Manufacturing Processes – Casting and Joining
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Lecture – 17
Advanced Welding Processes

Hello and welcome back to the course on the Manufacturing Processes - Casting and Welding. Let me remind you, we were discussing resistance welding in our last discussion session, and we said that here we have the electric current which generates the heat in the joint between the two surfaces and that heat joins the two surfaces.

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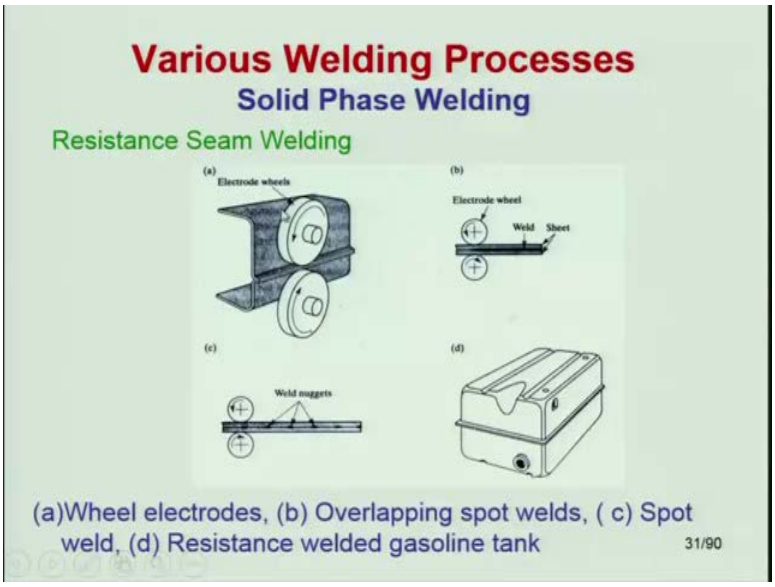

Here we have shown wheel electrodes used for seam welding. Then we have the overlapping spot welds, we have the spot welding and the resistance welded gasoline tank that has been shown to you. This is the gasoline tank which has been welded by the resistance seam welding.

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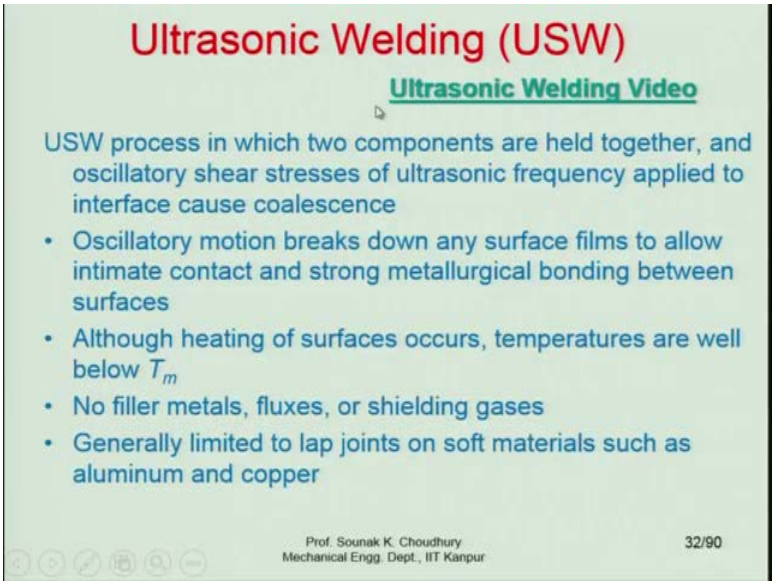

Next example is the ultrasonic welding. In case of ultrasonic welding, I also told you in my earlier discussion that in ultrasonic welding a very high frequency or ultrasonic frequency vibration is used. Because of that vibration the dirt and the grease from the two surfaces to be joined can be removed and because of that also the heat will be generated that will help in welding the two parts.

The ultrasonic welding process in which two components are held together, and oscillatory shear stresses of ultrasonic frequency applied to the interface cause the coalescence, the welding. The oscillatory motion breaks down any surface films to allow the intimate contact and the strong metallurgical bonding between the surfaces.

This ultrasonic frequency can be up to 25 kilo Hertz. Normally it is between 15 to 25 kilo Hertz. It is a very high frequency as you can see. At that frequency the electrode may vibrate on the parts to be joined.

Although heating of surfaces occurs, temperatures are well below melting temperature because the heating occurs at a very small zone, very small area. No filler metals, fluxes or shielding gases required. That is an advantage for this, advantage of the ultrasonic welding.

Generally limited to lap joints on soft materials such as aluminum, copper etc. Once again these are the advantages that there is no filler metal, temperature well below the melting point of the parts to be joined and so on. I would like to show you a small video clip that will clarify the working principle of the ultrasonic welding.

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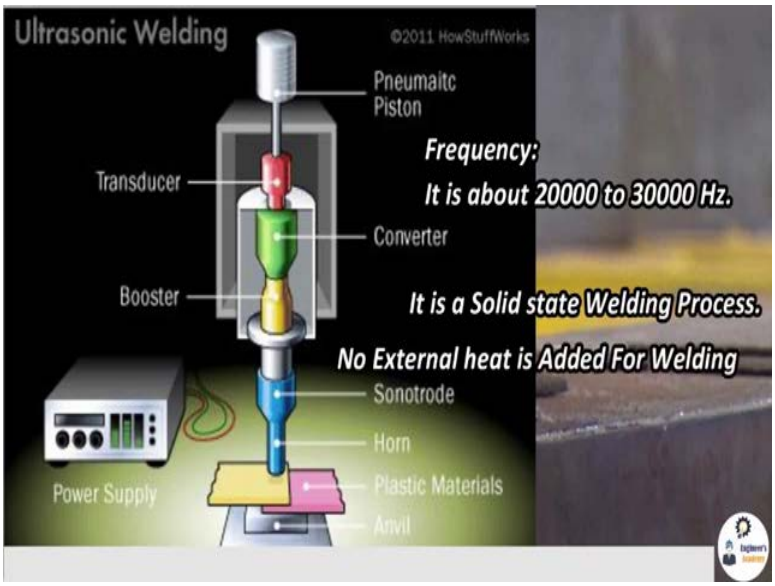

