Welding Metallurgy

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Lecture – 21
Heat Sources in Welding

Welcome to the lecture on heat sources in welding, so now we will discuss about you know different type of heat sources which are used in welding process because as we know that in welding, we have a heat source which is used to increase the temperature you know in a localized place and then further depending upon the type of welding process, you will have the temperature distribution inside the specimen.

You will have localized welding taking place or the collisions of the material taking place, so first of all we will talk about the different you know heat sources because that is also one of the way to classify the different welding processes. Why heat source in welding is important because in this era of energy crisis, we need to also understand that which type of welding process will be giving you better efficiency you know thermal efficiency.

So, when we talk about the heat sources certainly, we go for the; we try to go for the heat source which is readily available as well as which is cheaper but many a times we have to choose the heat source in such a manner that you have to have the specific desired properties like you may have to take certain heat source, where the width of the heat affected zone is smaller or time required is has to be very, very small or so.

So, you will; we will encounter with different type of heat source and how their efficiency is varying, how we calculate that; that for that we will having; we having some light in this lecture.

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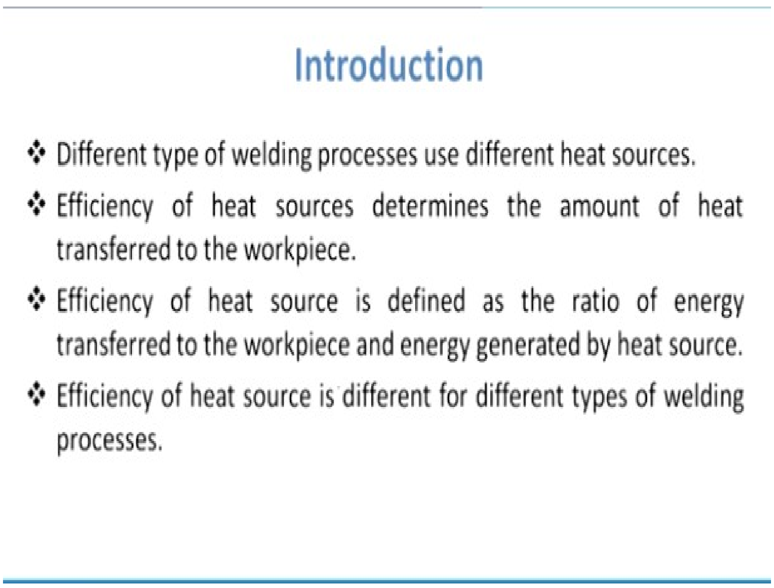

So, the different types of welding processes use different heat sources that is very common and the efficiency of heat sources determine the amount of heat transferred to the you know work piece so, you know efficiency more means the heat which is generated more part of the heat is you know transfer to the work piece to increase the temperature, so that the process of welding is facilitated.

Then, so efficiency of heat source will be defined as the ratio of energy transfer to work piece and energy generated by heat source.

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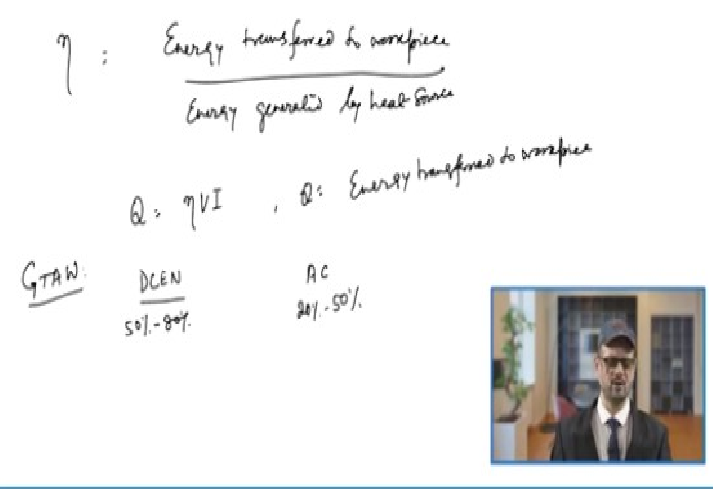

So, if you talk about the efficiency that is defined by η, so it will be ratio of energy transferred to work piece divided by energy generated by the heat source, so you know depending upon you know, the type of heat source you can have the generation of the energy which is done by heat source and then how much energy is transferred to work piece you know that will be calculated by the increase in the temperature of the body or so.

