which we can say as a Variance of an Ultrasonic Welding process. One is spot joint another is you can say Line Ultrasonic Joint where primarily if we see this in top this is the this is the upper plate and this is the lower plate like this to have been joined and then in this case joint is made at the interface along a particular line like this only. So, in this case ultrasonically welded joints like-- 3 joints but in form of the line.

So of course we have to use the sonotrode tip according to the shape which is desired. It can be of any other particular contour also like it can be triangular, it can be oval or it can be circular shape like spot weld so in that case, like say, here this is the top sheet and this is the, the bottom one and if you want to make the joint of a particular configuration in that case the sonotrode tip is to be made according to the shape desire like say in that case weld line will be made according to the geometry of the sonotrode tip shape.

And this will with the kind of a joint along which it will be made. This will be like the contour ultrasonic weld joints where the joint geometry will be governed by the geometry of the geometry of the ultrasonic sonotrode tip. So these are the different variance and as it has been said the process is limited to the thin sheets. Now we will see some other details and few examples of the typical situations where ultrasonic weld joints are used.

So we will quickly go through the figures and specific diagrams.

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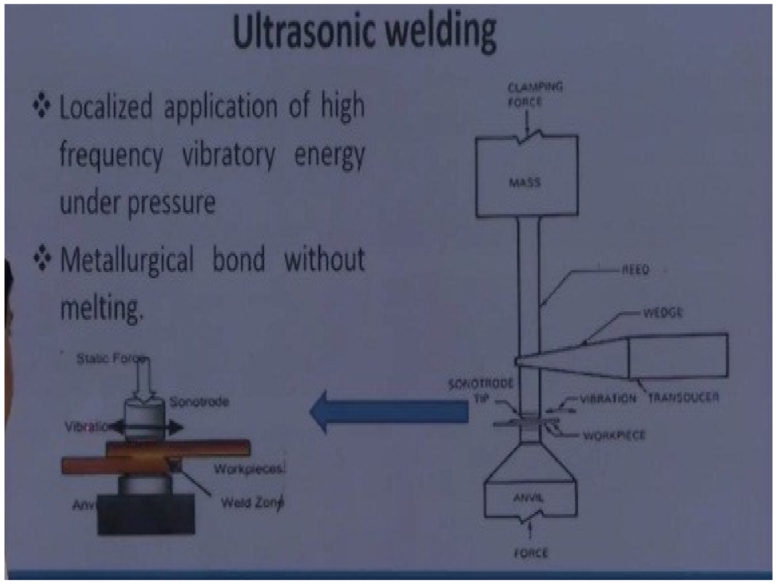

This is the dead weight or force through which mass or the force through which it is applied through the reed and then the wedge will be supplying the vibratory energy through the transducer to the sonotrode tip and here we have the sheets to be joint and this is the base or the anvil which will be providing the support to the clamping force as well the force which is generated being generated in course of the welding.

Very localized of high frequency vibratory energy under pressure and metallurgical bond at the interfaces created like there is Sonotrode tip, Static Force and Vibratory energy facilitates the, the deformation at the interface and that helps in development of the weld joints.

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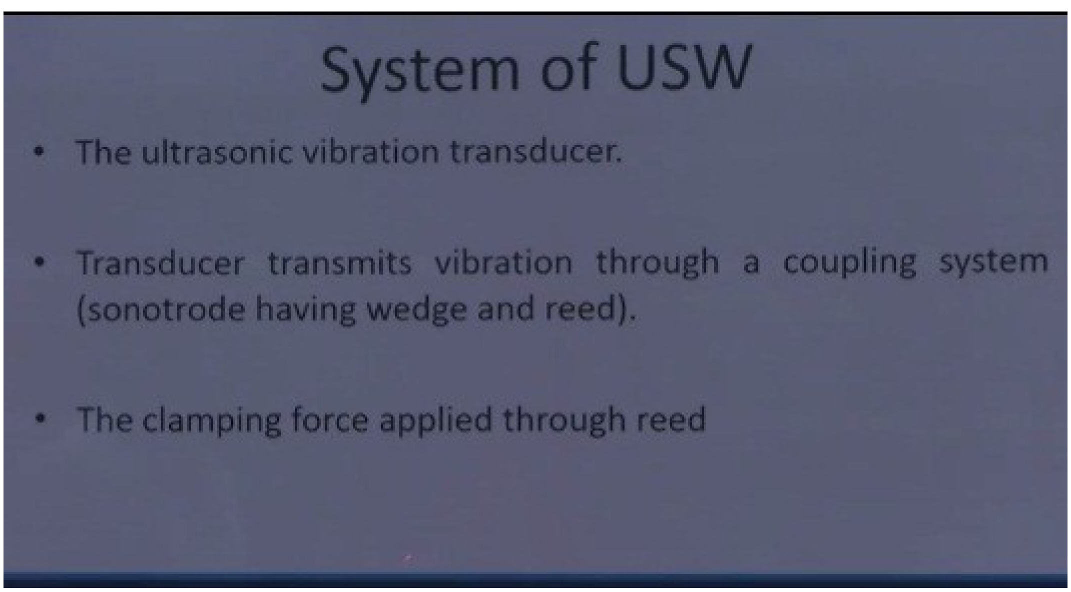

Ultrasonic vibration are transmitted through the transducers, transducers transmits the vibration through a coupling system and clamping forces are applied through the reed.

