Joining Technologies of Commercial Importance
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Lecture – 27
Magnetic Pulse Welding

Hello, I welcome you all in this presentation. This presentation is based on the topic magnetic pulse welding and this presentation is related with the subject joining technologies for the metals.

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So, the topic is magnetic pulse welding. This process is basically solid state joining process. So, there is no fusion at the faying surfaces or at the surfaces of the metal being joined. So, there is no fusion and this unique feature is exploited for joining the metals which are not compatible metallurgically, particularly metallurgically with each other in molten state. So, if they are not metallurgically compatible.

Then, such kind of metal combinations can be brought into weather using solid state joining technologies like magnetic pulse welding, right, so metallurgically incompatible because such incompatible metallurgical systems during fusion welding when they come together like aluminium and iron, or aluminium and copper, or copper and iron. When such systems in molten state brought together.

They form unfavorable inter-metallics after interaction or reactions in the molten state and formation of such brittle, poor inter-metallics, they lower down the mechanical properties as well as corrosion resistance of such kind of the weld joined. So, if we need to bring together the two metal systems which are otherwise in molten state not metallurgically compatible, then we can use magnetic pulse welding process which is one of the solid state joining techniques.

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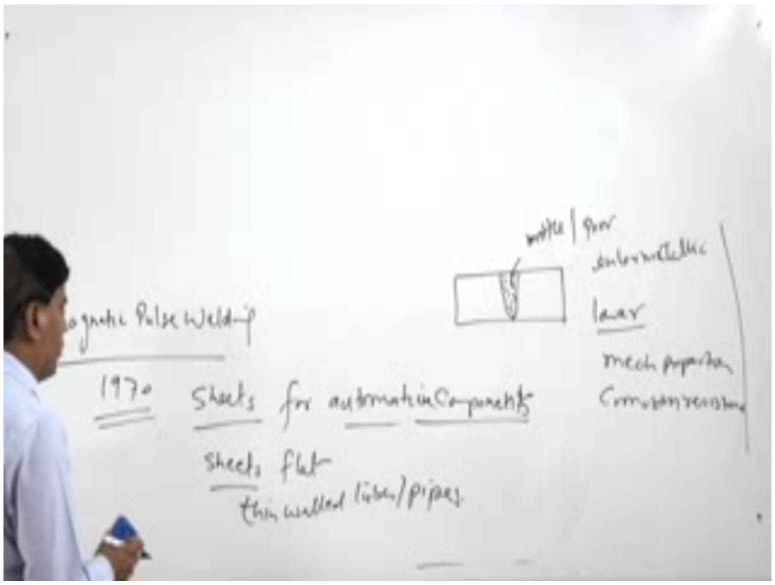

This process was invented long back in 1970s for specially joining of the sheets and for the automotive components. So, for manufacturing the automotive parts, this process was developed and still it is largely used for joining of the sheets which are plain or flat form and also thin walled tubes and pipes. So, we will see how this process works in which way which other solid state joining process is close to the magnetic pulse welding process and how it exploits, in which way the joint is formed.

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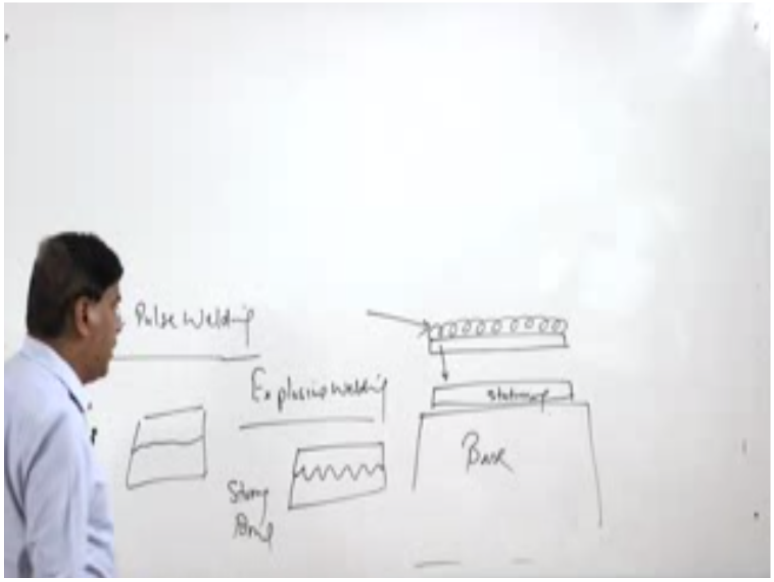

