Welding Processes
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Laser welding process Part 04

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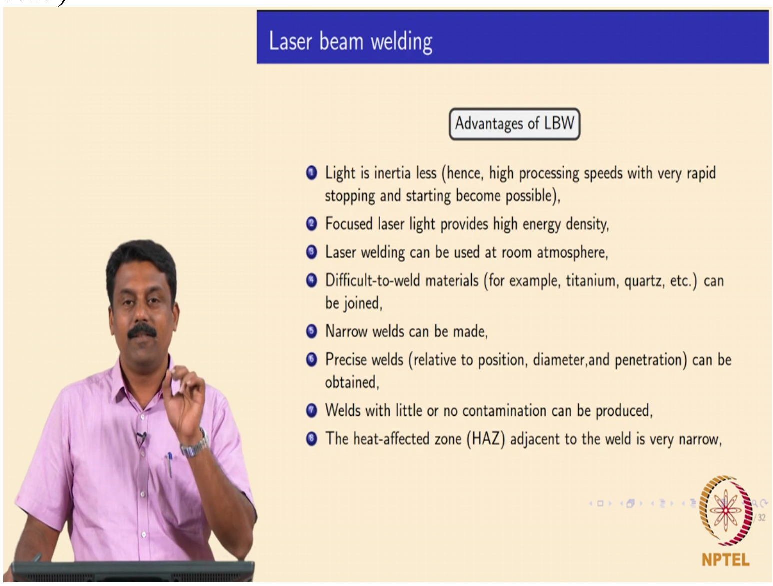

So what are the advantages of Laser beam welding? So light is inertia less. Is not it? So you can stop it any time in a fraction of seconds. So obviously you know there was an invention last week, reported in natural material. I do not know how many of you follow the newspapers. Right? So a university in UK, they invented a new camera which can record the purpose of laser. The pulses, pulse of a continuous laser will be smaller than femto second, 10 power - 12 seconds. And they invented a mechanism to record videos in several billion frames per second.

Student: (())(1:02)

Professor: Yes. So they could see the pulsing of a continuous wave laser. They could see how the laser actually coming out from the medium, even a continuous wave. Okay. And because of this property, the laser can be manipulated so nicely, they can generate the pulses of extremely tiny seconds. So they can generate pulses of each pulse lasting a femtosecond okay. So laser can be turned off and on with a duration of femtosecond. Okay. So these are all widely used for lithography applications.

For lithography applications means to generate electronic materials, to change the surface properties of materials. Right? So the materials like hydrophobic material, okay, what is hydrophobic material? Yes, like lotus leaf. Okay. So lotus leaf surface contains tiny dimples of a few nanometres wide and that makes the lotus leaves hydrophobic and people use laser of femtosecond pulses so that these laser pulses, they can be sent into the surface of the material, for example titanium to create that nano pillars as well as the surface of the material can be hydrophobic.

And we use femtosecond lasers or pentoseconds lasers. And we can manipulate lasers in various ways because lasers does not have inertia. So we can switch it off and on precisely. Okay. At a very rapid start and stop. So that is one of the important parameters, properties of the laser. Okay. So we can also manipulate. Right? The arc, it is difficult, okay. We always start (())(2:50) problem when we have arc and plasma. Okay. You press the button, it still you see something is going on. Right?

Because obviously we have transformers, capacitors, rectifiers and they have their response time. Whereas lasers can be manipulated precisely okay. And we can also focus the laser at every tiny spot. Is not it? The laser I showed you over here in the videos, they have a spot size of 50 microns, 50 microns. 50 microns. 4 kilowatt power can be focused on the 50 microns spot size. So enormous amount of power density. Okay. And with that, we can concentrate the the laser power into a very tiny area.

So we can increase the depth of penetration without affecting the micro structure of the material widely whereas in arc, you have an arc size, the envelope size of a few millimetres always. Okay. (())(3:48) typical the arc envelope size will be close to 5 to 10 mm. So the other distribution is much wider. So in laser, we can focus it using optics. Okay. So we can use as a light, is not it? So we can light can be focused by various optical based on the wavelengths, we have to choose the optical lenses. Okay.

