Welding Process
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Classification of welding process and definition of welding arc

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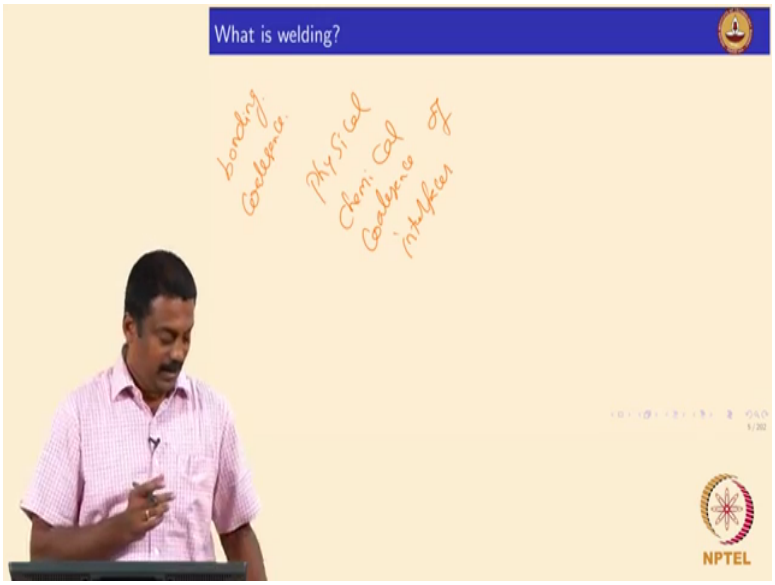

So first question I asked when I begin my class to define welding, ok. So what is welding? I want answers.

Student is answering: joining of the (())(03:29)

what is joining? So definitions would be self-explanatory right it is ruined it is do not raised another question, ok. Again come on what is welding? Come on guys so you are joining right, so what do you mean by join? What is it? come on yes go ahead.

Student is answering: bonding.

Ok. So, bonding right what is bonding? Something happens right you have one metal another metal you were trying to join what happens?

Student is answering: formation of bonds, ok.

How do you form a bound?

Student is answering: A metal fuse to each other.

What is fusion?

Student is answering: coalescence.

I heard some word coalescence, ok. What is coalescence? Coalesce, what is coalesce? It is a mixing right so what is mixing? Right, something is mixing to create a bond, ok. So what is mixing? So you have one block another block even tried to mix it together for example. So what happens? So yeah one phase another phase right, ok. So you have interfaces two interfaces are there right what happens to the interface?

Student is answering: it becomes one.

It becomes one, right. How? Two interfaces become one interface, something is moving. What is moving?

Student is answering: atoms are moving.

Atoms are moving, ok. Then and then atom is move, okay,

Student is answering: (())(02:38)

And then bond takes place right, ok. So if one atom moves from this place to other place what do you call that?

Student is answering: diffusion.

Yeah diffusion and a metallurgical term it is simple physical moment is not it. So it is a simple physical moment and then if they interact what will happen they will also chemically interact, ok. So if they physically move and chemically interact to create a bond so that two interfaces become one interface, ok. So now suppose if you want to now define welding so how do you define? So it is a physical and chemical mixing of interfaces right.

It is a physical and chemical coalescence, right. So it is a physical and chemical coalescence of the interfaces is not it, so you are physically mixing as well as chemically interacting, so physical and chemical coalescence of the interfaces so that you can enough two interface become is one. So there is a driving force because you are reducing surface energy, ok. So two interfaces become is one interface but can it happen without any applying any external driving force.

Student is answering: no.

No right, so then what we do?

Student is answering: heat (())(04:08) or pressure.

Yeah you need apply heat or pressure, very good. So we have (anothe) all terms defined physical, chemical, coalescence of interfaces and the interface coalescence does themselves no, do the coalescence does themselves no, we need to apply some driving force so that they coalese. So how you apply that I will give you the driving force by giving some energy to system and the energy is given by.

Student is answering: heat or pressure.

Heat or pressure or sometimes both is not it. So you apply either heat or pressure or sometimes you apply both, right.