So, this process is one of the you can say is very close to the explosive welding process about which we have already talked. This process works on a very simple principle, one system say this is base or anvil on which the component to be joined is kept so this is stationary and another component is kept, movable kind at some distance over which we place the explosive material and this explosive is detonated.

So detonation of the explosive accelerates the movable plate towards the stationary plate and impacts at very high velocity above certain critical velocity and this in turn results in the development of the joint at the interface and this interface typically is found to be of very wavy in nature so such kind of wavy structure at the interface results in the strong bond, if this interface is largely flat, then it results in somewhat poor strength of the bond.

So, in case of explosive bonding we need to be very careful in the sense that since explosive is used and it is the donated in course of the process this explosive is used to accelerate the process one of the movable component towards the stationary component so that it can impact with the stationary components presently high velocity to develop the bond.

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So, we need the lot of infrastructure and special precautions to use the explosive welding process but the magnetic pulse welding is close to the explosive welding process in the way that the acceleration of the plate towards the fix plate it also uses one fix plate, fixed one and another is movable and in this case sufficient gap is kept so that when it moves impacts with the work piece and here what we use basically the coils are used which are fat with the suitable high frequency, high current for very short period.

So the period is very short may be say like 50-100 microseconds current so this is time for which the current is fed and the current is of very high magnitude say 500-1000 amperes and it is allowed to flow for a very short period so when it happens a high strength, this such a flow up such a high current for a short period a develops the high density magnetic field.

This high-density magnetic field this results in the development of eddy current in the one of the plates which is movable in movable plate and the magnitude is so high interaction of these two means the development of a high-density magnetic field induces the eddy current so high repulsive force start acting on the movable plate so high force, high magnitude you can say high magnitude repulsive force start acting on the repulsive Lorentz force start acting on the plate

And which accelerates the plate at very high velocity towards the fix plate and when it happens the plate accelerated the movable plate accelerated towards the fix plate and impacts at high velocity which is say 500 up to 500 m/s such kind of impact result in the formation of the bond at the interface.

In the same way as we have seen in case of the explosive bonding so as in case of the explosive bonding here the interface also will be of somewhat wavy in nature one side we may have aluminium and other side it may be copper and similarly we may have one side the steel and another side we may have copper and it will result in the interface which is typically wavy in nature.

Greater is a waviness stronger will be the bond between the two and under such conditions of impact what are oxides or absorbed gases are present at the surface all these are destructed, broken so that the metallic continuity between the two members, dissimilar members being joined is established for developing the metallurgic bond between the members so this is the process of principle on which it is based.

So we have seen the high velocity acceleration is achieved through the pulse of high strength magnetic field, pulse of the high frequency current and a such a high-frequency current for a short period is fed through the discharge of capacitors because it takes a lot of time for charging of the capacitors and once they are the discharge such a high magnitude of current is allowed to flow through the coils.

So the high-density magnetic field is generated which in turn generates the repulsive Lorentz force that forces the movable plate to move towards the fixed plate so that after impact after the collision it develops the strong metallurgical bond.