So, if you talk about you know some processes like you have electro slag welding or electro beam welding, so in those cases if you see your Q will be eta VI, so you know in those cases, you have the electric current you know and the voltage which is supplied and in those cases, the Q which is the; so Q will be the energy transferred to work piece. So, if you look at those processes like force lag or electron beam welding in those cases, your supplied is generated by heat source will be VI.

So that is your energy generated by heat source and this is the; you know, energy transferred to work piece, so the ratio of Q to VI that will be defined as the heat you know, this efficiency of the heat source. Now, if you talk about one by one to of the about the different types of you know welding processes, so if you take the you know gas tungsten arc welding; GTAW.

So as we know that in this case you have the tungsten electrodes which are used and we certainly use some inert gases for the welding process. Now, in this case we can use the DCEN, so that is electrode negative and work positive because as we know that when whichever is connected to the positive terminal your two third of the heat is generated, so this is for the direct current supply.

And you may have the option of AC current also so, in that case you will have you know transferring the heat for the half cycle and half cycle, there will not be transfer of heat, so if you take you know the if you compare these two cases, so in that case if you measure the you know efficiency; heat efficiency, you will see that heat efficiency will be varying from 50 to 80%.

Whereas, you know in the case of AC, you will have so for half of the cycle you do not have that heating taking place, so the arc efficiency becomes somewhat smaller and in this case, it goes from 20% to 50 %, so basically you know because there will be cooling in that time, when there will be no heating, so that decreases the arc efficiency.

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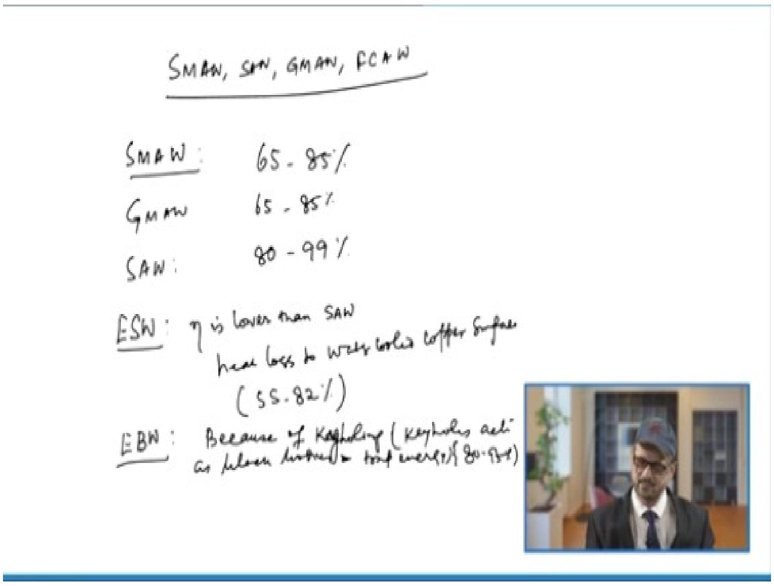

If you take the example of the shielded metal arc welding, so for processes like shielded metal arc welding or submerged arc welding or you know gas metal arc welding; GMAW or you know you have flux cored arc welding. Now, in these cases you know we use you know DCP or you may use the AC also now, in these cases you have the transfer of molten metal you know is going on, so you will have the consumable electrode in these cases, so they will be heated up.

And then you know, so in this case also you have the you know electrode in terms of wire, so that will be heated up you know but it here it is covered under a blanket, so you know so heat will be going to both the you know the electrode as well as to the work piece and in that case, your heat transfer efficiency will be somewhat higher and if you see that the shielded metal arc welding which is most of the you know, welding processes, many welding processes you know are you know done using the shielded metal arc welding process.

So typically, for the shielded metal arc welding process typically, it has been seen that the efficiency percentage is 65 to 85%, now if you go for the GMAW; the gas metal arc welding that also is somewhat close to 65 to you know 85%, so they are somewhat similar you know the this thermal efficiency or heat source efficiency is somewhat similar in these cases.

Now, if you talk about the submerged arc welding now, in this submerged arc welding as you know that in this case, you will have the blanket of fluxes there which is covering, so now this difference you know that the lower value or the value is somewhat not so high, it is because there is a loss of the heat to the surroundings also in such cases. Now, if you look at the submerged arc welding, where the flame or the arc is basically covered under the blanket of flux.