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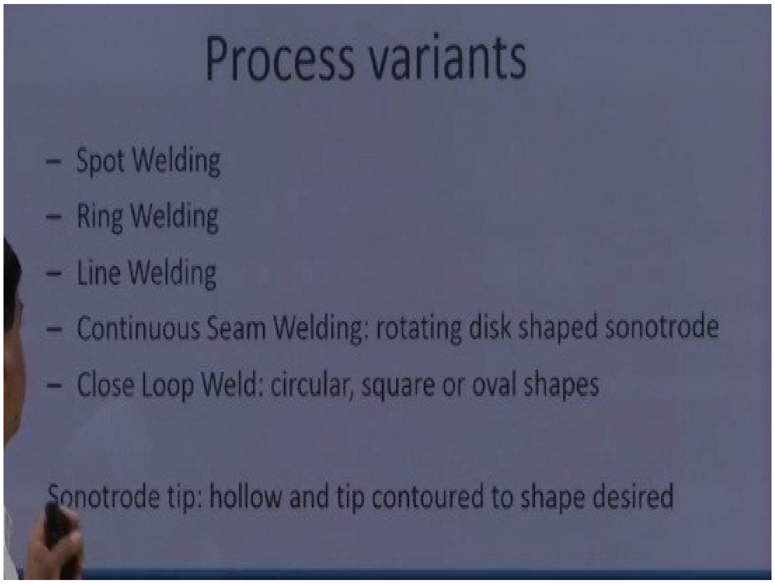

These are the various process variance as I have said it maybe Spot, Ring, Line, Continuous Seam wherein the rotating disk shaped sonotrode tip is used or the Close Loop Weld like I have explained according to the requirement of the sonotrode tip is shaped for circular square or oval shape, so sonotrode tip in that case made hollow and the tip is contoured to the shape desired.

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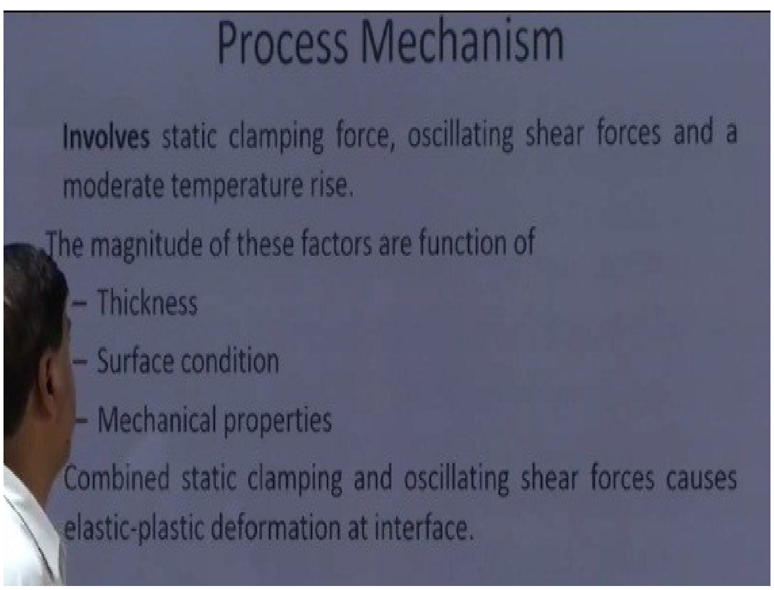

The different variables that affect the success of the process one is clamping force and shear oscillating force and under the process conditions due to the friction and deformation heat is generated so the heat generation is moderate. And these factors mean clamping force and oscillating force magnitude is influenced by means their selection depends on thickness of the sheet to be welded, hardness of the material in yield strength and the surface conditions of course.

So the combined clamping and oscillating forces causes elastic-plastic deformation at the interface.