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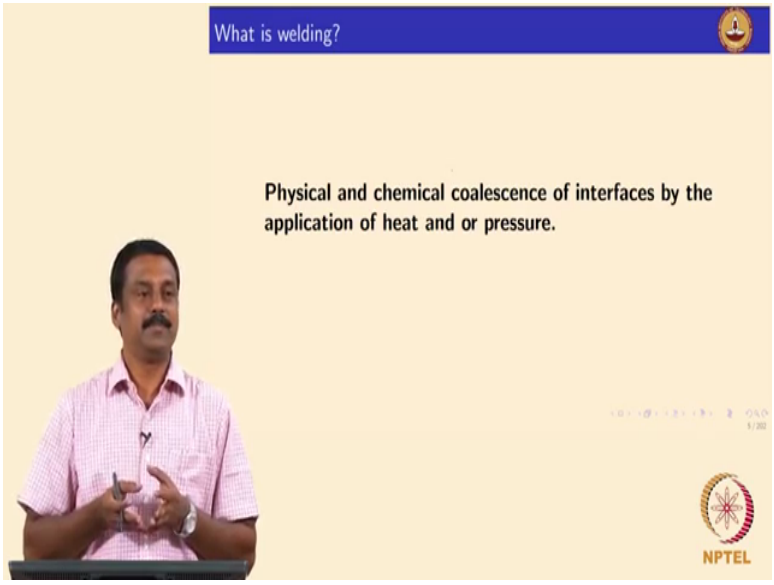

So we can define now the welding in classical terms is physical and chemical coalescence of interfaces by the application of heat and or pressure, ok. So this is the classical definition because everything is covered definitions would cover all the physical phenomena that are happening in a process, right. so we have a (chemi) physical coalescence as well as the chemical coalescence of the interfaces and how do you make the coalescence happen by application of heat or pressure are both, right it is clear.

So this is a classical definition of welding, ok. So this definition whenever someone joins my professors group the first question he asked is this and how good you answer this question based on thus is teaching would be. So I will also judge you by the definition how you are able to tell, so that I can define my level of teaching, ok. Now I understood the level okay good.

So now we define the welding, okay. So you have now welding process defined but then next question comes why welding? Why do to weld? I cannot join two parts by putting a bolt.

Student is questioning: corrosive

Corrosive, why corrosion-free?

Student is answering: (())(06:28)

There is the similar junction created when using mechanical connections, mechanical joints, right. So that means that there is a potential difference, so that is not good for corrosion point of view. The other advantage is weight reduction if you use a mechanical connection you are adding more material, right. so the the component weight increases, so the weight reduction by welding is enormous it sorts a homogeneous physical and chemical coalescence.

So there is no real sharp interface so corrosion problems are not there when you are doing welding. Similarly you gain advantage of not using mechanical connections you gain advantage in terms of weight saving as well, ok. So therefore the welding is advantageous in engineering applications because that you avoid the sharp interfaces which can lead to corrosion or stress partitioning, load partition ok.

If you have a sharp interfaces you are also load partitioning right there is the stress will be acting on always remember which is weaker, right. So again advantage of reducing removing this sharp interface in mechanical connections where the interface becomes smoother little smoother okay and you gain rate advantage. So these are the main engineering advantages you gain by using welding and the well becomes stronger I mean join becomes much more stronger than mechanical connections because of the removal of the sharp interface.

So when you use mechanical joints obviously the load will be distributing differently, right yeah it is clear. So these advantage of welding compared to the mechanical connections yes is clear. So now having understood what is welding, why welding will go in deeper, so right. So

we look at what are the common welding processes that are available currently for engineering applications or now we can classify them, right. We look at it ok.

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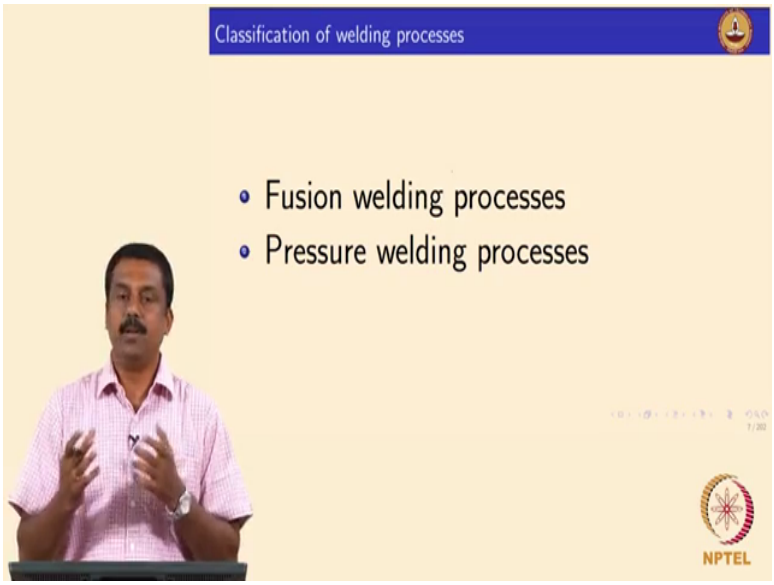

So if you look at the common welding processes we can classify into two again that from the definition, so definition says heat or pressure, so we can classify the welding processes those use heat to weld and the welding processes those use pressure or load to weld. So this is a very major classification there are various classification is possible inside a each processes and each methodology.