So, basically that loss is you know, minimum and in that case the heat transfer efficiency; this efficiency of the heat source is maximum and for submerged arc welding, it has been reported to be more than 82, so it is in the range of 82 you know 99%, so that is you know the value of the submerged arc welding process because of the you know arc being under the blanket of flux, your thermal; your efficiency of the heat source will be more.

Now, in the case of if you look at the you know electro slag welding, so if you take the electro slag welding now, it is the efficiency is lower, then that in submerged arc welding now, this is because you know there is a; so in this case, you have the water cooled copper shoes which are used in the case of electro slag welding and some part of the heat is basically lost in that.

So, you will have the heat loss to water cooled copper shoes, apart from that you will have some loss not very significant amount but will be some loss by radiation and also you know convection from the molten slag, so that basically because of this, the thermal you know the efficiency of the heat source in the case of electro slag welding will be somewhat smaller and it is reported to be around 55 to 82%.

Then if you talk about the you know electron beam welding process so, this is coming you know again, it is here you know, you are using the electron beams to do the welding and here you will have a phenomena of key holding is done and what happens that these key holes which are formed because you will have beams which are narrow, they will be going and so the key holing features basically, the hole which is formed of very small diameter.

Now, they actually work as the black you know surfaces, so there are black bodies and the radiation is trapped into it and a very high part of the you know heat energy is basically trapped into these you know, parts so, because of key holing, so you know these efficiency becomes smaller so because the keyholes act as black bodies and trapped the you know energy.

So because of that, these electron beam welding process that also shows you know the smaller amount of you know; so there will be some; otherwise it could have been even higher but otherwise these electron beam welding goes from you know 80 to about 95%, so you know in fact these key holes which act as the black bodies and trap energy, so in fact you know just talking in a different way, so it was; it is basically responsible for you know taking that energy mode.

And that leads to the higher value of the efficiency that is 80 to 95%, black body means it will you know absorb the radiation, so it will increase the temperature, there is very less amount of energy which is likely to be dispersed or to be you know to be emitted towards the environment, so that way it will be you know, its efficiency is quite high.

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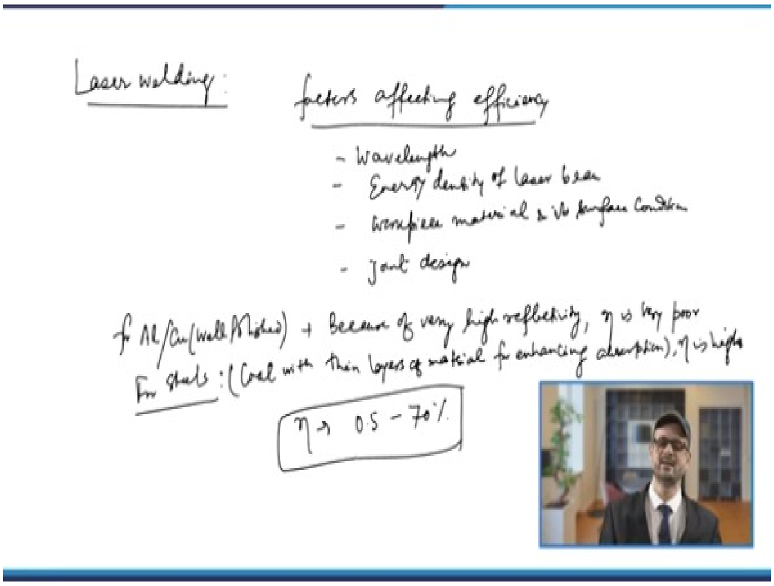

Next you know we will talk about the laser welding now, as we know that in the laser we will use the lasers and in the case of laser welding basically, the efficiency will be affected very much because of the wavelength and the energy density of the laser beam, so here the factors which are affecting the efficiency, so it will be say the wavelength, then you have energy density of the laser beam, you have a work piece material and its surface condition and joint design.

So basically, on all these factors, the efficiency for the you know efficiency of laser welding will be depending upon like if you have a very you know well polished aluminium or copper surface, so here the surface reflectivity is high, so for you know aluminium or copper which is well polished. Now, in these cases your reflectivity is quite high, so because of very high reflectivity, so efficiency is a very poor.