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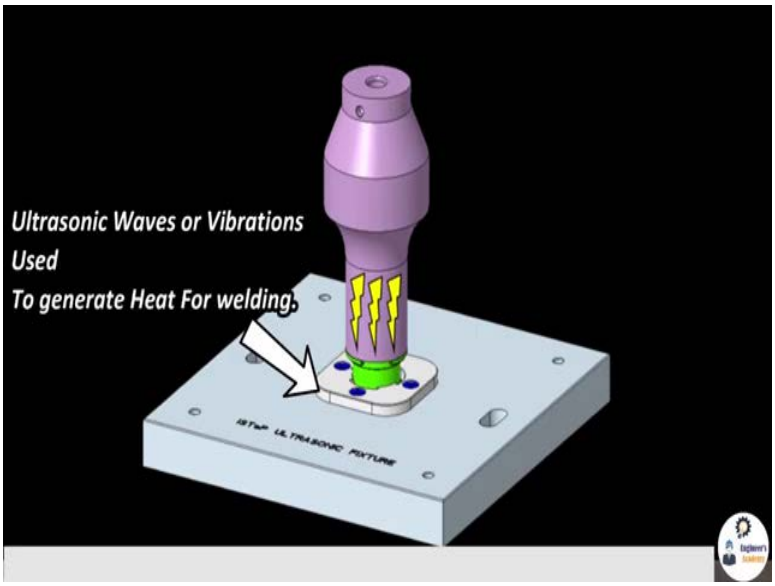

Ultrasonic welding is a welding process in which ultrasonic waves or vibrations are used to generate heat for welding. Ultrasonic means those vibration waves which have frequency above the normal hearing range. It is about 20000 to 30000 Hertz. It is a solid state welding process. Solid state welding is a welding process in which no external heat is added for welding.

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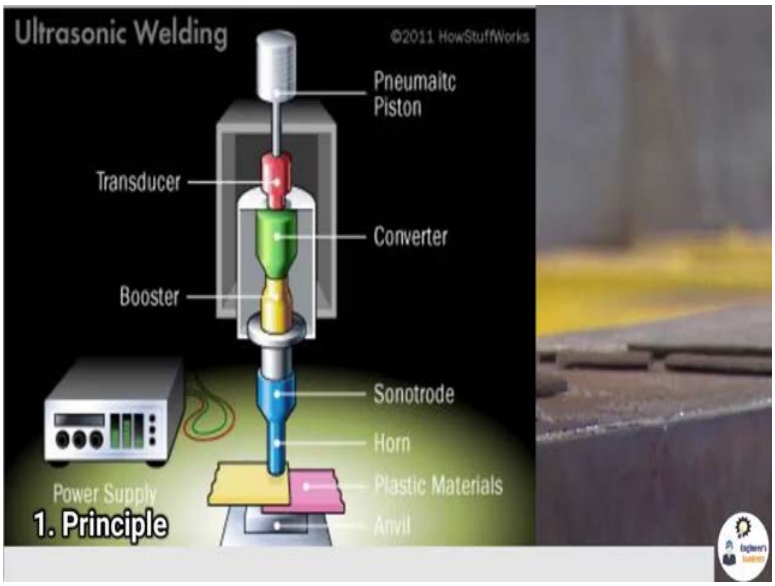

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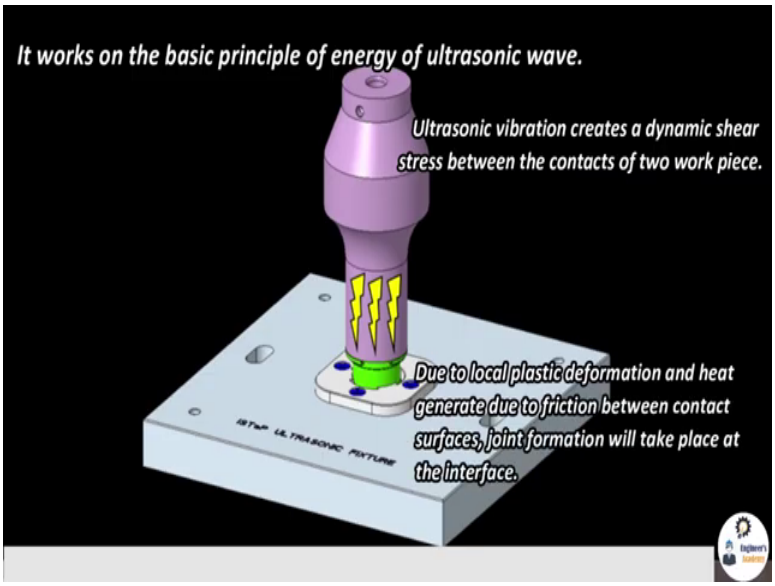

It works on the basic principle of energy of ultrasonic wave. Ultrasonic vibration creates a dynamic shear stress between the contacts of two work piece. Due to local plastic deformation and heat generate due to friction between contact surfaces, joint formation will take place at the interface.

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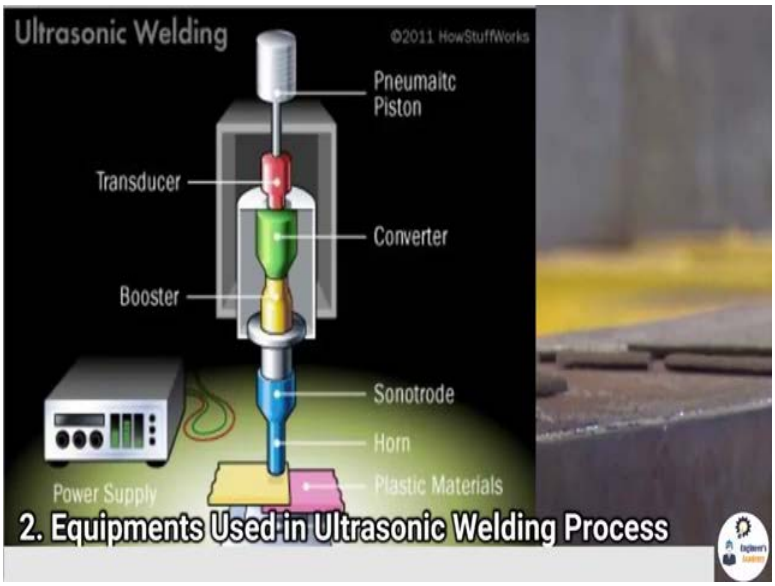

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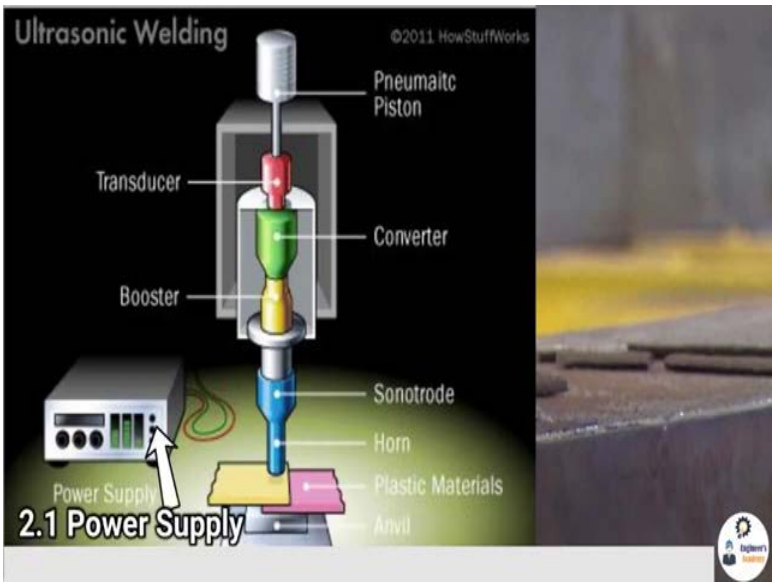

Now, let us talk about the equipment used in ultrasonic welding process. First is power supply. The ultrasonic welding needs high frequency and high voltage power supply. This power is needed by the transducer to generate vibrations.

