Advances in Welding and Joining Technologies

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Lecture - 01
Fundamentals of Welding and Joining Part I

So, good morning everybody now, I will start the introductory level of this course advances in welding and joining technologies. So, to some extent we know about the different welding techniques and we have seen in the several places the materials are joining simply gas welding processes or some other welding processes, but if we look into the signs behind this welding and joining technologies and then we can find out that, most of the subjects are involved in welding and joining technologies.

For example, here will be able to know that, heat transfer analysis the involvement in welding processes, material flow and any kind of stress analysis distortion level and metallurgical changes; that means, structural changes microstructure; that means, material science, metallurgical engineering, as well as mechanical manufacturing some design and all are basically involved in this in the welding processes.

So, we will try to get some idea some basic idea about this process. So, that we will try to cover the welding science and what are the technological development of this process till that? That we will try to cover in this module so, the module consists of this following sections the we can say that, first is the classification of the welding processes then what are the physics of welding processes? And then mostly use the fusion welding processes their development and different types of the welding processes.

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What are the brazing and soldering processes? Soldering processes in regular life we can see that to, we can use an some electric circuit board, that is typical application of the soldering processes, but brazing also industrial scale application also there, but we will try to look into that what is the typical mechanism of brazing and soldering processes?

Then adhesive bonding is one kind of the joining processes, we will try to cover this topics also physics of welding arc because, so far, much development has been done in the arc welding processes. So, we will try to get some idea about the physics involved the formation of the arc and in very specific to the welding processes.

Then more advanced topics in this section that is, what is the influence of the surface-active elements? And based on that what are the different welding processes has been developed or maybe existing welding process? What way we can modify these welding processes by considering the effect of the surface-active elements? And finally, we will try to cover the magnetically impelled arc welding process.

So, these are the module of this different section of this module and that, name of this module has been given in such the way that, fundamentals of welding and joining we will try to get some idea basic physics involved in the welding processes or most conventional welding processes the different technology of the welding processes we will just get some broad idea about the processes.

If we see that, almost all sector of the industry there is a need of joining of the materials that; can be done either fusing of the metals or may be using some adhesive or some other joining techniques. If we listed some of the applications area, so electrification, automobile, airplane, water supply and distribution, electronics, radio and television, agricultural sector, computer, telephone, air conditioning and of course, almost all sector it is covering this thing. So, it is indeed is very much important to know about, the fundamentals of the different welding processes.

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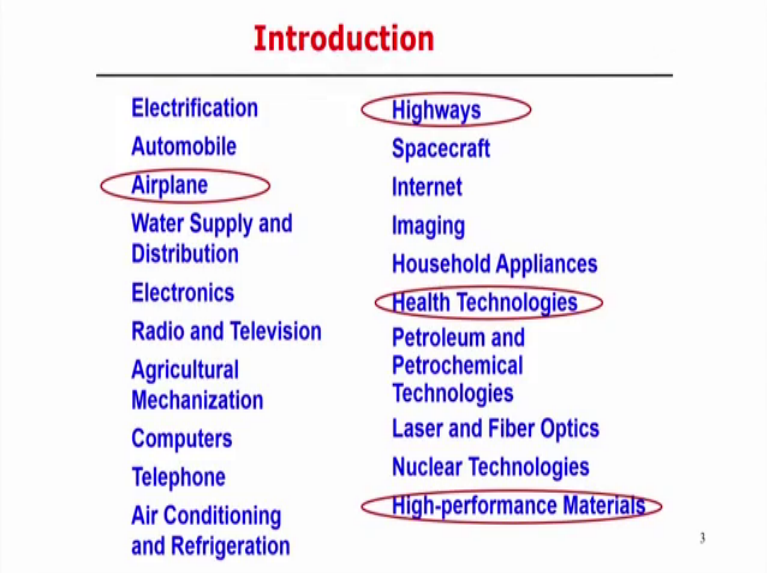

Now, if you see the mostly use this technology in the or in the air aeroplane or aerospace industry, highway, the health technologies, spacecraft, and the reselling, the different welding processes has been developed looking into the application of the high-performance materials.

So, it covers almost all the sector. So, here the importance of the welding processes and well before going into details, much details about all the welding processes, we will try to get some basic mechanism of all this process, probably it can be a review of the different welding processes, that mechanisms are only will be focusing in this part. You know how you can define that, what is the welding and joining?

So, there is no precision definition of welding processes or joining processes rather we can say that, when 2 metals specifically metallic materials are joined by fusing with the application of different type of the heat source.

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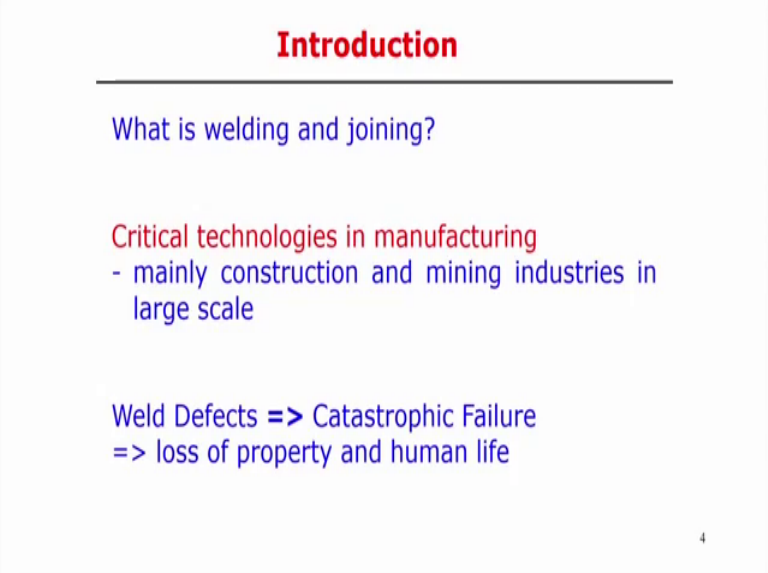

So, that in general, that is called the welding processes normally, welding involvement there is a fusion is there and joining processes may be in other way that for example, that when you some first inert mechanical riveting and use the first inert to joining the 2 components, that is also that is also termed as a joining processes, but there is no need of any kind of fusion or may be atom to atom violence's is not required in that cases.

So, that can be considered as a joining process for example, even in adhesive bonding also if you use some glue and to join 2 materials, that can be also called joining process, but here the mechanism on joining process different from the fusion processes. So, that fusion is happening in the welding and joining processes specifically, that is termed as the fusion welding process.