So generally the common classification is those use heat or fusion welding processes under pressure welding processes. In both cases, for example in fusion welding processes you will also apply some cases pressure but rate controlling heat, if a heat is rate controlling so then it is commonly known as fusion welding processes or if a load is rate controlling then use pressure welding process, right.

It is clear but again this is not a real good classification because I have been telling right so we can either use heat or pressure or sometimes we use both vary. Heat it will be the rate controlling and the pressure will be assisting the coalescence the process, whereas in another case the pressure is rate controlling where heat is also used to ease the coalescence, okay. So we can classify into broadly the processes into two major classifications even if use fusion or heat as an heat source mainly or pressure by in a way of making our joint, okay.

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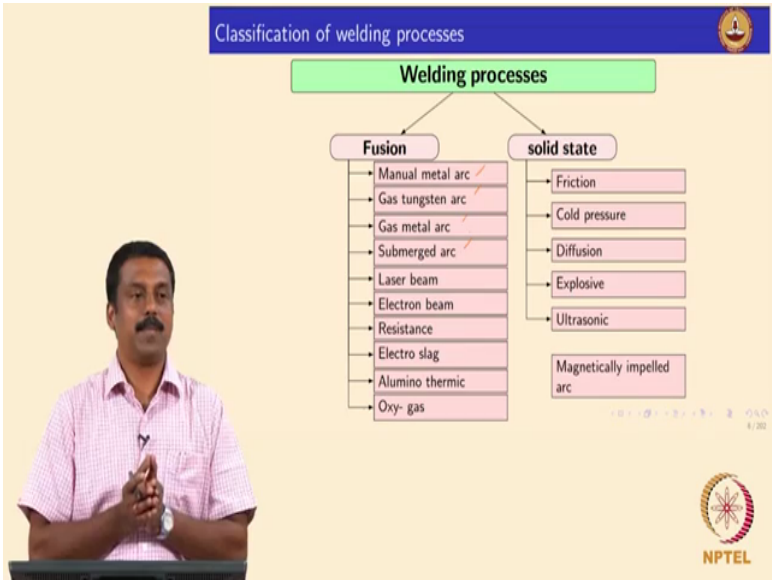

So suppose if you make a well a welding process where you have a liquid presence at the interface so we call it as a fusion welding process, ok. If the interface is not molten interface after welding if you see that if you make a bond in solid state there is no liquid when you make a joint, ok. There are couple of exceptions but in generalise roll is so when the liquid is there at the interface when you are joining the that interface so that is known as fusion welding process.

So when you make a joint in solid state there is no liquid, liquid is pushed apart if the liquid is present or there is no melting of the interface, right. So that is known as the solid state welding process okay and then further based on the heat generation mechanism we can stop classify these two processes into various processes like for example I would listed the fusion welding process.

These are commonly used the fusion welding process used for engineering applications. It is based on the heat generation mechanism and how we change the process based on changing the consumable changing the electrode, changing the gas and changing the atmosphere or changing the heat source from arc to say plasma or laser or electron beam, are you generate heat and just by a resistance heating you still have a liquid, so if liquid is there we call that process a fusion welding process, okay.

So you can list all the processes that are available like a manual metal arc welding, gas metal arc welding, gas tungsten arc welding, submerged arc welding, laser beam, electron beam,

resistance, electro slag, alumino thermic, oxy gas, okay. So these are all the processes where the interface melts and if you move to solid state welding process where there is no real melting of the interface, liquid does not really quite us only the solid unmolten region coalescence.

So for example friction and there are variant the various variants of friction processes simple friction welding, drive direct rotary friction two rods are rotated against each other and then you generate heat or linear friction, ok so linear friction welding are fixed on steel where over are then rotated against the interface, ok or cold pressure, simple pressure welding, so you can apply a simple person as well and it works.

So in my during my PhD time so I had to supervise a laboratory for a B Tech students, so in their process and we wanted to make in a simple backing plate, a simply plate and we also stored into machine it mill it very nicely and students somehow did it so perfectly it is heavy (())(14:15) steel block and they brought it or put it on the welding table, you could never remove it, it is still there.

if you have a perfect interface, so if you have a extremely uniform interface and if these two interfaces come into contact to each other and if you apply a sufficient load you can also make a cold pressure joining. So interface preparation if it is really good you end up making a joint, ok. So that by just by applying a simple load, so cold pressure welding ok and diffusion bonding, ok.