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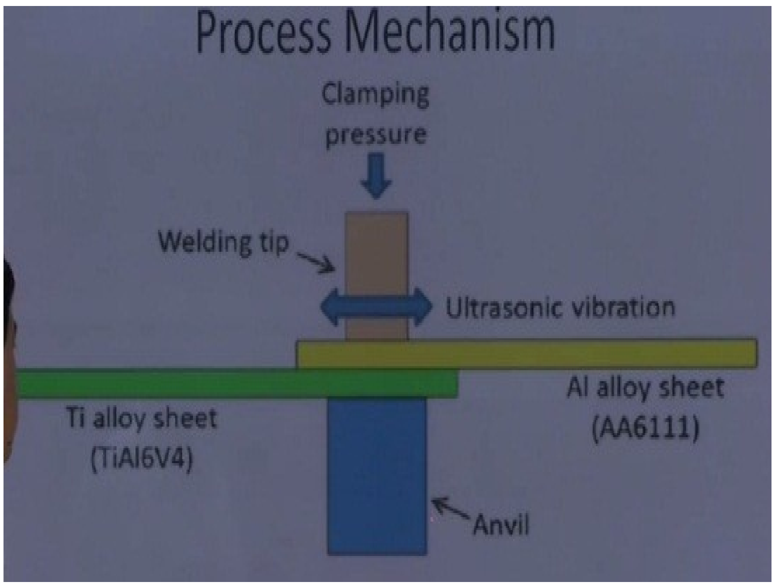

This is what we can see the clamping force and the ultrasonic vibrations appearing in form of and the two sheets are welded and the samples are supported over the anvil.

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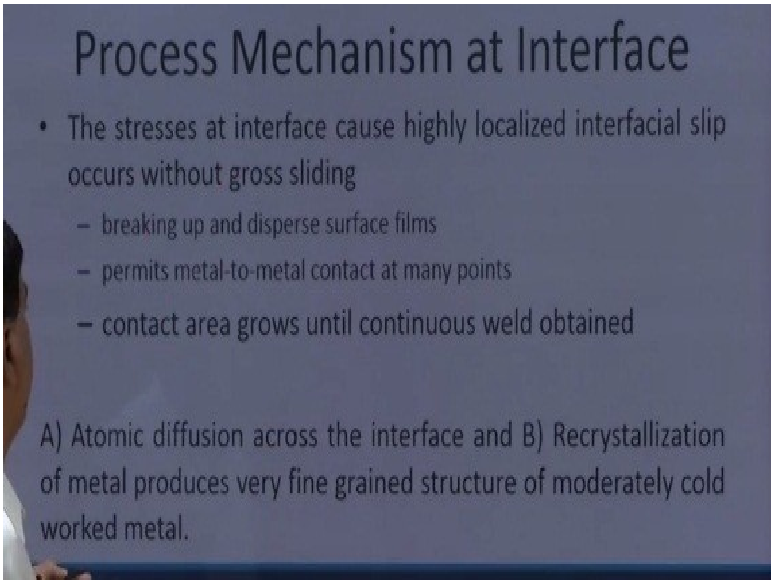

So in course of the process what happens initially the contact at the interface breaks the surface films in oxides, disperses them and metal to metal contact is established, gradually the Elastic-Plastic flow of the material at the interface continuous which in turn grows the size of the weld base. And in this process itself diffusion at the interface takes place and at the same time frictional heat causes enough rise in temperature for recrystallization to take place that in turn refines the grain structure.

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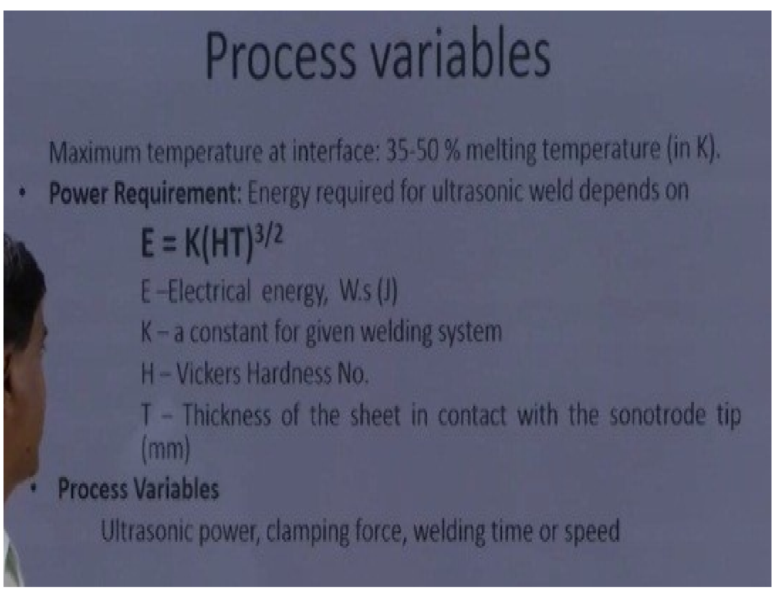

As I have said, the success of the process depends that how effectively energy we can supply and how much energy we need to supply so energy to be supplied electrical energy to be supplied in course of the process is found a function of the hardness of the material because hardness and thickness T and this will be governing the kind of how effectively the sound weld joint will be made.