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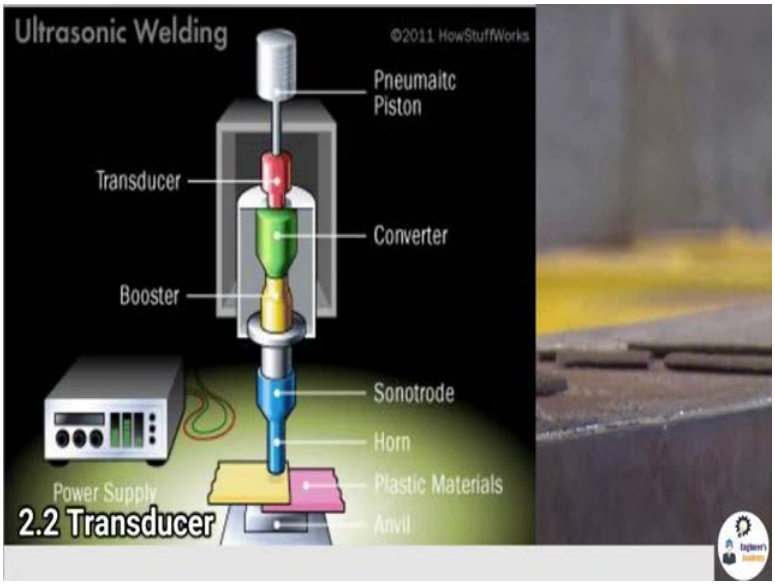

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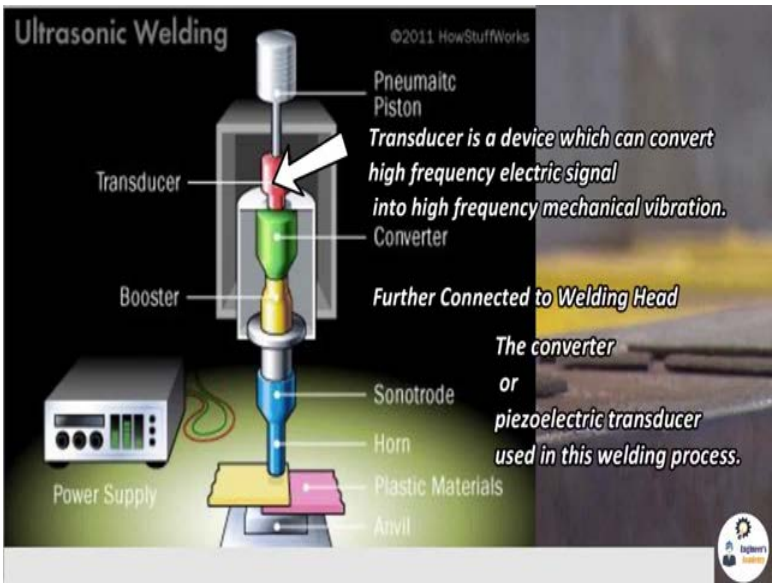

Second is transducer. Transducer is a device which can convert high frequency electric signal into high frequency mechanical vibration. This is connected with the welding head. The converter or piezoelectric transducer used in this welding process.

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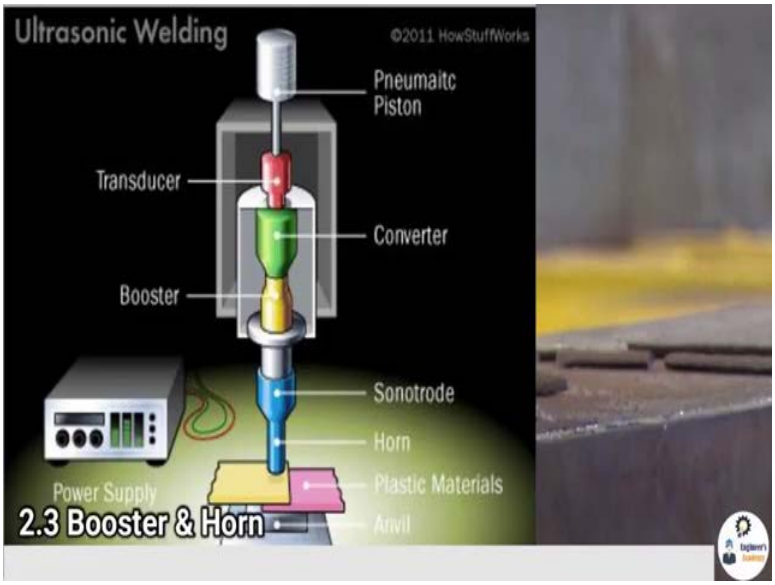

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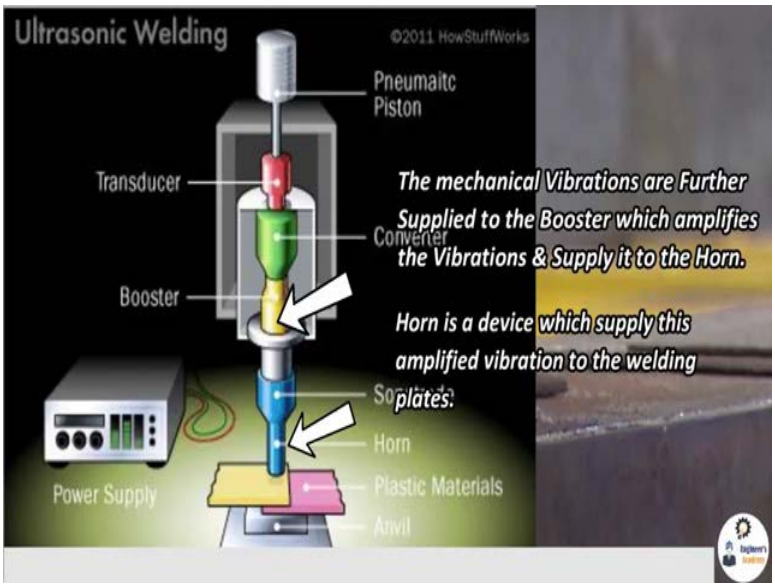

Third is booster and horn; the mechanical vibration created by the transducer is supplied to the booster which amplifies this vibration and supply to the horn. Horn is a device which supply this amplified vibration to the welding plates.