And then we can focus the light power into a very tiny area. Okay. And then the other important application of laser compared to electron beam is laser welding can be done at room temperature, at room atmosphere, at room temperature room atmosphere. The electron beam obviously needs some vacuum. We will see in the electron beam welding in subsequent slides. And some materials very difficult to weld by conventional fuse welding techniques like arc welding and plasma welding. For example, titanium.

When titanium oxidises okay. Significantly, so in a way plasma is the best to weld titanium because we have a dual gas. Is not that? Production is very high from the atmosphere. So plasma building is the best to weld titanium. And laser can also be used because the exposure of the material is very tiny. So do not expose much larger volume and we can also use a proper shielding which can control the oxidation of titanium.

And the materials for example quartz, as long as the material observes laser, that is okay. So we can use the move, we can weld those materials using laser. So some of the materials, we cannot use arc. It is very difficult to fuse there as laser can be used. And based on the beam size, spot size and the fit up, we can also make very narrow welds and very precise weld. Okay. Because laser again manipulated, can be manipulated by using an optics. Even if it is very difficult to reach, the laser source can be focused onto a geometry which is not reachable otherwise by arc or resistance part welding definitely. Okay.

And weld as with little contamination because you can also have an a shielding right? And because of the very confined heating what it do, the HAZ, heat affected zone is very narrow and you will have a very steep temperature gradient. Okay. Because the keyhole can be hardly a 1 or 2 mm if we are using a beam size of 50 microns. Okay. So you will end up forming a keyhole of 1 mm, the Whirlpool of 2 or 3 mm size. So very fine seam can be made using laser spot size of 50 microns or so.

And because of the confined heating, the heat is also extracted rapidly because we have a much more mass. So the temperature gradient will be very steep. Right? And due to that, the heat affected zone is also very small, very narrow. Right? It is clear? Good good.

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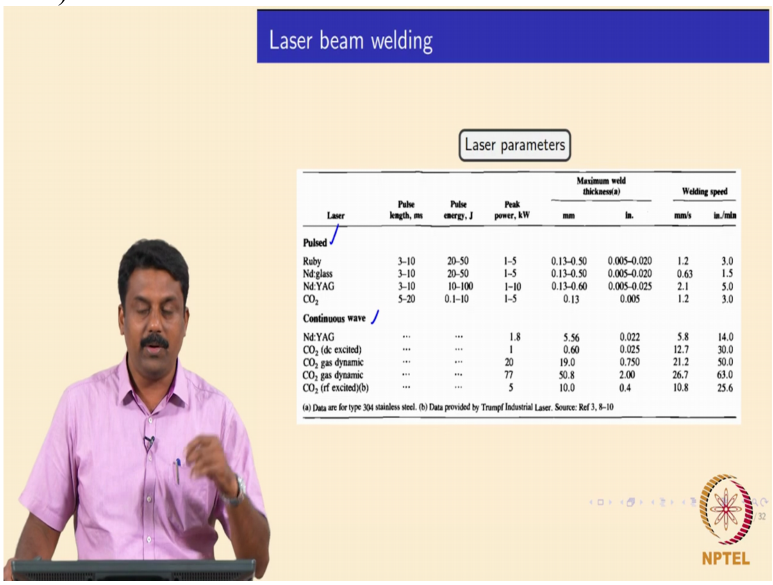