Because you know most of the energy is reflected and it does not contribute towards the heating of the material, so in those cases your efficiency becomes very, very small, so now so for certain type of you know materials like you have the continuous CO_2 you know, it is continuous we have CO_2 laser, it has been seen that it is of the order of 1%. Now, if you have with the steel's; if you take steel, so if you know; now the thing is that if you try to alter the surface characteristics, so that the absorption is increased.

In that case the; you know, the efficiency is likely to increase, so if you take the steel and if you know coat; so if you coat with you know thin layers of material for enhancing you know absorption. In that case, efficiency will be higher, so basically you know if you are able to establish this key holing feature which is there in the case of electron beam welding in that case, you can have a satisfactory level of efficiency even in the case of the laser beam weldings.

So, for laser beam welding if you try to analyse the you know efficiency of the heat source, it varies from very small value to a reasonably good value and its efficiency is ranging from maybe 0.5 to even 70%, so if you look at it is quite small when you have a typical type of material which are very high reflectivity whereas, if you increase the absorption coefficient in that case, your, you know efficiency can be quite high as high as 70%.

Now, if you talk about the; you know other welding process especially, the; which uses the chemical fuels, the chemical energies, the heat source.

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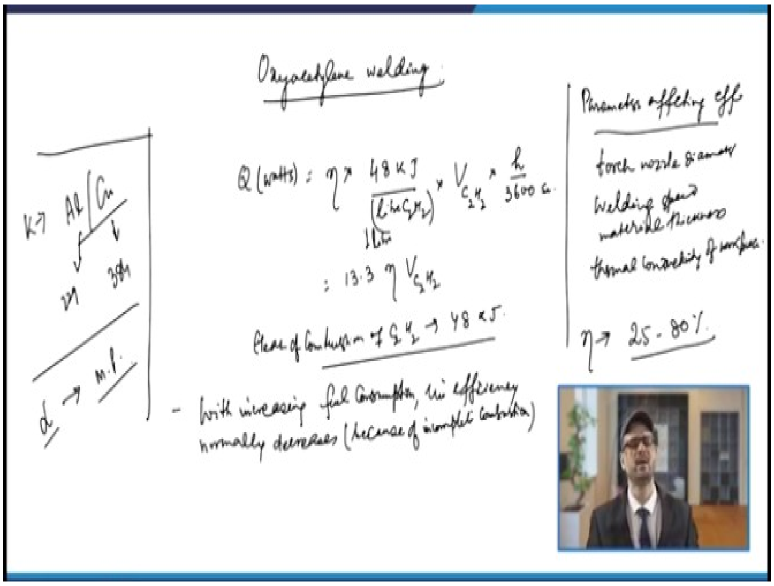

So, suppose you know you should take the oxy acetylene welding, so as we know that the heat is transferred by the combustion of the oxy fuel and the fuel which is normally hydrocarbon fuel that is ignited and the heat which is released from there that goes and heats the region where the welding has to take place. So, in those cases your Q that if you are measuring this in terms of watts, so it will be you know, η .

So, that is your efficiency of the heat source and it will be you know, you have the you know, if you take the acetylene gas as the you know, so heat source, so it will be 48, so if you take this will be 48 kJ in a per litre of you know per litre of C_2H_2, so one litre; for one litre, C_2H_2, it is you know, it is liberating 48 kJ of energy and multiplied by volume of C_2H_2, so what is the volume of C_2H_2 that you are taking.

And then you will have this h upon 3600, so that is your second, so this is hours, so you can have the; if you are measuring in terms of per second, you will have you know say divided by 3600, so if you look into that so, it comes as 13.3 so this will be $48000/3600$, so it will be 48 divided by 36, so it will be 13.3, it is something like 40/3, so it will be 13.3.

Now, 13.3 η and volume of C_2H_2, so this way you can calculate so, if you know the volume of C_2H_2, in that case you can measure the efficiency, so that is your Q, now this 48 kJ, this is the heat of combustion for this C_2H_2, so the heat of combustion, this is 48 kJ, so this is per litre. Now, for so what happens by if you know these volume how much of C_2H_2 is used based on that you can have the; and what is the Q.