Of course, we can say that, solid state welding processes also can be considered we generally say some say solid state welding process, sometimes also we can say which the solid state joining processes even the soldering and brazing, that is also the application of the third metal try to join the two different material by fusing the third metal, but not necessary to meld the parent metal. So, that is the basic mechanism of the soldering and brazing mechanism.

So, that is that also we can say one typical joining mechanism. So, in general we can say that, it is a not only welding or not only joining process we can say, it is a welding and

joining processes of the materials irrespective of materials or irrespective of any non-metals also.

Now, critical technologies in manufacturing mainly recent or maybe huge application or I can say the maximum application of welding and joining technologies, we observed the construction industry and as well as the mining industry and specifically in this case the joining or welding of the materials involves, there is a huge large amount or may be thickness or this thickness of the metal is very high in this case.

But, at the same time if we find out the very precision application of the welding and joining technologies that, we observed in the weld technologies by medical devices there, we can find out the requirement of the joining of the very small thickness may be, less sometimes it is requirement is may be less than 100 micrometre.

So, we say that, as such the application of the welding and joining observed from the very precision instrument in the level of 100 micrometre or less than that to a large extent that, we observe in the huge thickness of the bulk joining of the material we can find out in the construction and the construction specifically, if you try to make bridge there also apart from the rubber join the welding join can also be done for the construction industry specifically.

The example is the making the bridge the river bridge and then, another cases is the mining industry also we can find out, that is huge application of the large scale welding processes. So, apart from very large scale to very small case there is importance of the different welding and joining technologies

So now, here we will try to focus in general of the welding technologies and there is a separate module of the micro joining and nano joining section where, we will try to focus on the very precision welding processes in very small scale.

But, why it is important? The welding and joining analysis of all this welding and joining because, from the past it has been observed that, if the technologies of welding and joining are not proper probably we can find out, there is a formation of the defects and presents of the defects may leads to the catastrophic failure of the whole structure, and that can lead to the loss of property as well as the human life. So, here is the important to

analyse the different welding processes and if there is a permission of the defects or whether, we can chose the different welding technologies for without any defects.

So, this is not only the problem in the welding industry the permission of the defects by the improper choice of the welding materials or improper selection of the materials in the sense that, with respect to the material the if welding process has not proper then, there may be the problem of the formation of the welding defects not only this. Finally, if we use any kind of welding processes whether, it is solids welding processes or fusion welding processes we can found out that, there may be the formation of the some amount of the residual stress and distortion, that can be controlled what that cannot be completely avoided?

So, presence of residual stress also affects the life of the welded join. So, always we try to target to reduce the nature of distortion and nature of the residual stress. So, that is also another problem or maybe I can say that, it is the inherit that is the that, comes by inheritance the presence of the any kind of residual stress and defects during the welding process. So, in that sense it is also necessary to analyse or to know basic mechanism or basic engineering of the different welding processes.

Now, before that which welding and joining processes can be classified in the following way that, based on the different types of welding of course, the classification can be done from the different perspectives, so with respect to that one perspective you can say that, there a 3 different 1 is the fusion welding, pressure welding and friction welding.

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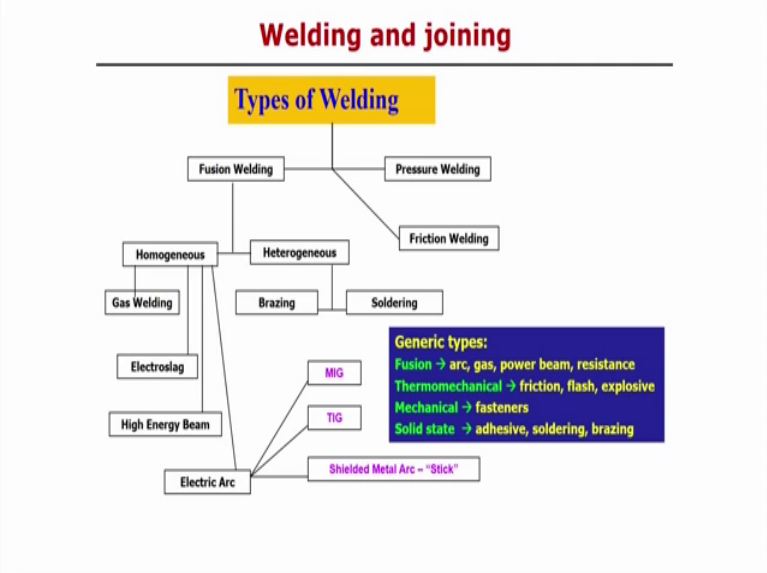

So, here basically the difference is that, nature of the heat source and how we can control the heat source? Or how heat can be generated to join 2 different or similar kind of materials? Fusion welding definitely we apply the source of heat source in such a way that, it should cross the melting point of the subset material. So, that it can fused together and upper solidification it makes the structure.

Pressure welding simply application of the pressure or may be application of the load is the main mechanism to do the joining of the materials. Friction welding of course, the heat is generated in this case due to the friction. So, in friction welding normally, we generally keep the friction welding the maximum temperature is below the melting point temperature.

So, in that in that, case they can they can be consider as a solid state welding process as well. So, this 3 types of welding processes and we can see further that, fusion welding processes can be classified as the homogeneous and heterogeneous welding processes.

And if you see other part is the heterogeneous welding processes, that brazing and soldering. The heterogeneous welding processes means that; we use the some another second or third material to join the similar kind of metal or two different type of material. So, in that sense it is called the heterogeneous welding processes and in the other case the homogeneous welding processes here, you can find out that not may not be necessary to using the third material may be, 2 similar kind of material they can join it is a and can

form kind of homogeneous structure. Even for dissimilar materials also they can join together, but finally, they can from the homogeneous structure.

So, in that sense it is called the homogeneous and the heterogeneous joining processes. So, homogeneous there are several types of welding process we can see that, gas welding process, electro flag welding process, high beam energy and the electric arc. So, all this all these cases the generation of the heat mechanism are in the all these cases are different, but common thing is that anyhow that, when you try to join two materials. May be, there is must be some amount of the heat generation should be there so, that the materials can be joined together.

So, but all these cases the source of the heat are different, 1st cases the gas welding simply bounding the gas is the that, actually converted the basically chemical energy and the converted to the heat energy and that, heat energy utilize to weld the materials then, electro flag welding also similar kind of may be in this case that, arc can be generated. Then, high beam energy also the beam means the either laser or electron beam that is the high source of energy can be used and electric arc based on the electric arc can be can also be used in this case. So, all this different types of the homogeneous welding processes, but in this case the heterogeneous welding processes mechanism are different from the homogeneous welding processes.