So metallurgy involved in it, so you pass or you transfer atoms from one interface to another interface by a gradient in the composition which can drive the coalescence of the interface, right. So that is a diffusion interface and you can also use ultrasounds, the ultrasounds can also locally deform the interface to care a less, ok. So ultrasonic welding and we also have nowadays a new process invented we are going to install in two three months in our lab as well.

That is magnetically impelled output welding, where we have arc under pressure. It is very difficult different which is rate controlling in this process. The arc is rate controlling or pressure is rate controlling so we left it hanging, ok. So in this diagram it is hanging because it uses both arc and the pressure, ok and we will come back to that or now when we look at the in detail.

So why it is hanging but this process uses both arc and the pressure to make the interface as coalescence, right. It is clear so this is the broad classification of welding process and we are going to look at each process in detail in this course, so starting from gas tungsten arc welding and gas metal arc welding, ok. So we will move on to the variance of gas metal arc welding, what are the advantages and what are the modifications that are made to make this process more efficient, ok and then we will move on to the resistance part welding, a resistance seam welding, resistance welding and then we move the laser beam welding, electron beam welding and then we look at some of the uncommon techniques like thermite, alumino thermic welding, ok and oxy gas welding and so on so forth, right.

So if you look at the modern development of welding process the invention of arc or use of arc for the welding process that happened somewhere in 18 1865 as so, okay. So the first weld when a human being made a modern welder not the archaeological weld, so the first weld was made using resistance heating, ok. So someone accidentally welded two wires copper wires, so when he has applied a current and there was a problem and the fuse together because of the force it made into one single wire.

So that was the reporter head first joining using an modern so called welding technology and then the arc came into picture the moment arc was you know controlled by a regulated power source and then arc welding developments took place somewhere in 1890 and they are on there are various modifications are carried out in arc welding process, right. It is clear, ok. So we will move on to the detail right, so first chapter we look at I have mentioned arc.

So it is important you will understand the first chapter what is this arc? why is it important great? The arc is there in nature as well or the phenomena that is happening in arc it is also happening in the nature in various ways, ok. Can you give me some example of natural arc or natural discharge?

Student is answering: lightning.

Ok, what else

Student is answering: gas park.

Gas park these are all yeah naturally occurring lightning for example but can you use it lightning for heat source, oye.

Student is answering: more than temperature (())(19:15)

It is momentary it is not stable, ok. You seen it to have a sustained discharge, all right so then only you can use it. If it is momentary spark is momentary, right so if you make it sustained then you can use it rate source so that is where trick lies so how do you make this discharge (sustained) sustainable, right. That is what you know we can control the arc to (visit) for another welding application, all right that is clear good.

Let us the classification is clear right, so how we classify the welding process, so we classify into two major fusion welding process and pressure welding process. So we may also apply pressure in fusion welding process and vice versa but the rate controlling is either heat or pressure and then based on the interface behaviour whether it is melting or not melting. So we can further classify the welding processes into the fusion welding process or solid state welding process, in fusion welding processes the heat source is different, we can use arc as a heat source even if use arc as heat source how you generate the arc? Ok.

And that can also vary and based on that we can also further classify into various welding processes, so and then we can also use a laser as a heat source diffuse to melt the interface or you can use electron beam or you can also use resistance heating or you can also as a simple gas compression like a oxy as a trim or oxy gas torch, ok. So we look at all the physics begin this process and then we move on to this whole stsate process, right.

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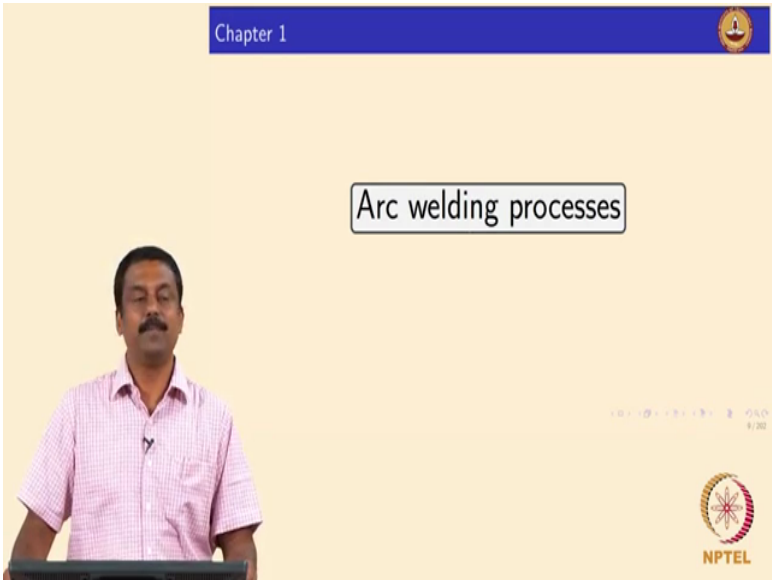

A little more to be arc welding process that is the first chapter, yeah.