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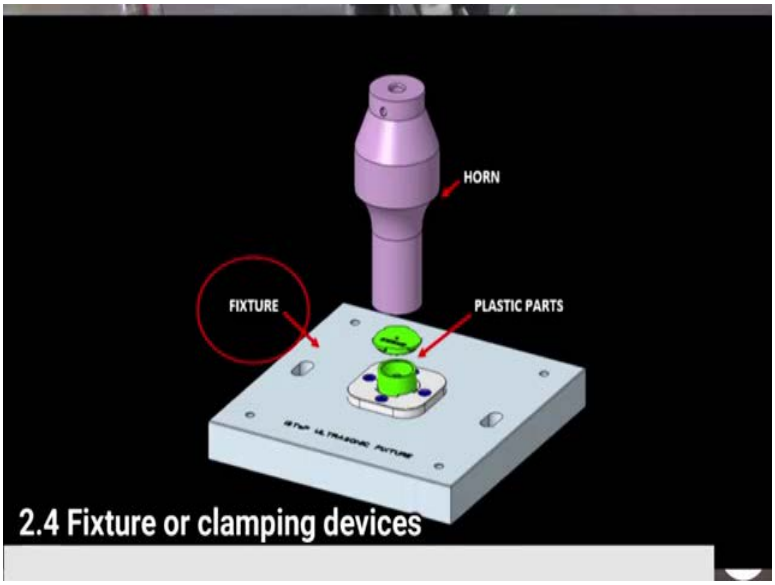

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Fourth is fixture and clamping devices. This device is essential in the ultrasonic welding. This uses either electrical, hydraulic, pneumatic, or mechanical energy to hold the plates into desired location.

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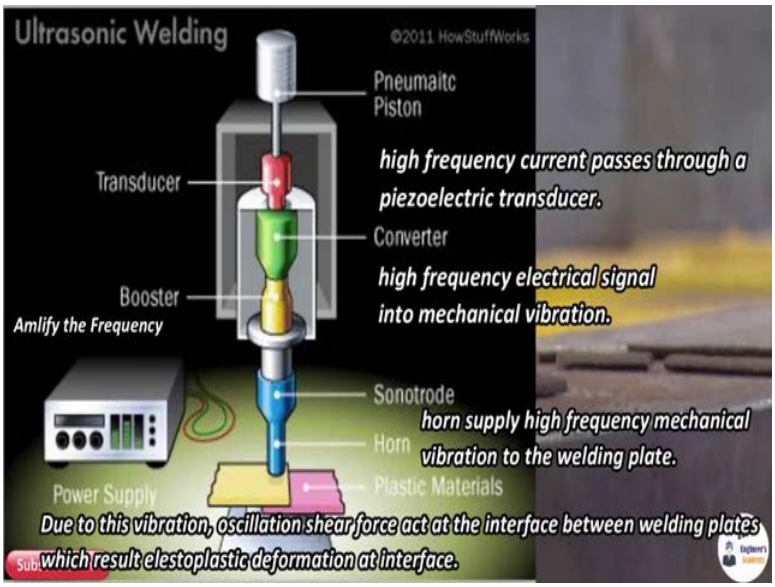

Now, we know the basic concept of ultrasonic welding. Let us see the working of ultrasonic welding. The start high frequency current passes through a piezoelectric transducer. This transducer converts high frequency electrical signal into mechanical vibration, this vibration further supply to the booster which amplify its frequency.

The amplified high frequency vibration passes through horn which is in contact with welding plate. This welding creates lap joint. One plant of the weld is fixed into fixture and the other one is in direct contact with horn. These plates are fixed under moderate pressure force.

The horn supply high frequency mechanical vibration to the welding plate. Due to this vibration, oscillation shear force act at the interface between welding plates which result elestoplastic deformation at interface. It also creates a localized temperature rise due to mechanical force and friction. This heat helps in plastic deformation at interface and makes a strong joint without melting of work piece or using filler metal.

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Let us talk about its advantages, disadvantages, and application.

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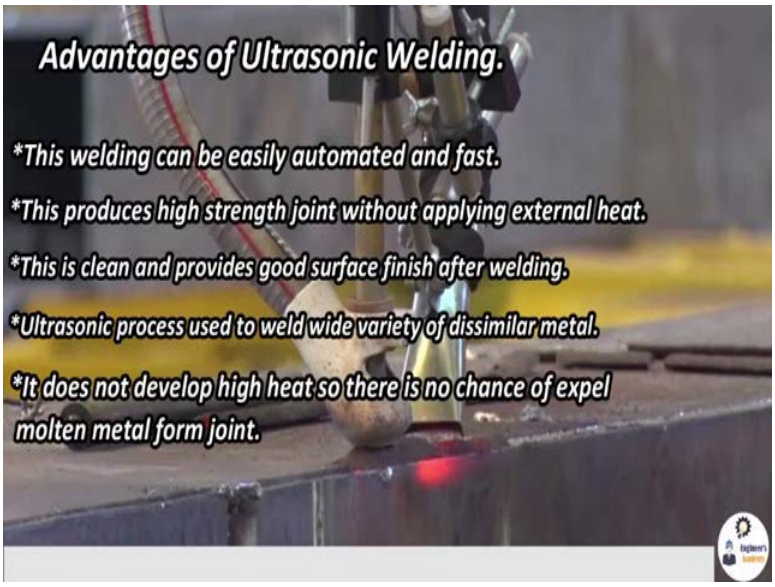

Advantages, this welding can be easily automated and fast. This produces high strength joint without applying external heat. This is clean and provides good surface finish after welding. Ultrasonic process used to weld wide variety of dissimilar metal. It does not develop high heat so there is no chance of expel molten metal form joint.

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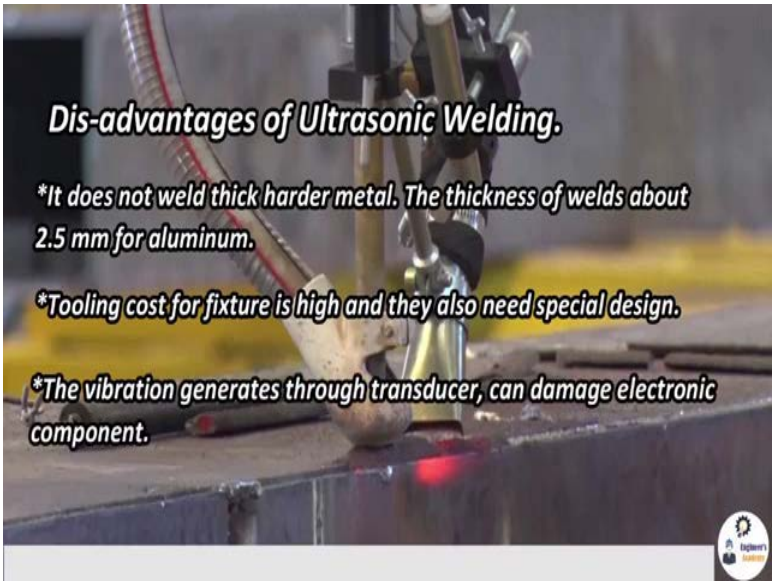

Disadvantages: it does not weld thick harder metal. The thickness of welds about 2.5 millimeters for aluminum. Tooling cost for fixture is high and they also need special design. The vibration generates through transducer, can damage electronic component.

