Basics of Mechanical Engineering-2

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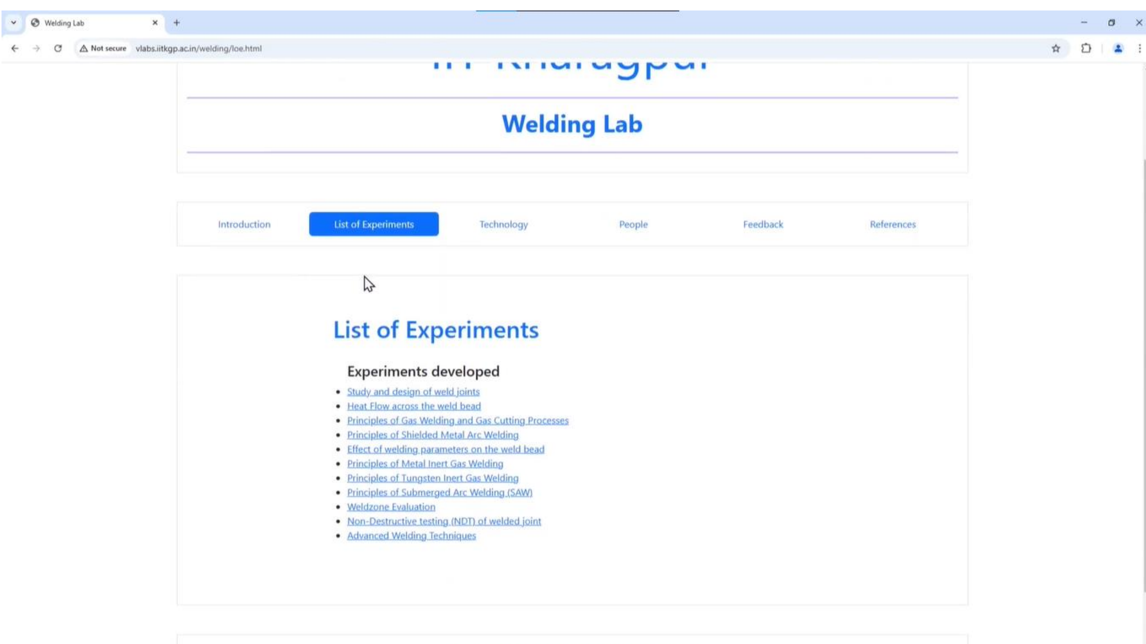
Week 08

Lecture 32

Virtual Lab. Demonstration (Welding)

Welcome to the last lecture of week 8. We are discussing welding technology in week 7 and week 8 of the course Basics of Mechanical Engineering II. I have discussed the problem statements on welding in the last lecture, and I have also discussed certain characteristics of the welding arc. Now, in this lecture, I will demonstrate the simulation—the virtual simulation on welding—which is developed by VLAB. For that, I will go to the Google page and type here 'VLAB welding.' Enter. The first link that appears is 'welding lab.' Let me click this link.



So, I now have a page opened which shows 'virtual lab' divided by an institute, and here is the list of experiments. That's just zooming it out. Study and design of weld joints, heat flow across the weld bead, principles of gas welding and gas cutting processes, principles of shielded metal arc welding, effect of welding parameters on weld bead.

Principles of metal inert gas welding, principle of tungsten inert gas welding, principle of submerged arc welding, weld zone evaluation, non-destructive testing of welded joints, and advanced welding techniques. Because this is a basics course, I will not talk about the weld zone and heat-affected zone, etc.

I'll just walk you through certain welding processes. Majorly, the gas welding you have discussed in the previous lectures—all of them are those discussed—but I will focus more on this virtual laboratory demonstration on arc welding and some of the advanced processes.

Now, first, I will go through metal arc welding. I'll just click the link, and we are opened to the demonstration page here, where we have aim, theory, pre-test, procedure, simulation, post-test, references, contributors, and feedback. This is the generic phase for the virtual laboratory that you have seen in the previous lectures as well. So, the aim is to understand the basic principles of the shielded metal arc welding process.

The theory regarding shielded metalwork, specifically shielded metal arc welding, which we have discussed, is again represented here. So, what does SMAW cover about the flux and all the layers of the weld zone? It is presented here: the slag layer is present because we have the electrode here, where the core is the metal, and outside we have the flux coating on the metal.