So, if you find the Q that is that will be basically the amount of heat which is required you know which has been used to increase the temperature, so once the temperature increases known to you and property of materials you know, then you know that for increasing the temperature up to that extent, what is the you know amount of Q that has gone into, so and this is the amount 13.3 $V_{C_2H_2}$ that is the amount which is generated by the you know fuel.

So, in fact by that you can measure the efficiency of the heat source, so it will be varying over a wide range because you know, it will be; so as the fuel consumption will go on increasing, the efficiency will decrease you know and the reason is because of the incomplete combustion, so you know with you know increasing fuel consumption, the efficiency normally decreases.

So, the part of the reason is you know because of incomplete combustion because you know you require the amount of oxygen also to have the complete combustion and if you are increasing many a times we are increasing for many reasons and there are certainly different types of flames which are available you know, I mean typically you have three types of flames so, oxidizing, neutral and carburizing.

So, if you increase the you know fuel amount more than what is required for the complete combustion, in that case there will be not be complete combustion taking place and in those cases, there will be loss of the fuel and that will basically decrease, so the efficiency, so because of incomplete combustion, so that way your efficiency will basically be changing. Then if you talk about these you know, oxy acetylene in welding processes here the efficiency will also depend upon other parameters.

So, parameters which will be affecting this efficiency, so for that there are different parameters like you have torch, nozzle diameter, then you have welding speed, you have material you know, thickness and thermal conductivity of work piece, so this way these are the parameters basically, they will be you know instrumental in deciding whether the efficiency is high or low.

Because ultimately, you know you have to think that you know how you can increase the with the same amount of fuel in what way the temperature has of the material can be increased, so once you increase that temperature means, you are utilizing the energy of the fuel for its you know use. So, if you typically what has been reported is that the efficiency for these oxy acetylene gas welding process varies from 25 to 80%.

So, if you will see there are extreme values, if you may have very less value when you have the you know, wastage of fuels in many situations or if you have the different type of material properties where it is not able to you know restore the heat, it is dissipating the heat at a very fast rate, so certainly the temperature will not increasing, so that way or even the speed also, if you are going fast in that case, it is not able to increase the temperature you know in certain localized zone.

So, these are you know the typical you know parameters which are affecting the thermal efficiency of these you know processes, so similarly you know in other processes also you may have the different you know working parameters which affects you know the efficiency of the heat source to certain extent and that is why you get a range; you get a range that you can if there is loss; if the loss which is there which that loss becomes more you will have the you know efficiency toward the lower side.

And if you try to minimize the losses to the surroundings, you can increase the efficiency many a times, we do certain measures to basically reuse the heat you know which is liberated to the surroundings, so there is you know regenerative, you have reuse of those energy which is being dissipated to the surroundings, so that way you can you know increase the efficiency of these processes.

So, apart from you know the so, if you try to see the you know different temperatures, different properties, the properties which are used basically for the heat sources now, I mean when these heat sources are used, some of the you know material properties we may be you know in need of knowing and those material properties which are basically you know important for us.

They are basically the thermal conductivity of the material source so, say suppose you know K and depending upon the K you know, it also depends that which type of welding process should we choose because if the K is very high and if you are taking a material, if you are taking a process where the heating rate is not so fast in that case, in the time which is available all the heat will be dissipated towards the you know through the work piece.

So, for materials like so that challenge is there for materials like aluminium or copper whose conductivity is quite high, if you look at its conductivity it will be you know for aluminium it is 229 kJ/m/second/^{0}C, so something like similarly for copper, it is even higher, it is 384 J/m/second/^{0}C.

So like that you will have a while for other materials like even if you take about the steel, it is something near to 41, then you will have the Inconel which has even smaller that is 18 or so, so for titanium alloy, it is 27. Another property which is you know also coming into picture many a times will be your thermal diffusivity $\alpha = \frac{K}{\rho_{cp}}$, so it will be depending upon K as well as the CP.

And you know so and then apart from that the most important thing is melting point, so when we have a higher melting point material, then you have to selectively choose a typical you know process like if you have to melt a material of higher melting point like if you have go for a steel then you know the oxyacetylene welding will not be preferred, so because you require a large amount of heat, your melting point is higher you know for or even for titanium.

Another factors also there like may be oxidized or so for certain materials, so depending upon the material properties like the K or the α or the melting point you take these different heat sources and also we try to minimize the losses by you know using the processes in such cases. Thank you very much.