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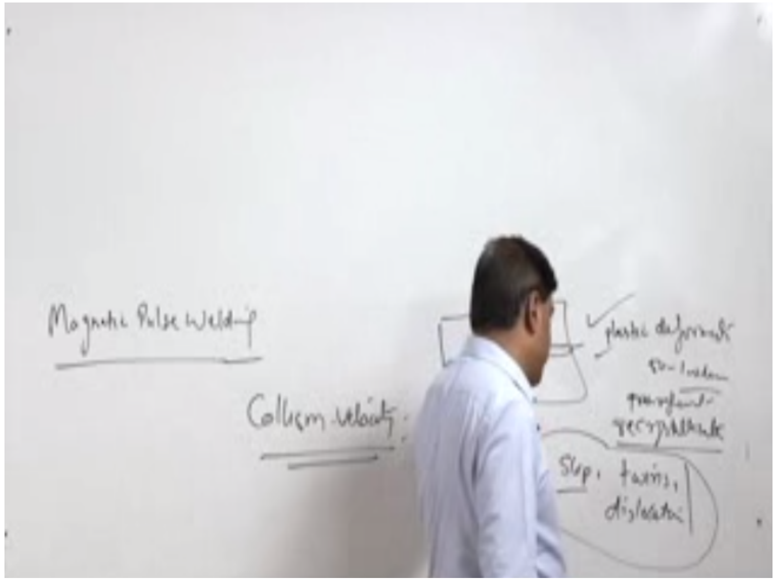

So, if we say the nature of the process and certain conditions are important for successful welding in this case one is the collision velocity. The velocity at which impact is taking place must be high enough, otherwise the bond will not be formed and the too high velocity also can result in the partial melting so the important thing is the velocity at which impact is taking place is high enough, say these are the two members which are being joined.

So whenever there is a impact lot of interfacial surface layers experience that deformation. So due to the impact at such a high velocity results in the very localized plastic deformation. This deformation may be limited to say 50-100 micrometer and such deformation also means this due to the impact temperature rise also takes place sometimes at very near surface layers it causes the re-crystallization formation of the new grain at the same time lot of slips and twins and dislocations are also generated at the near surface layers.

So near surface layers experience the plastic deformation over narrow layer, the decrystalization is also observed, the grain refinement also takes place and apart from this, the microscopically or you can say metallurgical the factors indicating the deformities due to the deformation the slips twins and dislocations are also generated near the interface.

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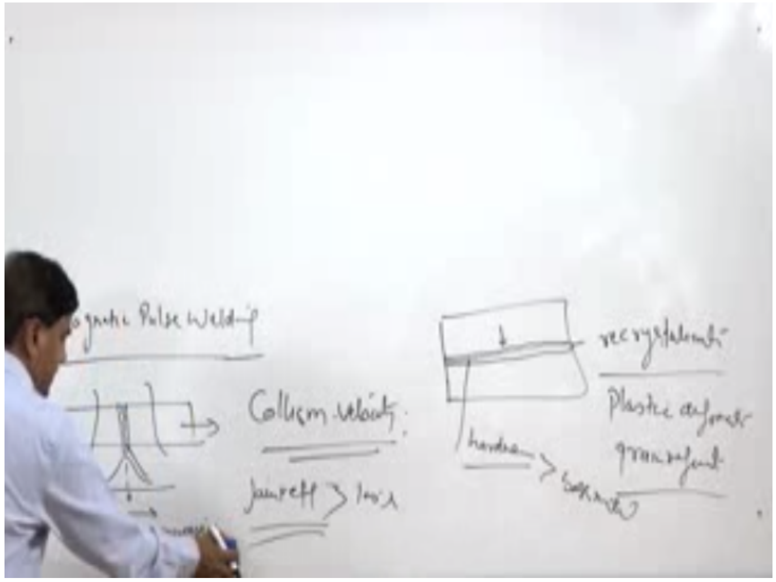

So all these are deformation related effect and generation of the re-crystalline grain structure, means re-crystallization of the near surface grains coupled with the plastic deformation and the grain refinement. These three factors in fact results in the somewhat higher hardness of the interface is greater than the base metal, so if we take any typical joint produced using the magnetic pulse velocity welding process.