Laser	Pulse length, ms	Pulse energy, J	Peak power, kW	Maximum weld thickness(a) mm	Maximum weld thickness(a) in.	Welding speed mm/s	Welding speed in./min
Pulsed							
Ruby	3–10	20–50	1–5	0.13–0.50	0.005–0.020	1.2	3.0
Nd:glass	3–10	20–50	1–5	0.13–0.50	0.005–0.020	0.63	1.5
Nd:YAG	3–10	10–100	1–10	0.13–0.60	0.005–0.025	2.1	5.0
CO_2	5–20	0.1–10	1–5	0.13	0.005	1.2	3.0
Continuous wave							
Nd:YAG	···	···	1.8	5.56	0.022	5.8	14.0
CO_2 (dc excited)	···	···	1	0.60	0.025	12.7	30.0
CO_2 gas dynamic	···	···	20	19.0	0.750	21.2	50.0
CO_2 gas dynamic	···	···	77	50.8	2.00	26.7	63.0
CO_2 (rf excited)(b)	···	···	5	10.0	0.4	10.8	25.6

(a) Data are for type 304 stainless steel. (b) Data provided by Trumpf Industrial Laser. Source: Ref 3, 8–10

So some of the laser parameters, just took it from a handbook for your reference. For future I mean you can use it. For example, the pulse laser and continuous wave laser. So what is difference between these 2? Pulse laser, obviously you have a pulsing. Continuous wave, in the (())(7:00) produces continuous wave. The laser is continuous but continuous laser is a relative term. Okay. Inside the continuous wave also, you will have pulses but they are overlapping like femtosecond pulses.

It becomes continuous. It is objective, okay. So in fact one of my former students argued with me point defects, zero dimension, one dimension, two dimension, okay. So I can see is a okay. So it is an what you call it is a zero-dimensional defect. No Sir, he said no no, you can measure the size of the vacancy. Okay. It is a three-dimensional. So what you call it is in a zero dimensional defect. Similarly, a continuous wave is relative. Okay. It is still a continuous wave, it also have very tiny pulses which are overlapped. That is why it is a continuous wave.

Is not it? So the pulse laser is a Ruby and CO2 and NDR pulses. So if you look at say for example, 0.5 mm, and you can use 1 to 5 kilowatts, so generally ideal is same favourite, 1.2 mm thick, still if you want to weld right in overlap configuration, right. So the laser is generally done in overlap condition. So it will be 2.4 mm. Is not it? 2 times T. And if you want to have a full well seam formed like these, 2 kilowatts should be sufficient. Yes. 2 to 2.5 kilowatts, you will have a full penetration weld of 1.2 mm thick sheets overlapped to each other.

2 to 2.5 kilowatts, you will have a very nice weld made in steel. Aluminium, you need to use a slightly higher power, the reason is the absorption. Only 10% for aluminium. Firstly, it will be about 20% or 25% absorption whereas aluminium, aluminium does not absorb light. That is the reason, when you heat up aluminium, it always remains white because everything is reflected. Okay. Whereas if you heat up the iron, you will see the change in colour, right?

So that means all the colours are absorbed. Only the orange colour is sent out. So there is absorption. Whereas aluminium in heat, it is very dull. It is always white because nothing is goes in. All the light is reflected. Okay. The same, when you use as welding aluminium alloys, the absorption is very minimal. Okay. Only 10%. So efficiency of laser welding aluminium alloys is extremely poor because of poor absorption of laser. Okay. So some of the parameters as listed from the handbook, you can have a look at it. Okay.

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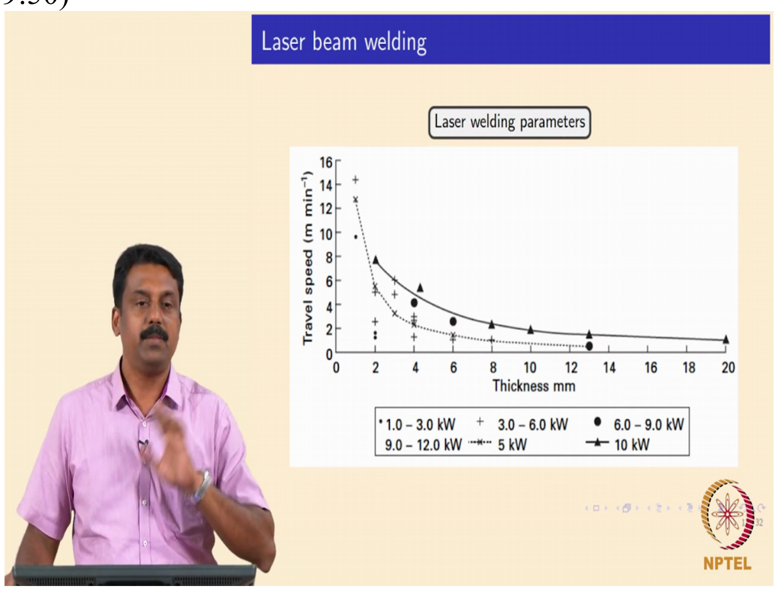