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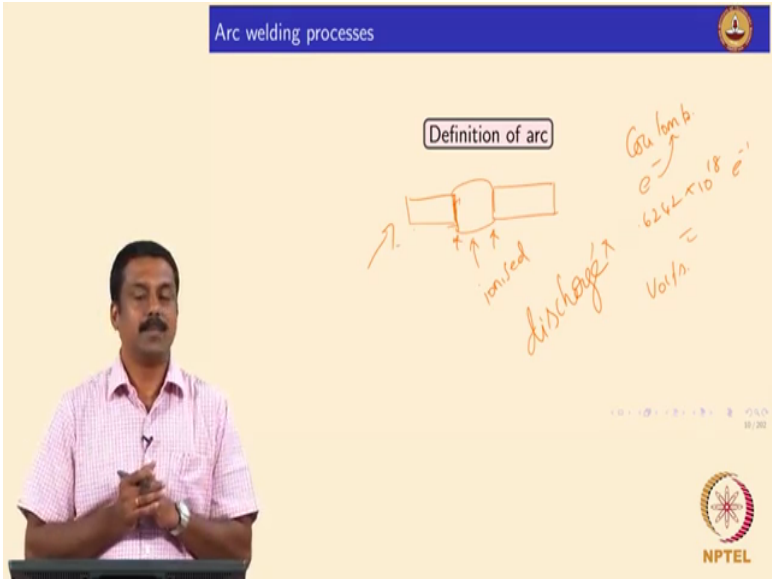

The first question again I will start with the definition, so if you clear about definition you are also clear about the concept. Let us define arc, so what are the important parameters are the fundamental rate controlling factors you may expect in arc?

Student is answering: potential difference (())(21:52)

What is it?

Student is answering: potential difference quite high.

Quite high potential difference that means voltage is high.

Student is answering: (())(22:00)

Electrons on a high state, okay. Where you need a electrons state? suppose if you have conductor, ok you pass a current from say this point to this point it can travel, right the electrons are charge carriers they can be transported as long as they have potential difference, right. So how do you define this the charge carrier there must a unit, right what is unit of this charge carrier?

Student is answering: coulomb.

Good, very good. What is coulomb?

Student is answering: (())(22:21)

Yeah you feel free I am not going to scold you, right if you say wrong answers and something is moving, right what is moving?

Student is answering: electrons.

Electrons are moving, very good. So what is relation between the electrons and coulomb?

Student is answering: one coulomb is equal to.

One coulomb is equal to?

Student is answering: 1 point 602 into 10 power 18 electrons.

1918, ok. So at any point of time number of coulombs define the amperage, right the ampere we define coulombs per second at any given time is how much coulomb is there that defines your the charge carrier, density. A unit of the charge carrier is coulombs per second at amperage, right. So if you pass say this much Coulomb electrons or one Coulomb or whatever over this conductor and it kept at a potential difference but the electrons would happily will travel because there is a potential difference, there is a conductor and through which these electrons can travel, right.

So I use a word potential difference you also use the potential difference, what is the potential difference? How you define out what is unit of potential difference?

Student is answering: volt.

What is volt? Definition when you say one volt, there must be a definition, right. So these are the basic things basic definition you need to understand, come on go ahead some words some terms you can give, you have defined Coulomb, ok. So if one coulomb travels our potential difference no second over unit length it is one ampere, right. So what potential difference can give you one volt, yes so you need to think about energy electrons cannot travel by themselves, right you need to what is the driving force? What is the push? Can you do some work? Right how the electrons do work to move from one place to other place? How do you define that? Yeah.

So if you want to attend my class you need to spend some energy, yeah. You are spending energy you are burning energy, right. So what is unit of energy?

Student is answering: joules.

Joules, good so now can you relate joules per second is what? right so now you define volt, so when one coulomb of electron travel in a second over one meter the work done is one Joule, if the work done is 1 joule then the potential difference is 1 volt, ok. So in other words if the potential difference is 1 volt when 1 ampere current passes through that it gains 1 Joule of energy, right or if 1 ampere travels through a potential difference of one volt the work done by the electron is 1 Joule when 1 ampere current travels.