It will have somewhat the deformed layer comprising the re-crystallized zone, grain defined zone and plastically deformed zone having the much higher hardness as compared to that of base metal. So, if we plot the hardness variation, like say is the interface and this is the distance, distance increasing from interface, if you plot that then we will see that at the interface hardness is higher as compared to that away from the base metal.

So mostly in such cases the failure takes place from the base metal and not from the joint. This indicates that the efficiency, joint efficiency, or joint is much is stronger than the base metal or efficiency of the joint is > 100%. This is what indirectly we say that if the joint is stronger than the base metal, then efficiency of the joint is > 100% because this calculation is based on the, this kind of efficiency calculation is based on the strength of the base metal and strength of the joint itself.

So whatever is a weak metal, wherever is the weak link in the joint, that fills, so if the failure is occurring from the base metal then it will be indicating that the base metal is weaker than the joint.

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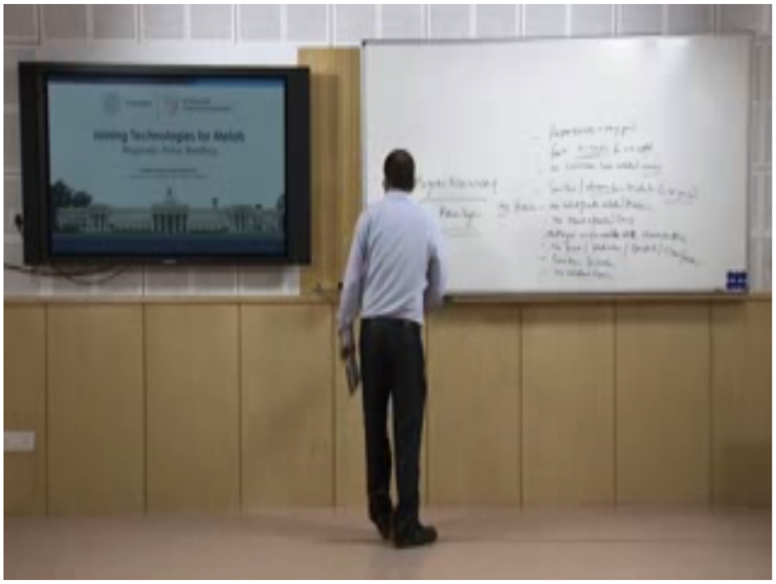

Now we will see certain, certain advantages, disadvantages and limitations associated with the process, so as far as the advantages related with the process is concerned what we can say the most important advantage that there is no fusion related to the process means no solidification are related problems. There is no heat affected zone. Absence of heat affected zone show there is no major unfavorable HAZ, heat affected zone, characteristics.

There is no external heat application so are we can say no fumes or radiations or smoke which is generated so process is very clean and it is green because there are no fumes, no radiations. The interface has mainly the deformed interface, re-crystallized interface with the grain refined structure, so it is largely free from distortion tendency, no residual stresses, same time it can combine the similar and dissimilar metals equally good.

So similar and dissimilar metals can be joined without any problem. Similar and dissimilar metals can be joined equally, effectively during the welding. Then, since the heat affected zone is the absent, so there is no metallurgical change near the interface so no corrosion loss related issues which are typically observed in case of the fusion welded joints. The process is very fast in the sense it takes just 10-100 microseconds for 1 weld.

But certainly the time required for loading unloading and charging of the capacitor is too much so in that way if we will see the productivity of the process is a still quite good as compared to the other fusion welding process. However, the time required for developing the joint is a very short, further repeatability of the process is very good and that is why this process can be effectively used for development of the joined consistently of the same quality for the mass production purpose.

Now we will see are certain limitations apart from that so many advantages associated with the process, there are a few limitations also which need to be considered while selecting the process so that it can be applied effectively for the given application so the major limitation associated with this process is somewhat same as that of the explosive welding process and that process is limited to the lap joints.