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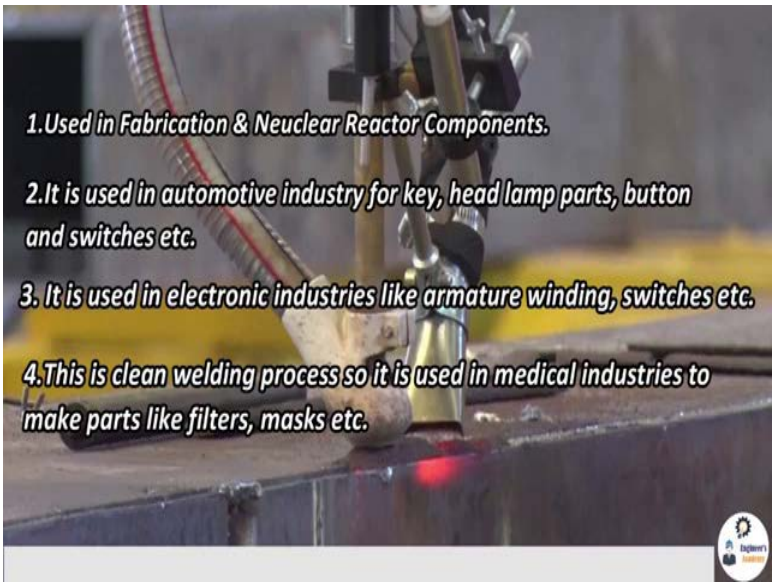

Applications: this welding is used in fabrication of nuclear reactor components. It is used in automotive industry for key, head lamp parts, button and switches, etcetera. Ultrasonic is used in electronic industries like armature winding, switches, etcetera. This is clean welding process, so it is used in medical industries to make parts like filters, masks, etcetera. This is all about ultrasonic welding process.

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here is how the ultrasonic welding process works, you have seen that. Of course, it was shown in the diagrams. But point wise everything was explained in a proper way. It was said that it is 25 to 30,000 Hertz is the frequency at which the two metals are joined. Only thing is that here if the parts are very thick, plates are very thick then it is difficult to join.

And normally the softer materials are joined. However, the ultrasonic welding is a clean welding process, and the weld pool is very clean because, there is no other machining, or any other process will be required to clean the welded zone as it is required in case of other welding processes.

Therefore, this is very conveniently used for many parts. Generally, limited to lap joints on the soft materials such as aluminum and copper, and that should not be very thick.

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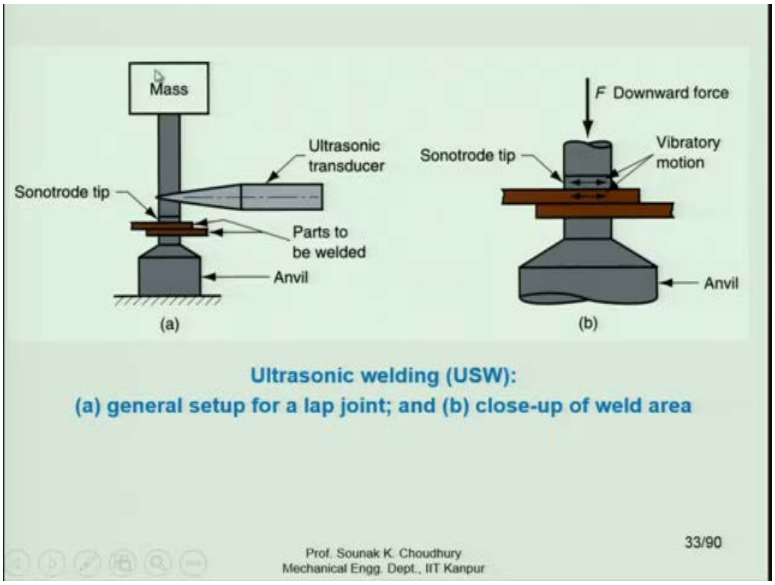

Here these diagrams also show that this is the mass, this is the transducer, this is the cone, this cone is used as an amplifier for the transducer, it amplifies the vibration, to be applied at this point, transducer is here. And as it was told to you that this transducer uses the piezoelectric elements and if we pass the current, piezoelectric elements will expand.

If we pass the high frequency current it will expand and come back to the initial position at that frequency at which the current is being passed. Suppose the current with 30,000 Hertz frequency is passing through. With that frequency it will vibrate. That is the principle which is used here in the transducer.

This is the tip. This tip is in contact with the parts to be welded, these are the two parts to be welded. The lower part is attached to the anvil, and this part is attached to that with the help of that tip. Here it is shown that this is the vibratory motion that you are getting, that is obtained along with the downward force to weld them. Generally, set up for a lap joint, and this is the close up of the weld area that has been shown in the exaggerated form.

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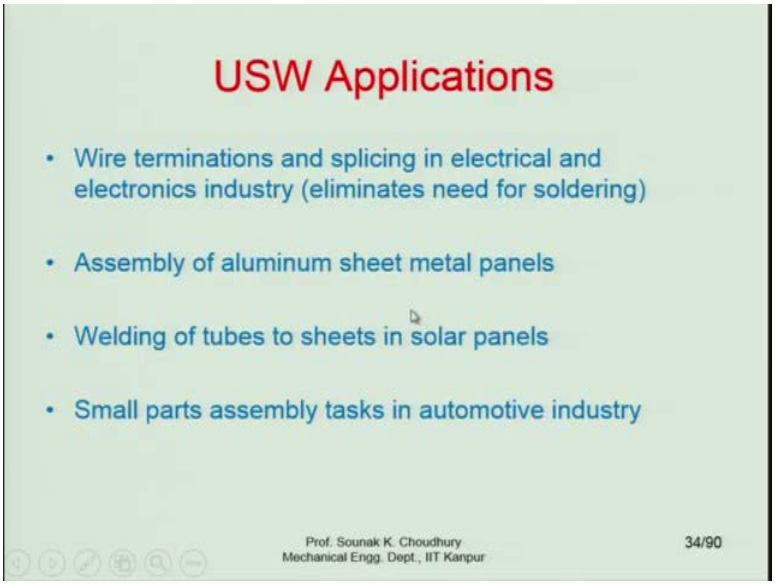

The application, as mentioned in that video, is in wire terminations and splicing in electrical and the electronics industry, eliminates the need of soldering. Instead of soldering it can be ultrasonic welding and it can be done very fast. Assembly of aluminum sheet metal panels. Welding of tubes to sheets in solar panels. Small parts assembly tasks in automotive industry and so on. These are wide applications of the ultrasonic welding.