So typical parameters, laser welding parameters when you have lasers, there are 2 controlling factors only. So not like laser efficiency, efficiency is also there. But here the typical parameters- the laser power, welding speed, that is it. Okay. So the laser power and the welding speed, that is what is going to determine the penetration. Say for example, this graph, I took it from John Irish. So see if you are building a 4 mm thick plate in overlap configuration, so the travel speed obviously, if you are using it say 1 to 3 kilowatt laser dots so you need to use a very small, very slow laser speed and obviously if you are using higher power, for large thicknesses, so you can have a process window established as much now laser power and the travel speed. Okay.

So very simple you do not need to worry about like in gas and arc welding. So you will have current and voltage and electrical shielding gas, those are all factors which is going to affect the penetration. In this case, very simple. Laser welding, power and travel speed, that is it. It would control the welding parameters. Good.

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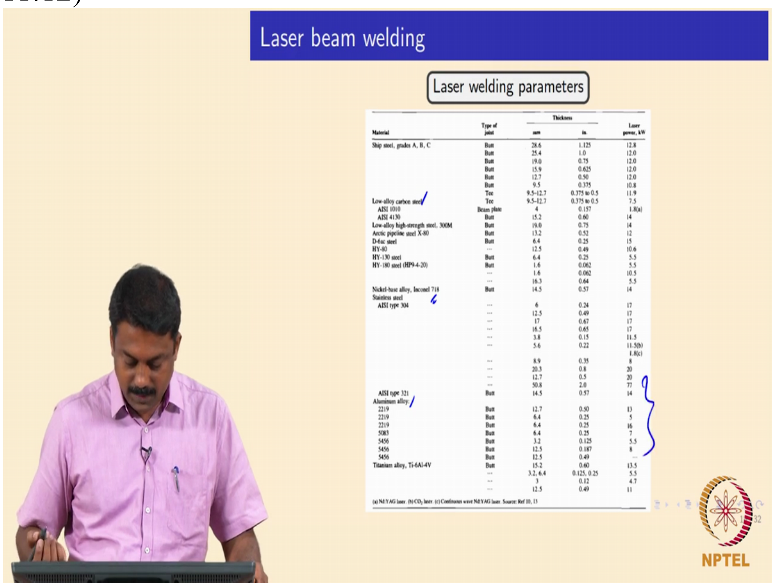

So again, so some of the parameter generally we use if you look at the commonly used. Low carbon steel, pipeline steels, nickel base Inconel 718 okay. Aluminium alloys. So aluminium alloys when you are using it, you always have to have a very high power because of the poor absorption. The same goes for titanium as well. Titanium also needs a slightly higher power. Good.

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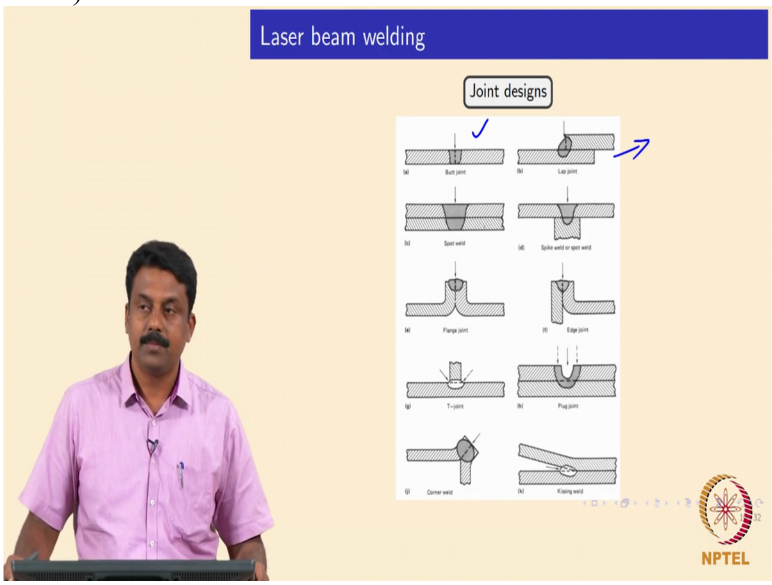