So, heterogeneous process in case in generally, we conventional we can find out the 2 different types of welding process, one is the brazing another is the soldering. So, in details we will discuss about all this processes. Now, other things we can see that, electric arc welding there are 3 different types of mig welding, metal inert gas welding or gas metal arc welding then, T welding, tungsten inert gas welding or gas tungsten arc welding and shielded metal arc shielded metal arc welding.

Also, that is sometimes it is called the stick welding, that most of the cases we observe the metal arc welding process and we practically we can observe and the in any kind of construction site, that using of the different types of the welding processes. So, that can be that are categorised as the electric arc welding because, in this all these cases they produce the electric arc.

So, in general that generic types can be classified of the welding and joining processes or rather I can say the, what are maybe? You can say the rather than classification here, we

can say what are the different types of welding processes here? So, in this case fusion welding process see the arc, gas, power beam, resistance that, actually can be categorised as a fusion welding processes, thermo mechanical processes can be considered as the friction flask explosive welding process.

So, in this case the not only thermal condition may be, some mechanical energy also required in this case and in general, that is called the thermo mechanical energy utilized for all this cases and fusion welding only heat energy or may be, thermal energy is utilised to conduct all this type of welding processes.

Then mechanical joining processes. So, it is not the welding, but it is the joining process because, frost inert can be used simply joining of the 2 components. So, that is called the mechanical joining process or may be in general, that is the joining processes, solid state welding process another generic type of welding or and joining process, that is called solid state, that is adhesive soldering and brazing can be categorised as distance because, in this case the temperature actually below the melting point temperature of the substrate material.

So, in that sense it is called the solid-state welding processes. Even for friction state welding process, that is there also the mechanical steering, as well as frictional heat generation are responsible for the welding of the materials. So, that can be or can also be categorised as the in that, solid state welding process.

So, point is that, when we try to classify the different welding process. So, we need to consider the different perspective to classify the different welding process. So, this is these are the one way, the different types of welding process normally exist. If we see in other prospective whatever, we can classify the welding process. So, before that we look into that, what the different types of welds we generally observed?

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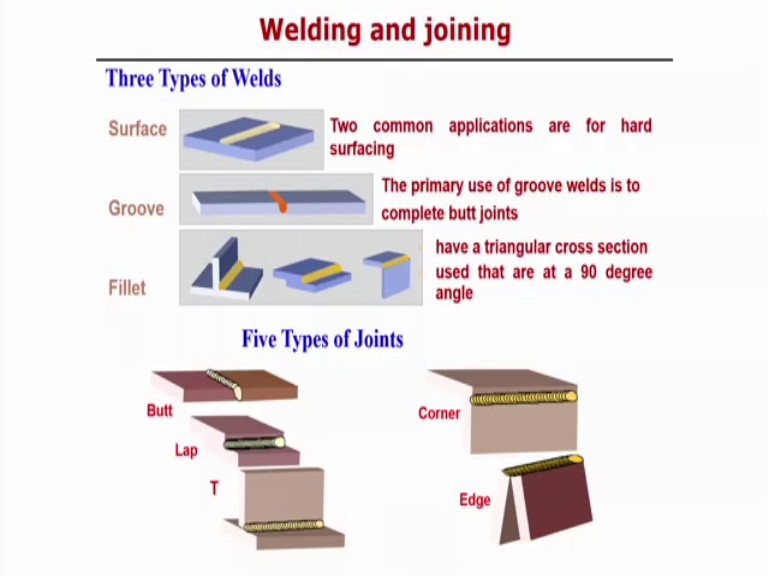

In the first figure if you see that, that is the 3 types of welds the first one is the 2-common application of for the hot surfacing basically surface welding means; that means, the it is application of the heat and making the joining of violence's of the materials is happening only over the surface.

Second one is the groove welding making a groove between the 2 plate and that, can be that groove is fill using some filler material. So, the primary use of the groove welds is to be complete the butt joints. So, configuration the butt joint because, in this case 2 plates are flat and they are join at the edge and either use using any filler material or not. So, that can be that also one type of joint that is in general, that is called the butt joint. Butt also can be considered as a groove joint if we try to make some groove before, the welding of these 2 metals.

So, another types of weld, that is also fillet weld. So, fillet welds the configurations of the geometry or of the base metal are different in this case. If we see although, it waking the kinds of T section, but one side it is weld or fill filled by the welding material. So, that is call the fillet weld. So, have a triangular cross section used or that are at 90-degree angle.

So, filler weld it can be done for a T cross section and the lab joint lab to different metals of joint and then, that can be welded using the materials or it can edge joints or it can be 2 edges having 90 degree perpendicular they can be join using the fillet.

So, these are the type of welds different welds butt type of the joints can be other way we can observe that, butt joint simply joining of the 2 materials over the edge and then, lap joint when the lapping lap joint the 1 plate is in over the another plate and any 1 of the contact is can be join using the filler material. So, that is called or without the without using the filler material, that is called the lap joints.

So, here the geometric configuration of the joint are different in this case here, if you see that T joint, T joint means, that 1 plate is horizontal plate is there and over this 190-degree vertical plate kept and then, both side can be join or single side can be joint, that is that is called the T type of joint corner joint. So, the 2 plates are keeping perpendicular with each other and that, corners are joined using the welding processes and edge joint. So, over on the edge the geometric configuration different, but over the edge the weld can be done.

So, from the figure it is obvious that, there are there are different types of welds and or there are different types of the joints we can observe practically, by simply by what way we can configure the different materials? We can say, different substance materials in that, way we can find out this different nature of the types or nature of the weld joints observed practically.

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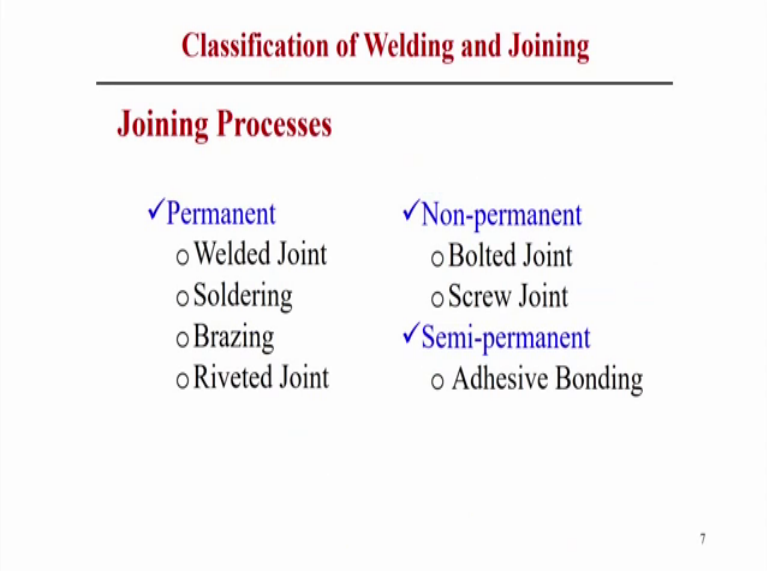

Now, again we come back to that, classification of the welding and the joining processes may be other way we can in general we can say that, joining processes. So, joining

processes itself include the welding processes also. So, in the joining processes we can see the there are 2 different one is the permanent joint, another is the non-permanent joint, another is the semi-permanent.