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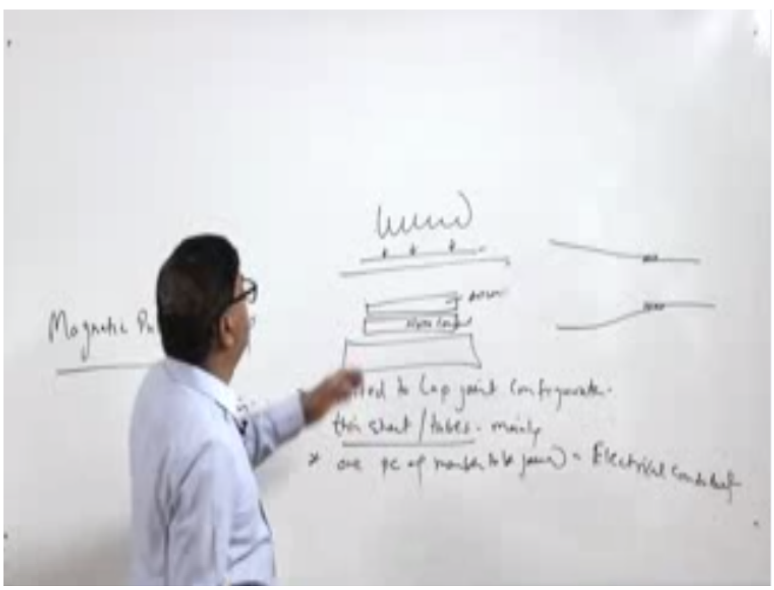

So the first major limitation of the process is this one is limited to the lap joint configuration so this is one thing we need to use the either sheets like this or we have to use like say the tubes are to be welded and tubes will have the overlapping zone and then the joint will be formed, so the system is limited to the lap joints, mainly it is used for the thin sheets as well as tubes.

But it can also be used for a different configurations or the complex designs which are otherwise difficult to be achieved using other processes, so limited to the thin sheets, mainly for thin sheets. Then, it is necessary that one part or one piece of the members to be joined is electrically conducting because the eddy currents are induced then they will be repulsive Lorentz force will be pushing one of the sheets towards the another member with which it is to be joined.

So, in this case it if the this is one of the member agrees another will see that the high is strength magnetic field induced develops the Lorentz force and which pushes it towards the another sheet. So it has to be conductive otherwise we have to use some driving plate in that case one member and this will be the driving plate member, this may be non-conducting and this is another member and then this is the driver one.

So driver one basically pushing the non-conducting plate when it is brought in close to the another coil having the high-strength which is capable to deliver the highest strength electromagnetic field and the induced the eddy currents in the driver plate for realizing the required movement in the movable plate.

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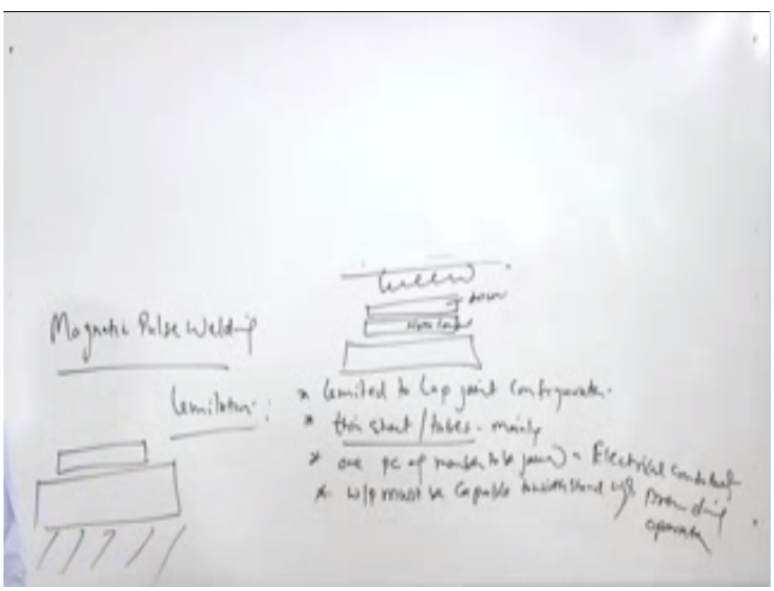