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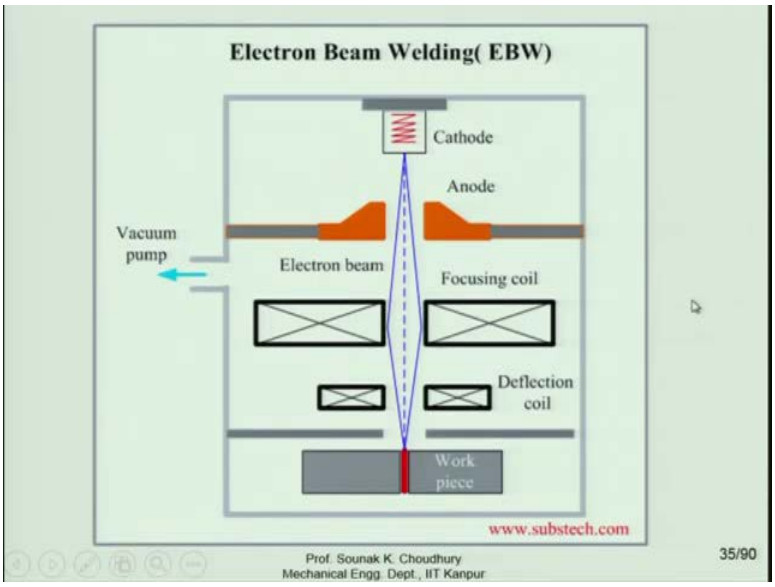

I told you initially that there are beam technologies which are very widely used in practice because, different kind of beams like ion beams, or electron beams, or plasma, arc, they can be used since the beams can be concentrated at a very tiny spot, in a micron

level tiny spot and the wattage can be very high, that is, the power concentration can be very high.

Let us take one example here. It is electron beam welding and let us see how it works. There is a cathode, and there is an anode here. This entire set-up is the electron beam machine or electron beam equipment from where the electrons can be generated, through the cathode and the anode. This is the electron gun.

The electrons, as the avalanche of electrons, are generated by the electron gun in the form of this ray, and this will be focused using the focusing coils. Those are the electromagnetic coils, with the help of that the beam can be focused at a very tiny spot.

There is another coil here, which is also electromagnetic coil. This is the deflection coil, so that this beam can be traveled. In place where you have to have a complicated joint, which is a contour type joint, for example, in that case the beam has to be rotated, beam has to be rotated along with that contour.

NC, CNC programming is used for rotating this deflection coil along with that the beam can be rotated. Of course, the rotation is not very complicated which is used here. This is the work piece, and these are the two parts. At this point, very high concentration of heat is generated because of the electron beam which is focused at a very tiny spot.

Workpiece is melted, and these two parts are joined. Normally it is done in the vacuum. The entire cabin will be connected to the vacuum pump, so that this operation can be performed in vacuum.

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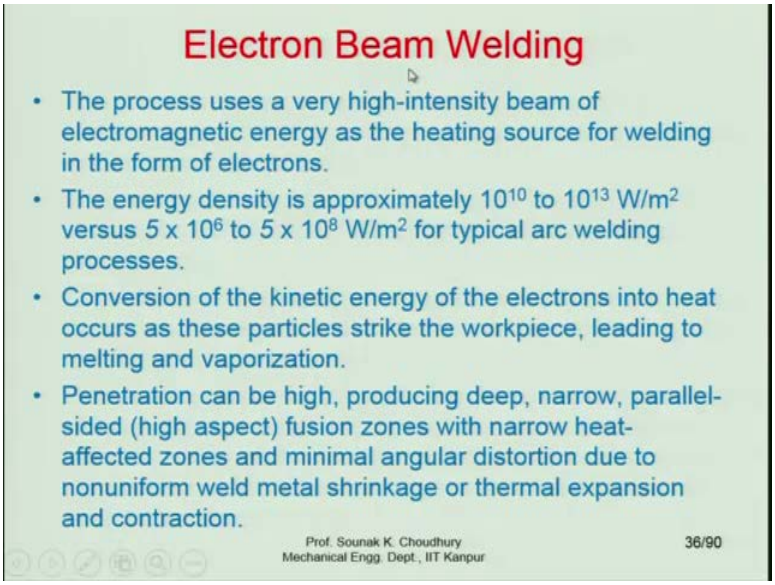

Electron beam welding: whatever I said is written in this slide in detail. The process uses a very high-intensity beam of the electromagnetic energy as the heating source for welding in the form of the electrons. The energy density is approximately $10^{10} - 10^{13} \frac{Watt}{m^2}$. So, as you can see that this is really very high energy concentration.

In typical arc welding process this energy concentration is $\left(5 \times 10^6 - 5 \times 10^8\right) \frac{Watt}{m^2}$. Now you can compare this value with the value $10^{10} - 10^{13} \frac{Watt}{m^2}$ which can be generated by the electron beam.

The conversion of the kinetic energy of the electrons into the heat occurs as these particles strike the work piece leading to melting and the vaporization, because it creates very high temperature. And temperature is so high that it can melt and evaporate any metal irrespective of the hardness of the metal.

Penetration can be high, producing deep, narrow, parallel sided, with high aspect ratio fusion zones with narrow heat affected zones and minimal angular distortion due to non-uniform weld metal shrinkage or thermal expansion and the contraction. As you can see that this is a precision welding process as well and process takes less time. The electron beam welding process itself goes on very fast.

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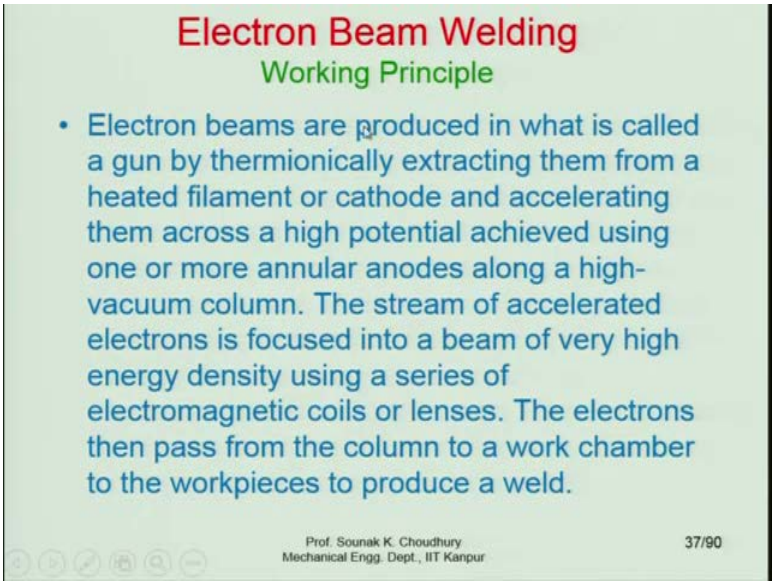

The working principle is that the electron beams are produced in what is called as a gun, as I said that electron beam gun by the thermionically extracting them from a heated filament, or cathode and accelerating them across a high potential achieved using one or more annular anodes along a high vacuum column.