So, from that way, we can categorise the different joining processes, first is the permanent joint may be, welded joint can be considered as a permanent joint and because, violence's of the material happen in this case it can it may happen either in the liquid state; that means, cross the melting point is above the melting point temperature or it can happen the in solid state as well also. So, both can be considered as a permanent joint.

Second is the soldering and here also soldering the soldering is when soldering is done joining between the 2 components, the solder material needs to melt and it can join the 2 materials, but not necessary to make the parent metal. So, this also creates the permanent joint. So, similar philosophy also for brazing also and this also call the permanent joint and of course, may riveted, riveted joint this one kind of I can say the mechanical joint also, but this is also this can be considered as a permanent joint.

But non-permanent joint in the sense, that bolted joint and the screw joint because, it is possible whenever, requirement required this possible the disassemble of the joining materials. So, in that sense it is considered as a non-permanent joint where in, other way welds is riveted has been when riveted joint can be considered as a permanent joint in the sense that, if you want to disassemble the components. Then, you need to break the riveted part, that is why it is considered as a permanent joint, but it is not necessary for the bolted joint or screw joint.

Semi-permanent joint can be categorized as the adhesive bonding because, adhesive bonding when we joining 2 materials, we put the adhesive between these 2 metals and at a curing of the after certain curing time the 2 components or 2 metals can be joint. So, that is the joint by using the adhesive bonding, but these adhesive bonding having some life after certain time they can they can disassemble, but the depends on the what type of adhesives we are using.

So, in general this adhesive bonding can be considered as a semi-permanent joint so, in that prospect for the different permanent, non-permanent or the semi-permanent joint.

So, this is the one way of the classifying the different weld joining processes so, in other way the welded joint so, that is the classification of the welded joint.

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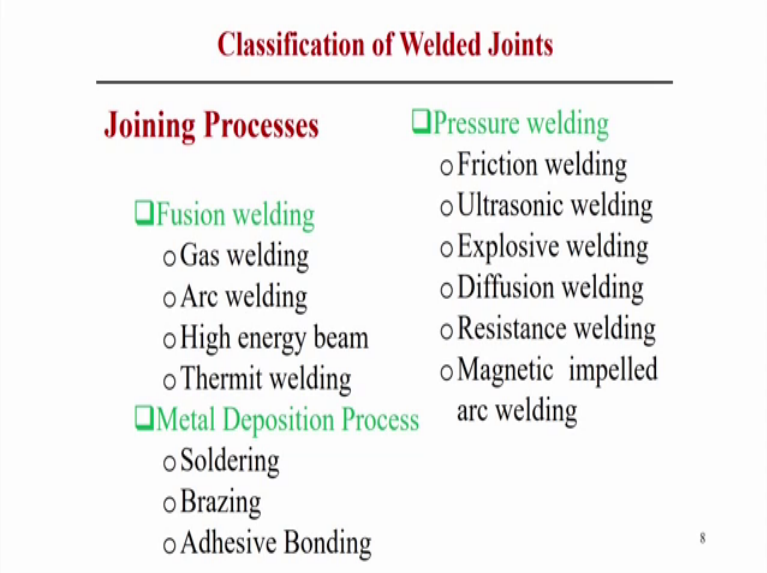

So, several joining processes the fusion welding then, metal deposition process and pressure welding this 3-main categorisation can be done, when you try to classified of the weld joint. So, if you look into that, what are the different types of the welding process include in fusion welding process? That gas welding, arc welding, high beam energy welding and thermit welding. So, all these cases we apply the heat source intensity in such a way that, it try to melt the basic material or base material and then, after solidification the permanent joint can be done.

So, in this case so, here nature of the heat source is applied in such way that, it will try to fuse the base material. So, that is why it is comes under the category of the fusion welding so, that fusion welding the source of the energy here in the by creating the arc or chemical in the using the gas or using the high beam energy like laser and electron beam.

But, in case of metal deposition process the sense of the classification is different in this case of course, we use the source of the energy different energy is it try to fuse the material, which solder material, but it is does not fuse the based material. So, that is way the metal deposition process in the sense, that we use another extra material to join between the 2 metals, without reaching the melting point of the 2 material.

So, soldering, brazing and adhesive bonding also comes into under this category. So, that; that means, we use some extra material to join between the 2 components, without melting the parent components. Pressure welding other categorisation is that, here you can see that, what are the different welding processes includes in the pressure welding process; That friction welding, ultrasonic welding, explosive welding, diffusion welding, resistance welding and magnetic in arc welding.

So, in this case normally the pressure welding means, the application of the load is required. So, that actually tries to create the joint or deep bonding between the 2 components or 2 materials. So, friction welding of course, apart from the pressure some frictional heat also generated in this case, that actually helps to violence's of the components or materials. Similarly, ultrasonic energy can be used in this case to joining explosive when the using sub explosive in this case the using some explosive and then, highly deform the components is highly deform the high rate of plastic deformation happen with the component and then, these 2 components can join in the solid state creates the solid state welding processes also.

Similarly, resistance welding also resistance welding in this case that, we apply that resistive heat also, but at the same time to make the joining process we need to apply some mechanical load as well. So, in that sense the resistance welding of resistance the it creates the due to the ohmic heating, it creates the generates the heat. But at the same time we need to apply some constant pressure or may be some variable pressure also so, that the welded can be done.

So, apart from the various kind of the source of the heat or generation of the heat, there is also some mechanical loading condition is also required in case of the pressure welding. Anyway, we will try to discuss of all the different types of the welding processes as well individually. So, by looking into that, different way of classification of the welding processes. Now, we will try to focus on the, that physics of the welding process.