So one-piece of the members to be joined must be electrically conducting or otherwise it will require the another driver plate which will be pushing the movable member and the another thing the work piece or the work pieces must to be capable to withstand high-pressure, generated during the operation or during the welding. So in this case especially like in case of the flats it is not a big problem, flat sheets are well supported with the base.

And after the impact, they will be formed and the entire load will be taken without any difficulty, but if the shape is such that the pressure being applied on one of the plates will deform the work piece, in that case, special supporting members will be used so that they do not deform under the effect of the Lorentz repulsive force which is being applied during the process.

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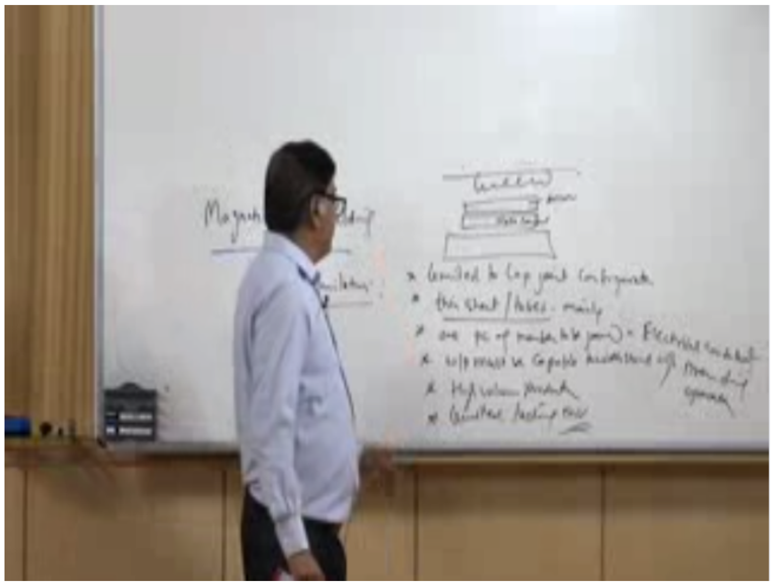

So is one typical example of this one is like say the tube joining in case of the tube joining, if this is one member and is another member and here the coils will be applied high-strength electromagnetic fields will be applied from all the sites in outer coil while which will be moving towards the inside, towards the in the inner surface of the work piece. So part two and this is part one, so part one basically will moving towards part two.

And if the force is too high then part two tube can get collapsed, so to avoid such kind of the deformation we can use the mandrel inside, so the mandrel first and then the outer tube two and then over this tube one can be applied, so this mandrel basically, mandrel or such kind of support system can be used to provide to avoid unnecessary deformation of the work piece if it is very delicate and thin in section.

Then a special supporting units and members can be used to avoid deformation due to the height

Lorentz force during the welding and another one. This process is justified only for the high volume production because the system is a costly and this one is a limited to the factory environment, means very heavy system is needed for developing the joint using the magnetic pulse welding process.

So it can be are carried out or performed in the factory environment, so although most of the mass production and such kind of the jobs are produced in the industry only or in the factory environment or in soft floor environment.