So the most commonly used joint designs are the overlap and the butt configuration. Okay. And in laser welding and electronbeam welding, when you are doing butt configuration, the edge preparation is very critical. Okay. So because of a very narrow heat source, is not it? So when you are willing but weld so the fit ups would be perfect. So suppose if the edge preparation is not good, okay you are preparing the edge something like this. It is most of the times B tech students and up doing that, okay. And even sometimes even masters students as well.

So if you prepare edge something like this and you have a laser which is pointing a 50 micron points, lasers is pointing out. It is maximum, the exposure area is hardly a millimetre. Okay. So every edge preparation is not good in butt welding consideration, you are not going to melt properly. You are not going to form (())(12:40). Right? So the preparation of the edge is extremely critical for laser and electronbeam welding because the (())(12:47) itself is very narrow. Right?

In arc welding, okay so it was a the envelop itself is about 5 mm. Is not it? So the laser, the arc will have a much wider heat source. So even if you have a small the the problem in the edge preparation, you can still overcome that. But whereas the laser welding and electronbeam welding, the edge preparation is very critical. So sometimes maybe because of that, you know overlap configuration, the lap welding is advisable.

So in this case, then we can go away with that problem. That is why in automotive industries, I mean this laser welding is done and it is mostly done with overlap configuration. Otherwise if you are using a very long, thick sheet, right? So the edge preparation is very tricky, right? So you can have a shearing and then shearing edge can have in a supposed variations. So if you are doing overlap configuration, is very nice. Is not it?

So the laser spot welds are also widely used and for some applications, it is by using a seam weld, you can reduce laser spot weld, the weld area by you just using a spot welds. And then the various configurations which are also commonly used like the plot joint, okay so it is also used. And then the corner weld as well. These are the common joint designs used for laser. Okay.

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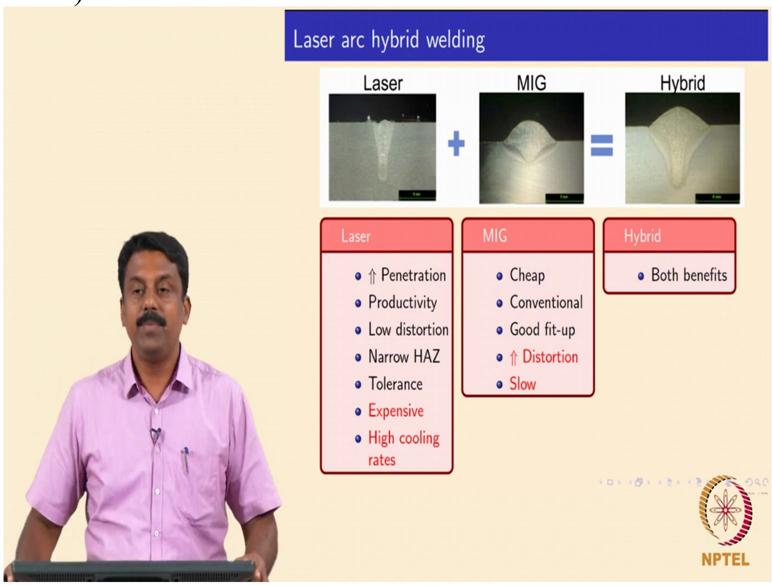

And then there are some attempts to combine laser and arc. Okay. Because laser and arc is always nice. So why? The, in arc welding, the penetration is very poor because the heat density, the power density is very low. Right? In laser welding, power density is very high but we have a very narrow weld. So that is what I first one, this slide. So suppose if you use only laser, so you will have a keyhole, this is a keyhole formation which is not a particular keyhole but you have a keyhole formed. But the well is very narrow. Okay.