The vacuum has to be generated because otherwise it cannot be focused, and it cannot be deflected. Otherwise, the beam will be affected.

Penetration can be high, producing deep, narrow, parallel sided fusion zones as I already said. The stream of accelerated electrons is focused into a beam of very high energy density using a series of electromagnetic coils, or they are also called the lenses. The electrons then pass from the column to a work chamber to the work-pieces to produce a weld.

This is rather simple. Basic task is to produce the electron beam. An electron beam is produced by the electron gun, readily available electron gun and that can be used in an appropriate vacuum zone, so that the welding can be performed.

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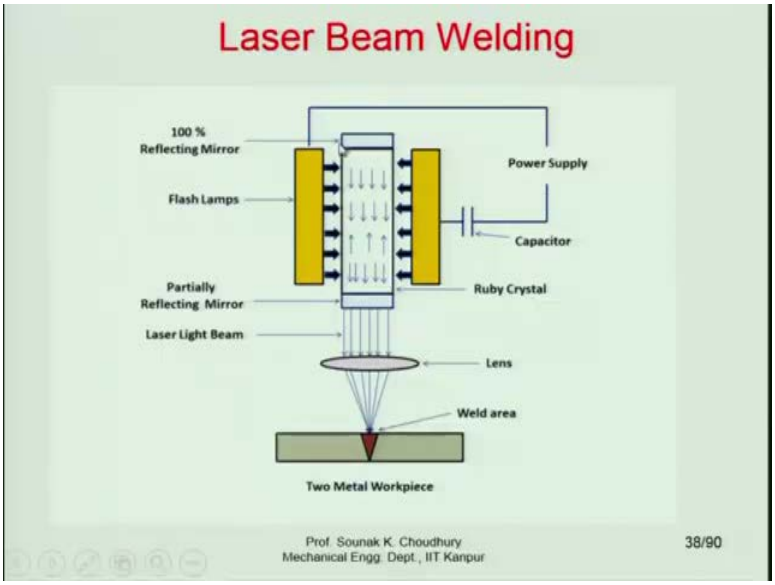

Another process, another beam technology is called the laser beam welding. In laser beam welding the beam is of laser instead of the electron as in case of the electron beam welding. Here we have the laser gun. Laser guns are also readily available.

Here we have the flash lamps, rays of which fall on the ruby crystal and that evolves the laser, laser beam and that laser beam can be focused at a very tiny spot, so that the temperature could go very high which can melt and evaporate the metal, the metal where it is to be melted. But here of course, we have the melting of that metal and that will create the coalescence of the two surfaces. That means they will get welded.

Overall, this is the power supply given to the flash lamps, so that the lamp can create the high intensity of the light which will be falling on the ruby crystal that is covered by the reflecting mirrors, so that the entire light can fall on the ruby crystal. This is the principle of the laser beam.

I mean creating the laser beam, how the laser beam can be created, and that laser beam falls on a lens which is used to focus the beam at a very tiny spot. And that is the weld area where the two metals can be welded. This is the principle of the laser beam welding.

By the way about this laser beam there is a legend that one King came and conquered one of the temples in India and the king was Alexander the Great. After conquering the temple, he went inside and got the Crown and put it on his head. Local people said to him that the crown belongs to God and the king should not take it, he should not put it on his head, or else he will die.

The king did not listen to them, he put it on his head and came out of the temple. The rumor is that after 3 days when he started from this temple he died. It is not known, of course what was the reason behind the king's death.

But scientists now explain that the Crown had Ruby crystals, and when the king put it on his head and went out, a very bright sunlight outside was flashed on the Ruby and the laser was created, which entered into his head and as a result, apparently the king died. That is of course is a legend and how much truth is in it, I cannot vouch for that.

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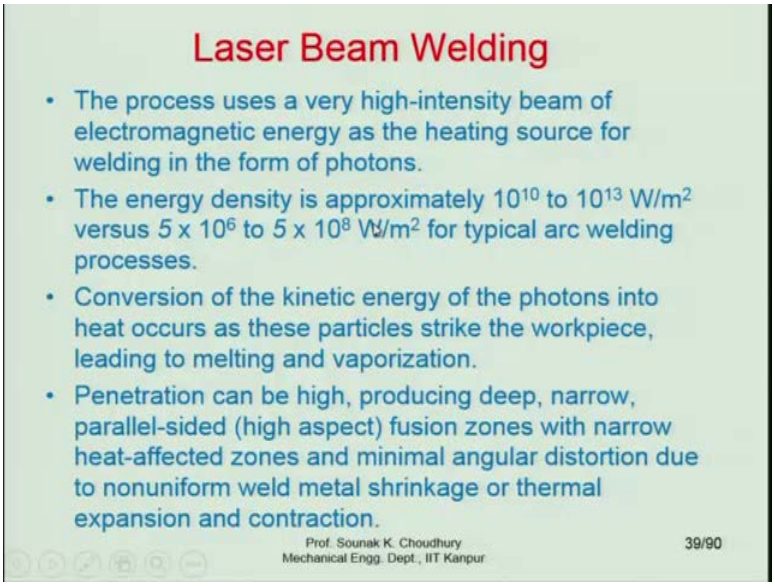

The energy density is approximately $10^{10} - 10^{13} \frac{Watt}{m^2}$. As I said that this is also very high. This we have already discussed in the case of the laser beam that the penetration can be high, producing deep, narrow, parallel sided fusion zones with narrow heat-affected zones.

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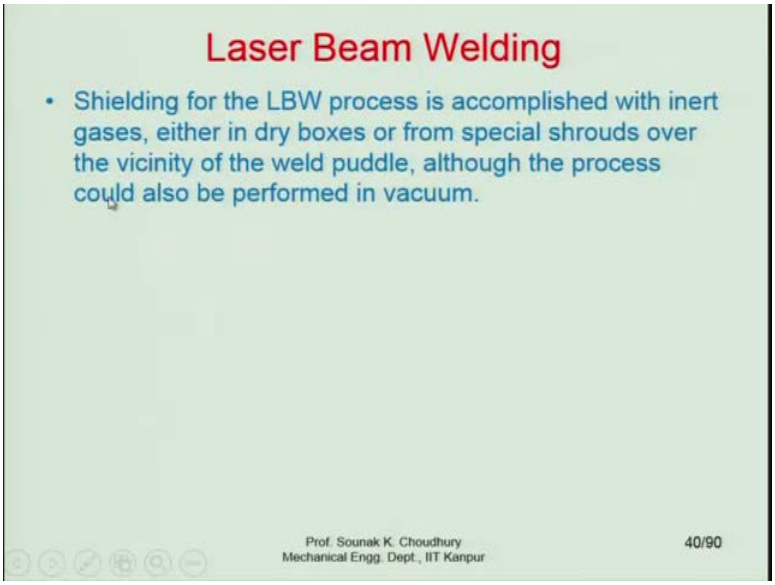

Shielding for the LBW that is the Laser Beam Welding process is accomplished with inert gases, either in dry boxes or from special shrouds over the vicinity of the weld puddle, although, the process could also be performed in a vacuum. Meaning that inside this is also closed, it can be in a vacuum, or it can be surrounded by the inert gases.