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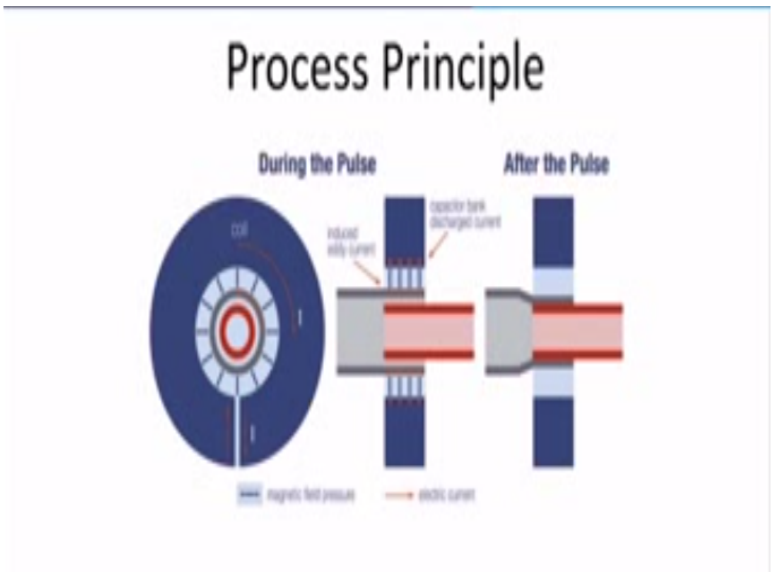

So this is what now we will be using this one, the PPT here, like say this is the outer tube and this is the inner tube, which are to be joined, so what we will do the capacitor bank, which will be supplying the high current for a very short period after the discharging. So the Eddy current when induced, the high strength repulsive Lorentz force is generated which moves the surface of the outer tube towards the inner tube and then the joint is developed the after the impact

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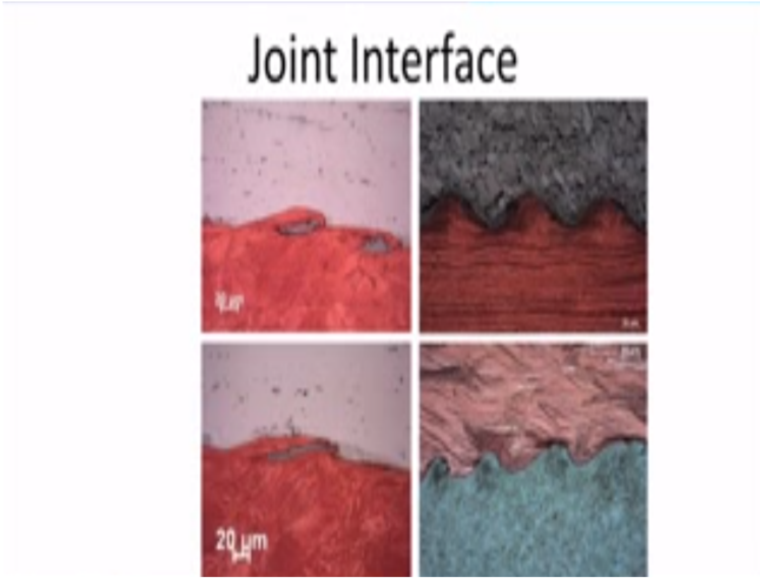

And you will see the typical photograph or the interfaces of the joints developed using the magnetic pulse, GMEW. These are the 2 diagrams which are showing the joining of the aluminium with the copper so the one with the light itched part is showing the aluminium and this reddish part is showing the copper portion and here we can see that the typical waviness or the kind of a bond

Which is more of the mechanical kind is reflecting, is developed in case of the aluminium and the copper one and typical wavy structure can be seen in these two cases where this one is the bond between the copper and the mild steel and this is the bond between the copper and the stainless steel and these morphologies at the interface are similar to that of the explosive weld joints what we have seen earlier.

So now I will summarize this presentation, in this presentation I have talked about the pulse, magnetic pulse, welding process, this is one of the solid-state welding process, primarily used for joining the thin sheets component of the dissimilar metal systems which are otherwise not metallurgically compatible for the fusion welding process. We have talked about the basic principle of the magnetic pulse welding apart from the advantages and limitations associated with this process. Thank you for your attention.