And if you are using just a GMAW, the well will be wide but the penetration will be very poor because of the power density of the arc. Okay. Now combining these 2 so we can have a larger penetration and then slightly wider bead. Wider bead is always nice because then the discharge partitioning will be much nicer. Right? If you have a narrow bead, the weld is very narrow. That means that when you are applying, you are using the weld in any application, the thrust is concentrating on a very narrow region. Okay.

So that means the weld, the narrow weld is prone for failure than if you have a much larger weld, the thrust is distributed over a large area. Okay. So laser properties, high penetration, productivity is higher because of the high power. Now distortion is minimal because of the narrow heat of it absorbs and the heat source. And you will have a very good tolerance. But whereas the laser is expensive and the cooling needs are much higher, so microstructure what is generated from the laser waves invariably if you are using steel (())(16:02). Okay.

Whereas in MIG, so you have a cheap and conventional good fit up and the distortion is higher and then process very slow. Right? Now by combining laser and arc, so we can get the benefit of both, laser and GMAW. Okay. So in this case I showed you are for example, what when we combine the laser and the heat source made and we can increase the penetration and we can also have much wider beam so that we get both benefits from the laser and the arc. Okay.

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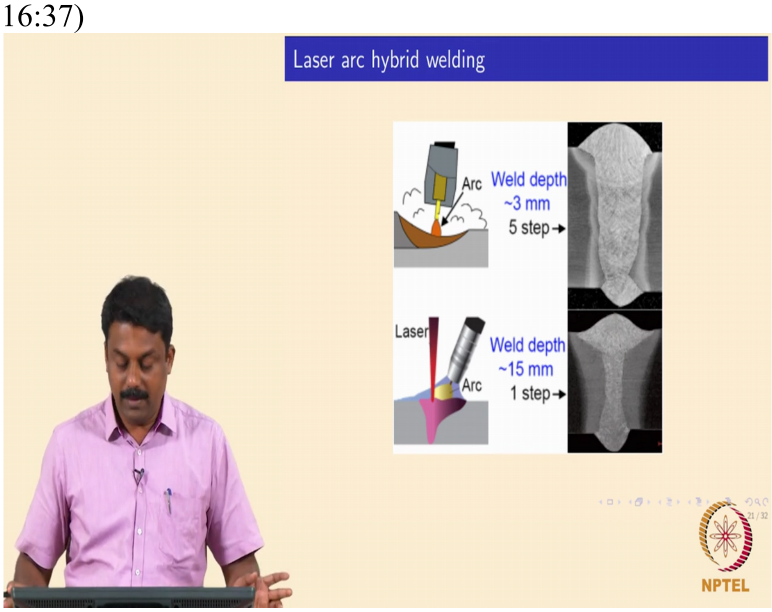

And we can achieve much larger productivity. Say for example, this a pipeline well, welding of a pipeline steel. Okay. So pipeline welding is done in a ship. Right? I showed you, I think I did explained in a jeweled configuration in our previous class I suppose, long back. So these welds are used for underwater. Okay. So this is an I think 60 pipe of 16 mm thick okay. And conventionally when you are doing welding, we have a route pass made and then subsequently 6 passes using GMAW.

Okay. So we see (())(17:25) passes. Okay. And then so route pass plus 6 passes are needed to have a weld by GMAW. Okay. By combining laser and GMAW and we can achieve the full penetration weld in a single pass because we have now a heat source which has been high power density and a GMAW which can supply enough material, enough liquid material to fill the weld cavity. So instead of having 7 passes, we can fill the weld cavity in one pass.