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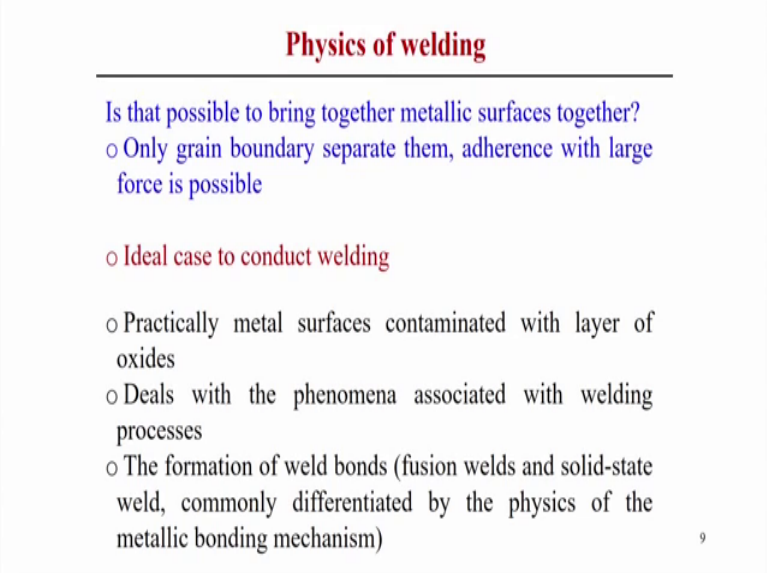

So, how the joining of the 2 materials comes and what way the different development of the in the welding industry has been terms. So, what the type? So, first question is that, if it is possible to being 2 metallic surfaces together, is it possible to join these 2 surfaces or 2 components, if that is possible then I think they are may not be necessary, that such kind of all this development in the welding processes.

But, let us look into that things since the only grain boundary separate them; that means, between the 2 metals, if that in that case 2 metals come in contact with the metallic surface come in contact then, joining adherence with the large force is possible, but this is the very ideal case. Because, that types of metallic surface may not be possible in practically because, that metallic surface most of the cases we can find out they are contaminated with the oxide layer. So, ideally it is not possible to may bring the 2-metallic surface if it is not contaminated with any kind of layer of the metals.

So, in that sense in absence of that layer, that 2 metallic surface in come in to the contact then it is possible to join between these 2 metals, but apart from this if there is a no if there is any presence of the oxides layer then, in ideal in that ideal cases it is possible to join, but practical cases most of the metallic surface equisetum with some of the oxide layer and it is not possible to join possible to join them, until unless there is a removal of the oxide layer.

So, that presence of that oxides layers is basically brings the concept of the different weld development of the different welding processes by the mainly by the application of the amount of or the some kind of creation of the generated heat between the surfaces. So, that actual practical that surfaces presence that, deals with the phenomena associated with the different welding processes and development of the different welding processes.

Now, the formation of the weld bead bones basically that fusion welds or even solid-state welding commonly differentiated by the physics of the metallic bonding mechanism. So, that is only difference the in weld bond or that is the only metallic bonding the nature of the metallic bonding what way we try to explain the fuse or solid-state welding processes either in the fused welding processes or the solid-state weld?

So, we will try to look into that, deviation from the ideal cases and what are the development of the welding processes can be done?

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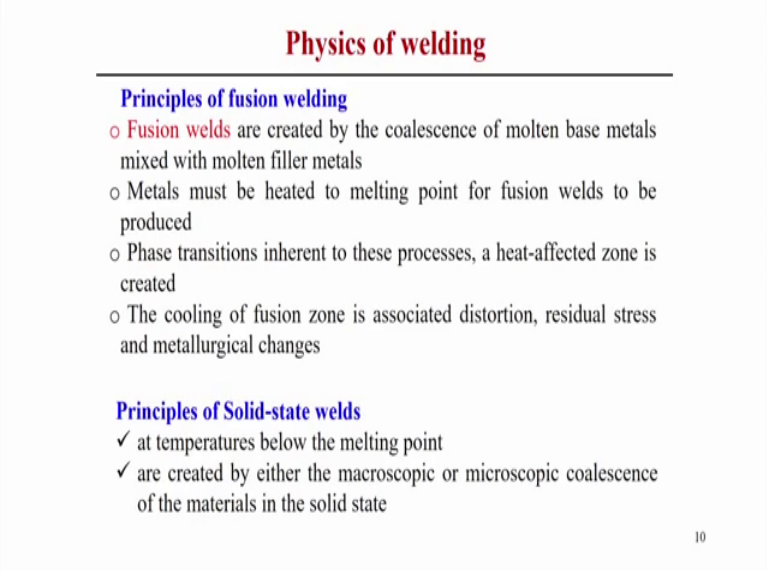

Now, before that we will look into that, what is the physics principle of the fusion welding processes? So, in fusion welding processes basically they are created by the covalence of the molten base metals and mixed with the molten filler metals not necessary always the filler metals are required?

So, in this case the fusion welding happens by the way, the metals must be heated to raise the melting point temperature for fusion weld to be produced. So, in this case what

happens raise to the molten temperature and they mix up the molten metal mix up and then finally, they solidify to the ambient temperature and then, actually makes the bonding between the 2 materials.

So, that bonding may happen either similar type similar type of materials or maybe 2 different types of the materials, but in this case the typically the fusion welding process it is characterised by the molten pool zone basically the molten zone and then, heat affected zone. So, heat affected zone also occurs because, the heat is applied to the melt the surface, but up to a certain extent there may occur the phase transition or phase transformation happens, and that is inherent to the processes. So, that phase transformation measure the phase transformation affect is basically indicated by the heat affected zone, and that heat affected zone is basically identified the microscopically or macroscopically as well.

But, after solidification or may be after cooling down of the molten pool and then, when the it is cool down to the room temperature then, there may be the possibility or definitely there must be some amount of the distortion and residual stress and over the solidification period the some metallurgical changes also happen. So, like the phase transformation also happens in this way. So, that metallurgical transformation of this can be better identified by the different size of the molten zone or different size of the weld zone or different size of the heat effected zone.

So, in this case what we understand that, in fusion welding process there is a necessary to apply some intense heat to the focus zone. So, that intense heat basically melts the selective part of the material where, about to join between the 2 components and after melting it subsequently solidify and creates some different metallurgical zones, may be that is called the fusion zone or heat effected zone and of course, remaining part is unaffected the base metal.

So, these are the typical characteristics, but other way also after solidified of the molten zone it is accustomed to some amount of the distortion and residual stress. So, this is the principle of the fusion welding processes. Now, what is the solid-state welding process? So, solid state welding process definitely the temperature should be below the melting point temperature and arc created by either the microscopic or the this is the basically created either the macroscopic or the microscopic violence's of the materials, and that

remains in the solid state. Of course, phase transformation may also happen in the solid state, but the team that that phase transformation happens below the melting point temperature of the materials.