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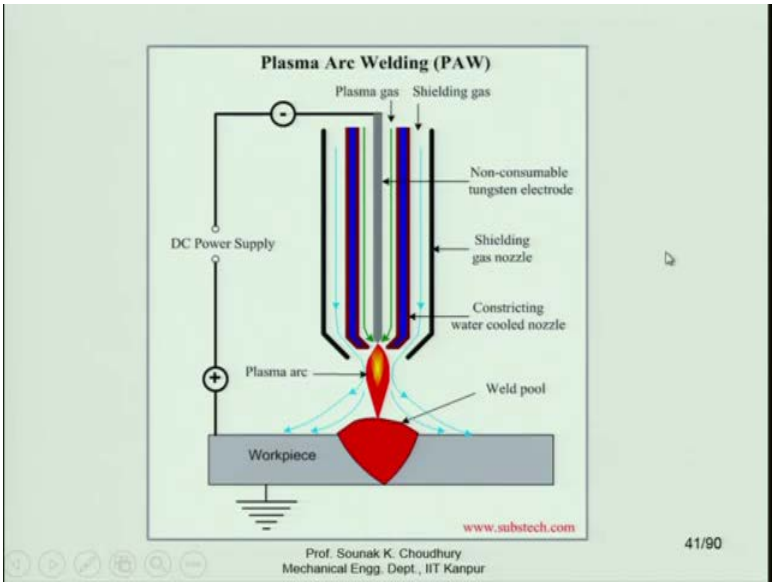

Here is another process which is called the plasma arc welding. Here the plasma is created. This is the shielding gas line, this is the plasma gas channel, and there plasma gas is flown, and this is plasma arc which is heating up the work pieces and they are getting coalescent. They are getting welded.

This is the shielding gas which is passed to shield this plasma arc and the welding zone, weld pool. Here we have the non-consumable tungsten electrode that creates the plasma. This is the shielding gas nozzle through which the shielding gas is passed. And here we have the constricting water cooled nozzle. Water cooled nozzle is required because the tungsten electrode gets heated up because of the electric current which is passed to create the plasma arc.

Work piece is made positive, and the tungsten electrode is made the negative. Through the negative and the positive electrodes, the DC power is supplied, and the plasma is created here. That plasma is channelized, surrounded by the shielding gas, and the welding is performed because of the high heat concentration of the plasma arc.

This is the technology by which the welding can be performed. Here the energy of the plasma is used which is a very high density energy as you can see, like in case of the electron beam or the laser beam as we have discussed earlier.

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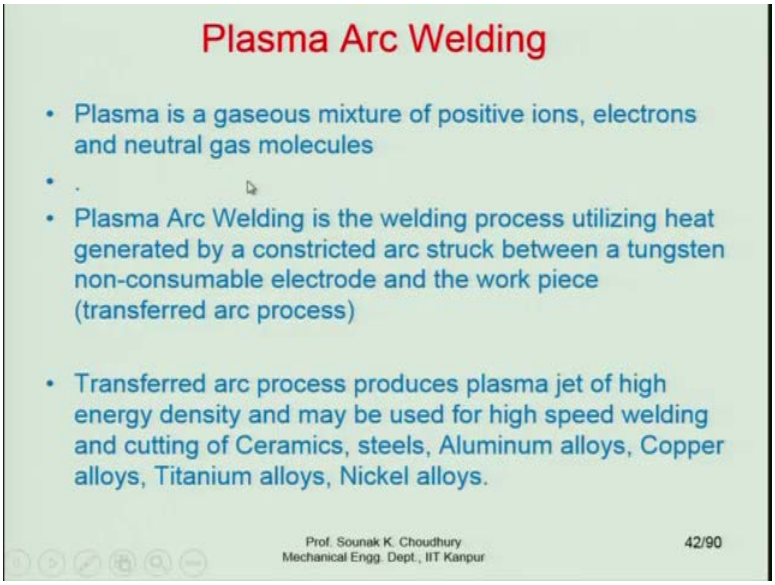

Plasma is a gaseous mixture of positive ions, electrons and neutral gas molecules. Plasma arc welding is the welding process utilizing the heat generated by a constricted arc struck between a tungsten which is a non-consumable electrode and the work piece, transferred arc process. This is called the transferred arc process.

We have already discussed how the process is performed. This is the tungsten filament, or the tungsten electrode, and this is the circuit which is made here. Transferred arc process produces plasma jet of high energy density and may be used for high speed welding and cutting of the ceramics, steels, aluminum alloys, copper alloys, titanium alloys, nickel alloys, and so on.

For a very wide range of work pieces and very wide range of processes, the plasma arc cutting or plasma arc welding can be used. Plasma arc cutting is also very popular. It can be used for these plates or these materials as well because this is the high speed welding and cutting of the ceramics, steels, aluminum alloys, copper alloys, titanium alloys; some of them are very hard alloy.

They can be used by the plasma arc welding without any difficulty. Because of the very high heat density the hardness of the material is not a factor. And you can see even there are brittle materials like ceramics; probably the cutting of ceramics, with the help of the other processes will be very difficult with the help of the processes where the heat density is not that high.

Because it is a very brittle material, and it can break during the cutting. Therefore, it has to be machined very carefully and one of the processes is the plasma arc cutting that is conveniently used for such brittle materials. Once again, there is a plasma gun and the plasma gun is made by passing the current between the non-consumable tungsten electrode and the work-piece.

DC power supply is required for that, work-piece is made positive cathode, and negative is cathode is the non-consumable tungsten electrode. Once the electric current is passed, plasma will be evolved and there will be shielding gas inside the nozzle.

So, the plasma will be directed to the joint between the two work pieces which are to be joined. The plasma arc will create very high temperature, which will weld the two surfaces of the work pieces. That is done normally in the atmosphere of the shielding gas, it can be inert gas.

this is the overall principle of the plasma arc welding, which also is used very popularly for a very quick cutting of the very hard and the brittle materials. The rest of the welding processes I will discuss in my next discussion session.

Thank you for your attention.