So that is how we define the voltage and the amperage, in case now you have a conductor which travels which passes the electrons from one end to other end which is kept at a potential difference, so now we break the conductor is one conductor here and other conductor here now you pass a current, okay from this end to this end would the electrons travel from this interface to this interface from here to here? Why? What happens?

Student is answering: Air.

Air is an insulator but if you want to still pass the electrons from here to here what should you do

Student is answering: pressing one more conductor.

Pressing one more conductor I will not give you a conductor only air.

Student is answering: more voltage decrease a gap

More voltage decrease a gap if you make it close to each other but even then you will not expect the current would be passing from one end to other end, more voltage are you apply a high energy or a lot of amperage then what will happen? Yeah then what will happen? What will happen to these medium in between these two conductor?

Student is answering: it will become ionise

It will ionise, so what do you mean by ionised? So the atoms and molecules would lose electrons by doing so they become positive ions, in this process you create more energy carriers is not it the electrons and ions are the energy carriers, right in solid conductor electrons are the only energy carriers but if you have ions you have both electrons and ions as a energy carriers, right.

So suppose if you supply enough energy in such a way that the electrons from here would interact with the medium in that process you create more electrons, right and if you create more electrons obviously the gas atoms and gas molecules would become ionized, right and this process is in roughly known as or yeah there is an a term controversy but you can always say that if this happens when you create more ions and this process is known as discharge, right.

So moment discharge happens you generate more electrons and ions and if you create more charge carriers in this medium what will happen? this charge carriers can transfer from this interface to this interface, right and this discharge can be various types of discharges. So you see the light is over here this type of discharge, right is not it lightning is a type of discharge, arc it is also a type of discharge, right only thing is the amperage current and the voltage potential difference will be different in various discharges.

For example you have a gas discharge here discharge in the gas it is also known as a glow discharge (where the) what is voltage here? what is the potential difference between the two terminals 230 volts in India, right so we use 230 volts amperage, come on guys you are an engineer is, right. So what is the current amperage you use it at home yes 10, 15, 6 somewhere out there about amperage, ok but in arc we use different voltages in amperage that is it, right.

It is the phenomena is the same what you use it over here and glow is to discharge, it is same as happens arc we have generation of electrons and ions in a gas medium but only thing is the current and voltages are different. So if you look at the varying current and voltage, there are three types of discharges which are observed you know when I carry it passes through a gas medium, ok.

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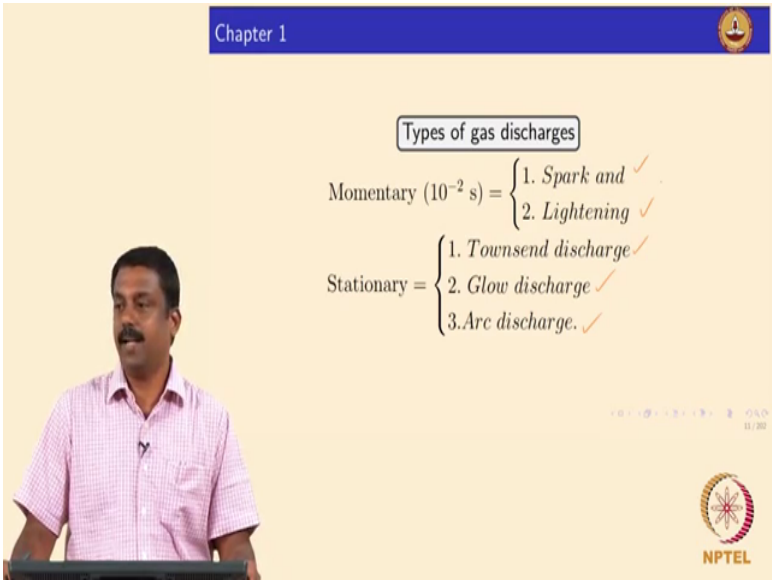

So the three discharges are known as the Townsend discharge, Glow discharge and Arc discharge, ok. And these are all stationary if you look at the natural discharges like a spark or lightning they are momentary not even a second, right. If lightning is sustained over a second more than a second then your problem, so it is a momentary the spark in lightning but if you turn the lights on the glow discharge as long as you have the energy the glow discharge is sustained is not it.

If you switch off these the input charge carriers then discharge also decays, so you make it sustained, right. So only thing is these difference between these discharges are the amount of current and voltage, right.