So, apart from this the fusion welding and sorry that, principle of the fusion welding we discussed and that principle of the solid-state welding process. Now, we come to that, point the physics of the arc welding process in the sense that when you try to because, arc welding is the mostly used process and most common processes also and in arc welding process we generally, control the separate parameters first is the voltage.

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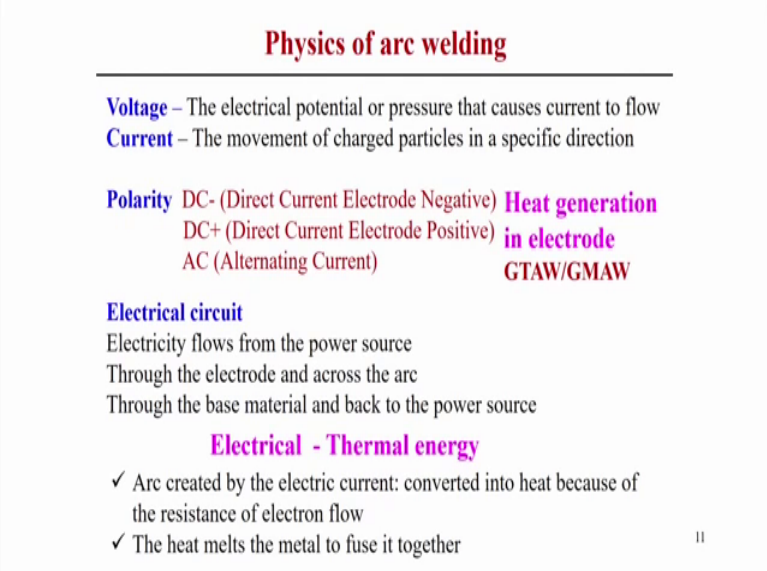

So, electrical potential or the pressure that, causes the current flow that voltage is the the potential, that is required to flow the current and basically the current can be defined is the movement the movement of the charged particles in a specified direction. So, voltage decides the flow of the current and current actually is basically in terms of the charged particle, and that flow one direction and then, that when the current flowing in specified direction and when it is creates the arc between the positive and negative charge work piece on the electrode material and then, it try to complete the electrical circuit.

So, that electrical circuit makes the development of the arc welding process, but in this case this electrical circuit or nature of the voltage and current is basically different from the other common electricity what we use in the 2 use in the this thing that normal current; that means, for a specifically for in a bulb here, you can see that common

electrical connection were the supply is basically that high voltage and low current normally the voltage around 240 volt and low current may be 5 rams like that.

But, when you try to use this electric current in the welding purposes the we use in different way, here the current requirement is very high and the voltage requirement is the low maybe standard or typical say 20 volt or 24-volt is required, but current may be depending upon the process arc welding processes or depending of the size of the work piece it can varies from 100 amps to say 200 amps like that.

So, that way the common electrical circuits is different from the what we use in kind of welding purpose, but point is that voltage current, that actually decides the power of the arc, but polarity also is another important factor. So, polarity means what way we can use a positive and negative cathode and how what we decide the cathode and anode? Which one should be positive? Which one should be negative?

So, there are several way to decide the polarity one is the DC; that means, DC minus; that means, direct current electrode negative, DC plus direct current electrode positive and we can use also alternating current depending upon the application of the application or maybe depending upon the materials and they are typical characteristic how is interact typical characteristics of the molten pool? What it is interacted with the surrounding materials or surrounding atmosphere?

So, here specifically the heat that, different type of polarity; that means, whether it is DCEP direct current electrode positive or DCEN direct current electrode negative or it may be AC depending upon the polarity the amount of the heat is generated in the electrode or amount of the heat is generated to the work piece. So, that depends on the in general the type of the polarity we can use for the in this welding purpose.

So, that maybe it is not necessary for the different welding processes follow the different type of the polarity, but for example, GTAW and GMAW the gas tungsten arc welding process and gas metal arc welding. In these two processes; we have the choice of the using the DCEN or DC or AC polarity depending upon the application or depending application on the materials.

So, I will come to that one later on what is the typical utilization of this thing? But, thing is that if electrode negative and work piece is positive in general in that case, the kinetic

amount of the energy electrode is basically exposed more on the work piece surface. So, in that case we can expect the more amount of the heat generated in the work piece surface. So, our if our objective is to melt the work piece material more in that case, we should use the DCEN polarity; that means, work piece positive and electrode should be negative in that in that, polarity around 70 percent it will be generated in the work piece.

But, our objective is to melt the consumable electrode for example; in case of gas metal arc welding process we use the consumable electrode. So, objective is to consume more electrodes. So, more amount of the heat general is more preferable on the on the electrode. So, in that case direct current electrode negative is more preferable in that sense uh. So, in this mode DCEP, that more amount of the heat will be generated on the electrode than, the work piece material and also AC current. So, certain typical material for example, aluminium this low melting point material, which is having high affinity to form the oxides.

So, in that case the AC current is more preferable. So, in this case may be in alternatingly the 50 percent amount of the heat generated in general in the local 50 percent in the work piece. So, the AC current basically helps to cleaning the oxide layer and the remaining 50 percent amount heat is generated on the surface. So, in that sense the cleaning action is required or maybe to remove the oxides layer. So, AC current is more preferable in that sense, that generally observe in the application of the welding of aluminium.

So, electrical circuit basically decides, that the nature amount of the generation of the heat. So, we can see the electricity flow from the power source and through the electrode basically if we consider the circuit in such way that, the through the power source the electricity flow and then, it comes to the electrode we use electrode and then, it again it passes through across the arc and then, that flow through the base material and again back to the power source, in that is way it actually creates the electrical circuit here.

So, formally we can say the electrical energy is basically converted to the thermal energy in the arc welding process. So, arc created by the electric current here the converted heat into because, of the resistance of the electric flow. So, resistance of the electric flow that actually responsible for the creation of the heat and the heat melts the metal to fuse it together, after that heat melts the metal and to fuse it together.

So, that physics of the arc welding process then, just we will try to cover here the basic concept of the which generally use in the arc welding processes next to that point enthalpy of melting basically energy required to melt the material what we can estimate? Or what are the factors is responsible for to estimate the melting of the enthalpy of melting?