So as per the thickness and the hardness of the material we need to supply the different amount of energies for ultrasonic welding process.

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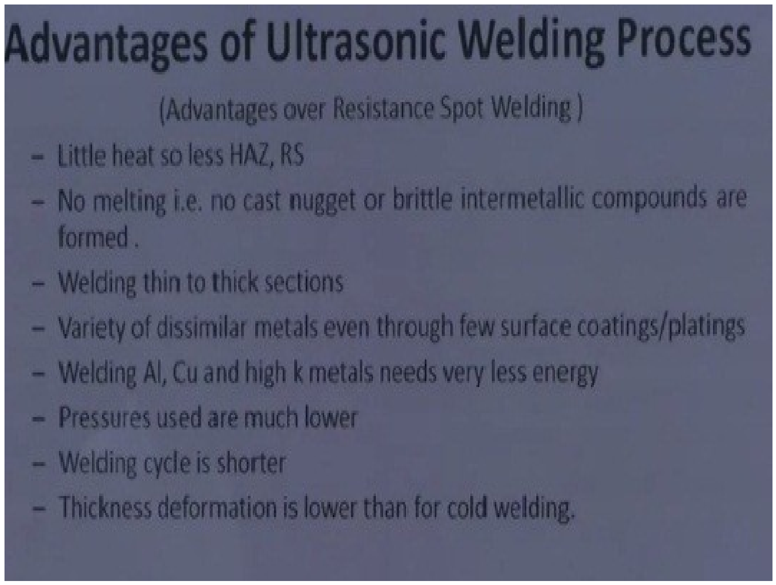

Advantage of processes I have said that very less heat is generated that to with the friction only therefore heat affected zone is very limited, RS are very limited, no melting so there is no nugget or intermetallic formation possibility. We can weld thin to thick sections but normally thin sections are welded thick sections are difficult due to the availability of the high energy ultrasonic welding systems.

Variety of dissimilar systems can be welded and these weldments can be made even through the thickness, so means if the base metal is coated then through the coating also the joints can be made by the ultrasonic process. So the amount of energies which are required for welding aluminum and copper they are much less as compare to that is required for resistance spot welding.

Similarly, the weld cycle is time is very short, pressures which are applied are much lower as compare to those which are used in case of the resistance spot welding process for joining of aluminum-copper and other high connectivity; high thermal connectivity metals. So thickness deformation, in this case also very limited as compare to the cold welding process.

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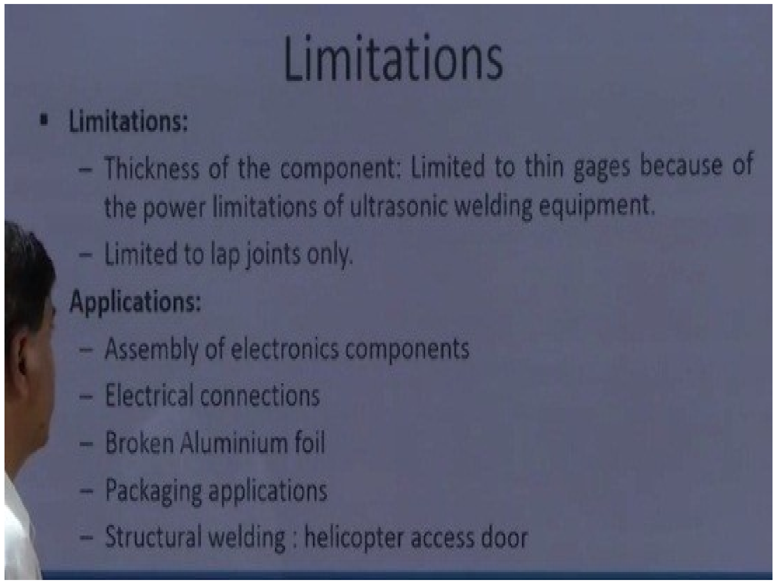

Limitation wise as I have already talked the process is limited to the thin gages because of the power limitations of the ultrasonic welding equipments which are available. And the process is limited to the lap joints only. Applications, the assembly of electronic components because the process is very light it can be used mainly for the thin gages and then electrical connections, broken aluminum foil, packaging applications wherever, so thin sections need to be joined of very delicate materials this process is used very effectively.

And in structural welding also like in helicopter access doors this process is effectively used. So now here I will summarize this presentation. In this presentation, I have talked the basic principles of the ultrasonic welding process, different factors that affect the soundness of the success of the process the process advantages and the limitations besides the areas where this process can be used. Thank you for your attention.