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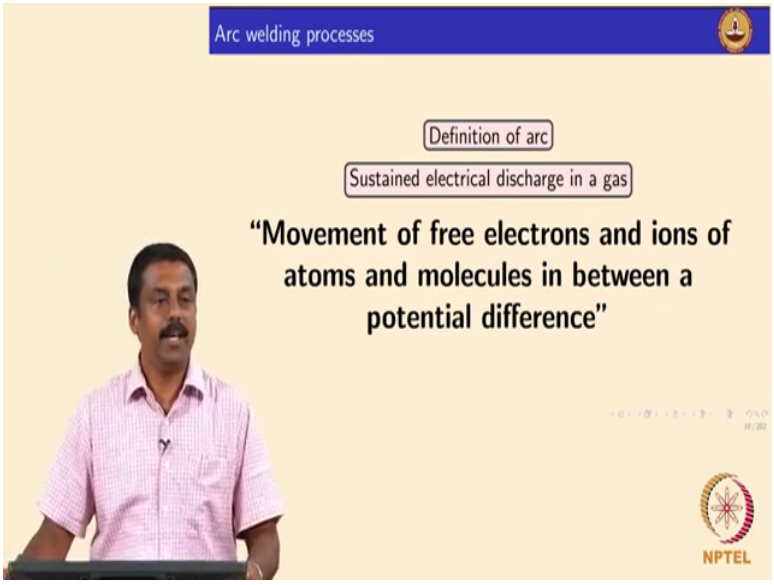

So we can define if you want to define an art it is the sustained discharge of atoms and molecules between the potential difference by doing, so the movement of electrons and ions are carried out, ok. So it is a sustained electrical discharge in a gas and due to this electrical discharge what do you mean by discharge? a creation of the evalons of ions and electrons by doing so we can conduct the energy or the energy carriers can travel from one interface to other interface by the movement of the free electrons and ions, those are generated by this discharge, right it is clear.

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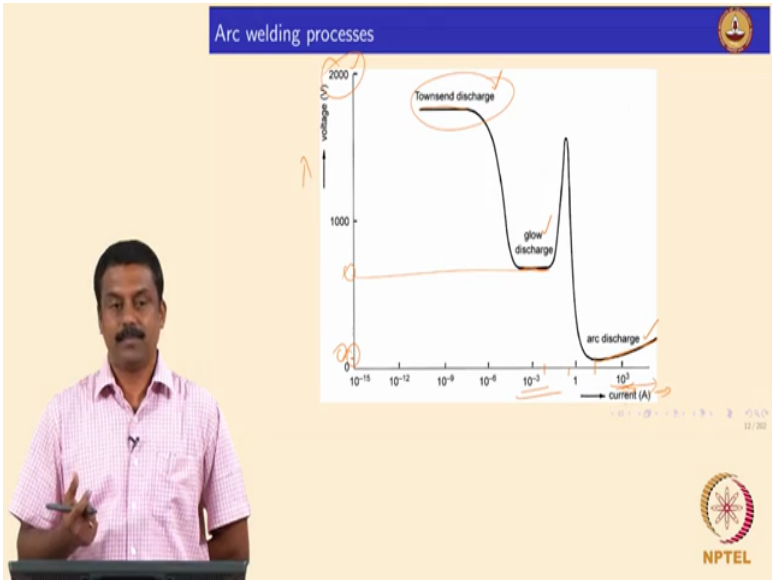

So there are three possible discharges and we can classify based on the current and voltages, whether it is arc discharge a glow discharge or townsend discharge. You see the nature of the curve in 3 discharges, there is distinctive differences compared in the end range. So we have voltage can go up to 2000 volts and here a current up to 1000 amperes. If you look at this region where you have a high current and extremely low voltage but if you look at the curve in these three regions flat. So that is the unique characteristics if you want to make these discharges sustained arc for longer time.

If the curve is going like this even for a small change in the amperage you have a large difference in potential difference or if you have a large small change in potential difference the charge carriers the amperage also changes then you have unsustained discharge that is not sustained sustainable, right. So these guys so in arc discharge and glow discharge and townsend discharge, you see that in the curve becomes four times.

So even if we change the charge carrier density the potential difference does not change much, that means that even if you pump up more current the electrons does not they do not gain much energy is not it, that is a difference right that is the definition of volt. If you pump up the electrons and electrons would start gaining the energy because of the change in potential difference then you cannot make it sustained they will collide and then you will have maybe explosion, like so you cannot sustain that discharge, so if you want to sustain the discharge even if you pump up current the potential difference would not change that means that these energy carriers should not gain much energy then you can make it sustainable.