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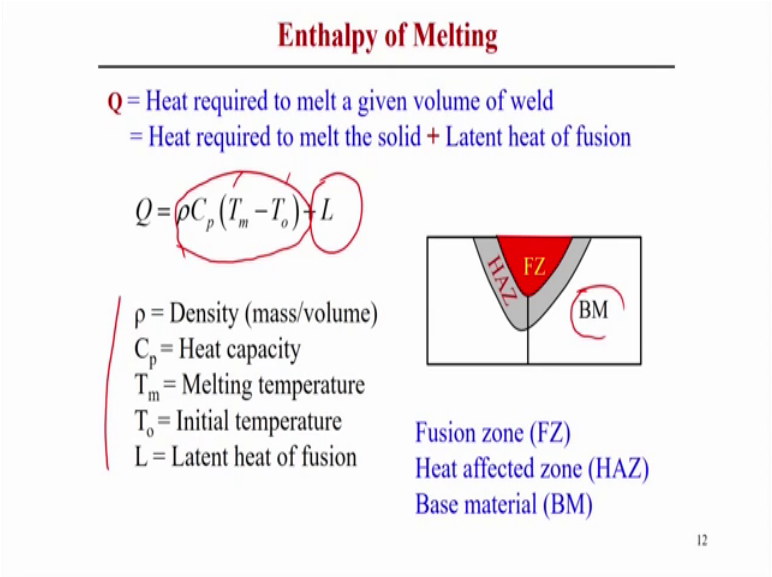

So, straightforward we can find out what is the amount of the energy required? That heat energy required to melt are given volume of the weld, we estimate in that way we can separate on these 2 part the heat required to melt the solid and then, latent heat of fusion that actually to change the phase from liquid phase sorry from solid phase to liquid phase some amount of the latent heat is required.

So, in that way we can estimate that Q equal to that, first component is basically the latent heat sorry the heat capacity or may be in this case, that is called the specific based on the specific heat, that component can be the melting point temperature based from the ambient temperature to the melting point temperature and the total heat content to raise the or heat required to raise the ambient temperature up to the melting point temperature, with the same phase solid phase that is the amount of the heat required.

And then, second part is the latent heat required to change the phase. So, that is why the total amount of the heat can be considered that is required to the volume required to melt a given volume of the material. So, once we estimate the amount of the heat and

typically we can find out the weld zone is like that, first is the fusion zone that is the molten zone of course, molten zone not exactly the amount of the heat generated just to melt, but here the application of the heat says it goes up to the some super heat temperature as a also. So, we are neglecting basically the enthalpy melting we are neglecting, that super heat that amount of the heat required to super heat the material.

Now, apart from the fusion zone it some part is affected up it is the solid state, but that is defined in the heat affected zone. So, that zone is affected by the heat, and that can be identified simply the by phase transition with this zone and of all these happens over the in the solid state; that means, without the less than the melting point temperature. So, that zone is the heat affected zone and other part is the base metal that is, the unaffected base it is not affected by the application of the heat in the source. So, this is the typical characteristics of a basically the zone of the different weld zones in specific fusion welding process.

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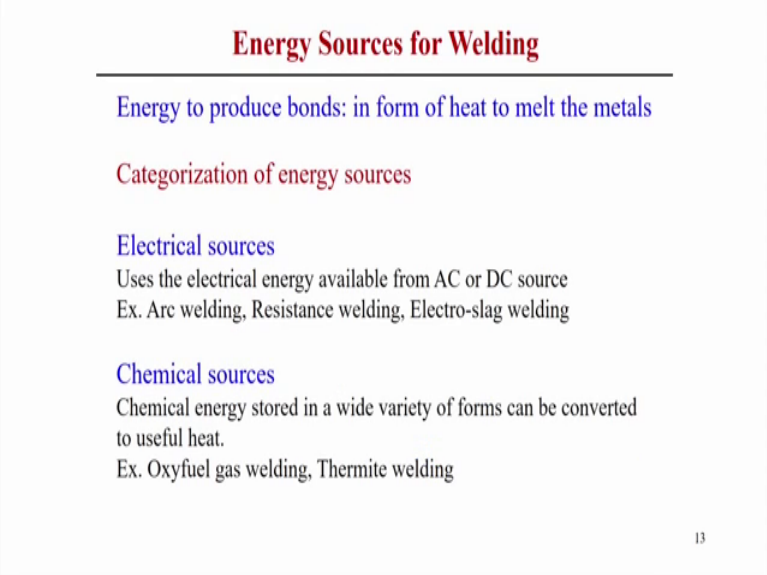

Now, what are the different energy sources are generally used in case of welding processes? So, of course, the energy here is used to produce the bond in form in the form of the heat first making the heat application the heat to melt the metals and then, cooling the cooling of the metals through solidification process. So, here we will try to the what are the different categorisation of the heat source may be used for the fusion welding processes?

So, first is the electrical sources of course, use the electrical energy either available in the form of the AC alternative current or in the form of the direct current sources for example, the different welding processes arc welding processes, resistant resistance welding process, electro slag welding all the different welding processes, we just use the source we use the different electrical sources to create the thermal energy.

Second is the another source of the energy for the welding is the chemical sources. So, here the chemical energy is stored within a cylinder and the in the different form we can use the chemical energy for example, the oxy-fuel gas welding. So, oxy-fuel gas welding we can use the fuel cylinder and to make the gas welding processes even for thermit welding processes in this case also that, we can use the chemical energy or of course, we use the some in this case we use the thermit is the mixture of oxides and other materials and that, create some chemical reaction and the reacts that, exothermic reaction and that creates the some amount of the heat and that, heat can be utilized for the welding processes.

So, in these cases the chemical sources actually acts as to produce the generated heat. Optical sources we can categorize the optical sources in this way that fused beam of the electron or laser, which is operated is actually operated according to the law of optics. So, in this case that it can achieve a high-power density creates it possible to the high-power density; that means, high concentrated heat can be possible as compared to the other welding processes.

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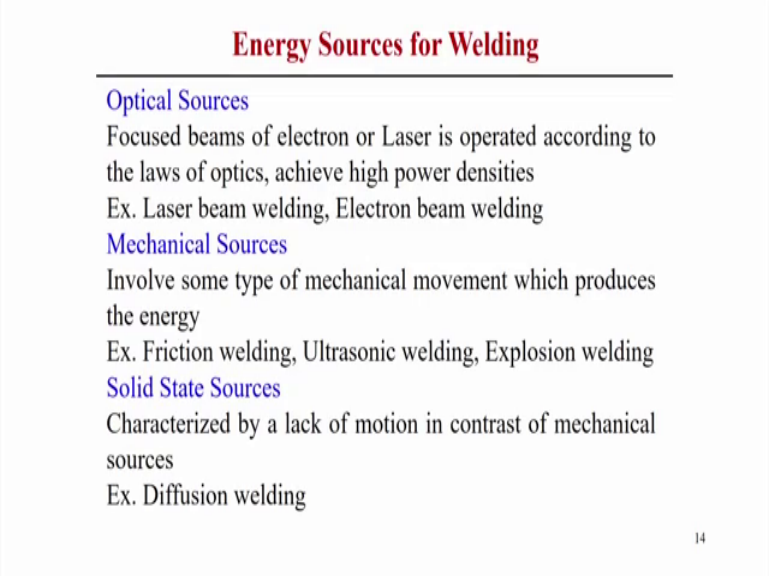

So, typical example is the laser welding laser beam welding processes and electric beam welding processes in these 2 cases we can use the heat source from the optical sources then, mechanical sources the in involve the some amount of the mechanical movement of the that, mechanical movement of the movement that, actually produce the amount of the energy for example, friction welding if you friction welding basically if we try to give the mechanical motion of the substrate material.

The high rotational speed then, even if it is contact with another material, that at the contact surface they are may be the generation of the heat due to the friction and that, friction happens due to the mechanical motion of the substrate material. So, in that way that some mechanical source can be used to generate the amount of the heat so, that friction welding, ultrasonic welding and explosion welding all these kind of welding processes the mechanical source is the actually produce the amount of the heat.

Solid state sources we can separate category the solid state sources in this case is the categorises it is categorised by a lack of the motion in contrast to the mechanical source is that is, in that sense we are not using the any mechanical sources here. Maybe we do not use the mechanical motion as a source of the generated heat rather, in this case may be the application of the concentrated load or may be distributed load is applied, and that is responsible for the joining of the material. So, that is one example is the diffusion

welding and, in this case, may be the source of the energy source of the energy can be considered as a solid-state source.

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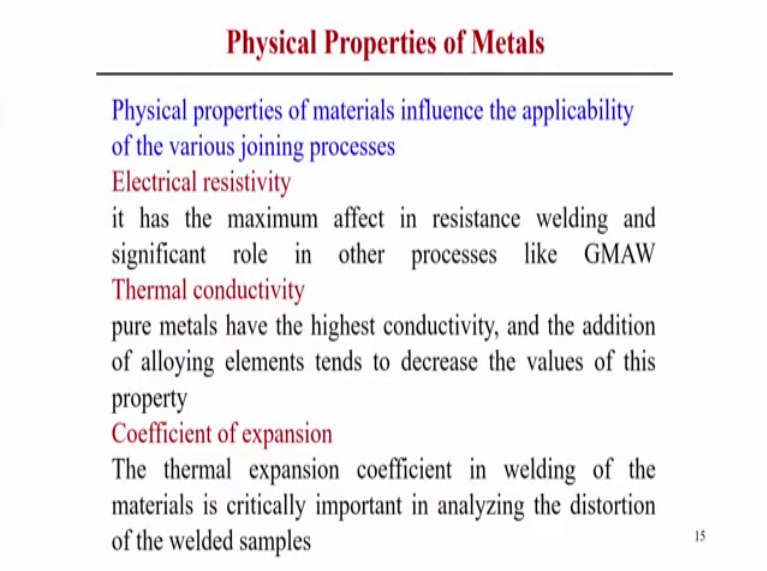

Now, when you analysing the different energy sources is required for the welding process now, we will look back to what are the different physical properties of the material? And which may be significant in very specific to the welding processes or to analyse the different welding processes? So, physical welding properties basically of the materials influence the applicability of the different various joining processes. So, that is why we need to know the different physical properties of the materials, and that actually decides what that actually relates to the applicability of the different welding processes. So, that is why it is necessary to analyse the different physical properties of the metals, first is the electrical resistivity.

So, electrical it is having the maximum effect in the resistance welding and significant role in other processes like, gas metal arc welding process or gas tungsten arc welding processor. So, that is why we should know the, what is the electrical resistivity of the material decide the applicability of the different welding processes in principle thermal conductivity. So, what way the materials can transfer the heat that, depends on the thermal conductivity.

So, for example, some material is having very high thermal conductivity for example, copper, copper is having high thermal conductivity. So, sometimes it is very difficult to

weld in the sense the application of the heat immediately the conduct away the amount of the generated heat. So, concentration of the heat is maybe is probably less in this case to melt the material. So, that is why, it is necessary to know the thermal conductivity of the; it is a very significant parameter, that this is the applicability of the different welding processes.

So, in general pure metal is happen good thermal conductivity, but if we try to allow if we add on the alloying elements generally the thermal conductivity reduces. Next is the coefficient of expansion the thermal expansion coefficients in welding of the materials also it equally important to analyse the distortion of the welded specimen because, the application of the thermal energy or there may be the thermal strain will be produce and the thermal strain is that, amount of the strain is that, depends on the distinguish or expansion coefficient.

So, or maybe if there are 2 different material there is huge difference in the thermal expansion coefficients probably in this case there is the difficulty of joining these 2 materials or maybe the 2 materials having the similar range of the 2 dissimilar materials having the similar range of the expansion coefficients. So, probably in that case the joining must be little bit ease.

So, that thermal expansion coefficient is another important parameter, and that directly linked to the distortion analysis of a welded join specific heat we understand the measure or amount of the heat content or it can observer amount or it can store the heat the amount is basically decided by the specific heat of a pacific material, ionisation potential. So, different materials the ease of arc initiation basically when we try to do the arc welding processes how is we can create the arc? And what way easily we can maintain or arc can be stable, that actually relates to the ionization potential of a specific material.

So, to get a initiation of the arc easily and we can stability as minimum as possible ionization potation material is required in this sense metal oxides of course, oxidation rate is another critical problem in the welding process. So, different materials the oxidation rate are different and the effective stability, when this meeting the metal oxides the stability of the metal oxides during the welding is basically affects the transfer of the heat from the any source or it also depends on the different alloying elements alloying elements of the parent metal.

So, that is why it is very important to the know the oxidation rate of a specific material or the nature of the metal oxides and when you try to weld when you try to select the an alloying process for a specific material it is necessary to analyse the metal formation of the metallic oxide just give the example that, aluminium oxide aluminium is having high rate of oxidation and easily form the aluminium oxide.

So, that is why when you try to choose the welding process we generally use the alternative current AC current such that, it clears or it removes the oxide layer in the half of the cycle and remaining time of the cycle time it is the simply heat the material. So, in that sense the analysis of the metallic oxides is required.