So if you look at these curves you see that glow discharge it happens the voltage is somewhere around the operational voltage, so what we have about say 200 to 500 finally find voltage volts where you have glow discharge or you can also make it lower but depending on the characteristics of the gas what you use generally commonly you can see that and law research can happen and voltages somewhere between say 200 to 500 (degree is) voltage, volts where you have glow discharge or you can also make it lower but depending on characteristic of the gas what we use.

In generally commonly you can see that and glow discharge can happen in the voltage is somewhere in between say 200 to 500 or so and the amperage range of say 1 to 10 or 15, right and we also have another discharge which is known as dark discharge or townsend discharge and that happens in natural ways a photovoltaic effect, ok. So it can happen in for

example you have and a cosmic ray also on a gas medium and you generate some discharge and if you have a very high voltages, so you may induce on a discharge, ok.

So that happens in every time when you have a high voltage system discharge, ok. Unwelding because we use arc and which arc is struck between extremely low potential difference you see that, 10 not more than 20 volts, ok so that is the one of the major advantage of using arc because system is operated at extremely low potential difference, so that is why it is safe to use when you touch something if it is 230 volts then you feel, so when you touch a secured if it is 10 volts do you feel, you don't feel, right.

So that is what make the arc heat source is very attractive because the system is operated in very low voltages but the amperage can go up to sec 1500 even close to 200 amperes, we can operate it from say ten amps to 1500, 2000 amps we still there is no significant increasing in voltage, it will be only 10 to 20 volts, ok. So this stage are discharge happens with a very high current and extremely low voltages and low discharge happens in the voltages ranging from say 200 to 500 and the amperage will somewhere around say 1 to 10 amperage in townsend discharge happens extremely high voltages, okay in very small amperage 1 or 2 columns of energy carriers are generated, ok it is clear.

So these are the common discharges that are used and based on the amperage the energy carrier you generate energy because in arc we have a high amount of current, so you can generate more heat. So we will look at in a subsequent classes how these high energy carriers electrons and ions they interact and then they produce heat or energy, ok. So it is to summarize the basic definition of the ampere, volt governs the heat generation, ok.

So ampere and the volt govern is heat generation and if the energy carriers how to be transported from one interface to another interface we need to have a discharge, okay so this discharge can happen so when you have an ionisation of the medium which is there in between the conductors and this ionisation lead to generation of more amount of ions and electrons and the movement of ions and electrons in a sustained way in a gas medium, ok It is known as Arc.

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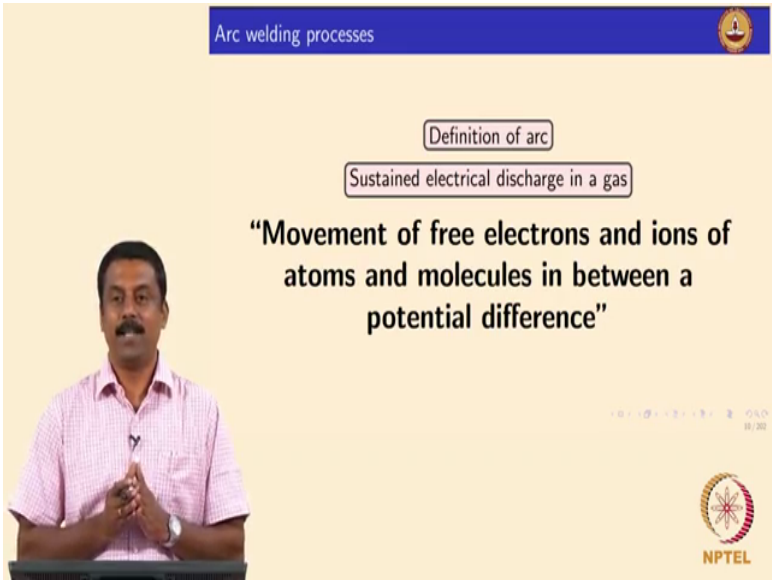

So in order to do that so you need to have a sustained discharge, so you need to keep on generating the electrons and ions, ok. I hope it is clear so we will finish this and then we will continue from next class. So any questions, so we looked at the definition of welding itself to summarize and then we move on to why welding and then we classified welding processes based on the heat or pressure based on the fusion or the solid state and then we started looking at the very important welding process, the arc welding process and we define what is arc, ok.

So we will go even deeper in defining the arc, what are the discharge mechanisms? what is discharge? Why discharge? And now heat is generated by this discharge and one of the factors controlling the discharge. We look at all the physics, these are all atom is physics, plasma physics, ok. So we will see you next class, ok will end up here, okay good thanks.