The flux covering is there, and this flux covering forms slag, and weld buildup is present. Between the weld buildup and the weld metal, we have the weld depth of fusion. So, all these components, all these parts, are here in the weld zone. Then, there's the theory regarding the different positions: flat position, horizontal position, vertical position, and overhead position.

These are the positions where shielded metal arc welding can be performed. Process parameters could include electrode diameter and electrode type. Welding equipment includes the power supply, electrode, electrode holder, ground clamp, welding helmet, welding cables, chipping hammer, and wire brush to clean the slag later. Advantages and disadvantages are given. The theory part is already covered.

Let me come to the pre-test questions. The first question is: What does SMAW stand for? This is shielded metal arc welding. What type of joint can be made using SMAW welding? There could be multiple joints: butt joint, lap joint, T-joint—all of them can be made.

Type of electrode used in SMAW welding. Electrode used is generally a stick that is having metal at the core and there is a coating of flux outside. The power source that is used in SMAW welding is both DC and AC power could be used. The purpose of flux coating in electrode in SMAW welding is to protect the weld from oxidation? Yes.

To provide this shielding gas? To improve the mechanical properties of weld? All of these are the purpose points. What type of metal can be welded using SMAW? It can weld steel, aluminium, copper.

All of these could be welded. What is the major advantage of SMAW? Speed, portability, automation. Automation is generally not there because big and big building are there that has more automation. A continuous supply of wire is there.

So automation is less there. So that is not an option. Because automation is not there, speed cannot be an option either. Portability, because the power supply is small equipment that can be taken anywhere. So that is, portability is a major advantage here.

During DCSMW, which polarity concentrates more heat on the electrode? Because it is direct current, reverse polarity is used. What type of groove is constructed for vertical position welding? For vertical position, a V-groove is constructed. Which of the following defects can result from using a wet or damp electrode?

Porosity could result. Lack of fusion, slag inclusion, undercut, porosity is the major answer here. Let me submit it. I got 10 out of 10. So that means all are correct.

The procedure is mentioned here now. The next step is to press the start button. Then select the type of operation of your choice. Type of joint. Type of material.

Press the start button to begin the process. Then the mouse can control the scroll to zoom in and out. Left-click and move the mouse to rotate. Right-click and move to adjust the setup. Repeat the experiment. This is a kind of simulation that you see in various CAD software, Computer-Aided Design software, where you try to drag the figure from one place to another. The animation of the figure deck is there, or you try to zoom in and out, or you try to move the overall figure from one point to another. All those controls are given here.

Let me proceed to the simulation. The procedure is given here again, and the first step is to press the start button. Press the start button, select the type of operation—there is only one choice here, shielded metal arc welding—and click here. Type of joint—there is a butt joint, and there is only one selection point. The type of material is mild steel, and I can start here.

Now, here is the simulation. I can zoom it out. It is showing the butt joint completed here. This is a simple, I would say, simulation or animation here, but we can keep picking different options. If not in this experiment, in multiple other experiments, different options could be chosen.

Now, the next step here is post-test questions. I click on the post-test; there are post-test questions. What is the typical weld position used in shielded metal arc welding? The typical weld position that is used here is, this should be all of these. The second question is: what is the typical shielding gas used in shielded metal arc welding?

Argon, carbon dioxide, oxygen—the other three are not the right answers. The next question is: what is the purpose of slag in shielded metal arc welding? The purpose of slag is to protect the weld from atmospheric contamination. How is the arc generated in a summative view? The arc is generated by striking the electrode against the workpiece.

The first answer is correct by using a non-conservable tungsten electrode by using wire electrode by using a gas shield to ionize the air. Other three are not the right answers. How does the electrode coating affect the welding process in SMAW? It affects the melting rate and deposition rate of the electrode. This is the effect it creates.

Which of the following is not a type of electrode coating? Electron coating is of multiple types. It could be rutile, no calcium, no fluoride, no selenium, no nickel coating is there. Chipping process after SMAW is done to remove the slag. Which of the following type of materials cannot be welded using SMAW technique?

High melting point, low melting point. Low melting point materials cannot be welded because the temperature of the arc is very high. Low melting point materials are generally soldered. So, high melting point materials are only welded using SMHW. The last question in post set is which of the following welding positions electrode is held at 45 degree to the work piece. So, in the horizontal position electrode is held at 45 degree.

I will submit it. So, I got 9 out of 9. Next is references, which were used to develop this virtual laboratory demonstration: Welding Handbook - Welding Science and Technology by the American Welding Society; Robert V. Messler Jr. - Principles of Welding Processes, Physics, Chemistry, and Metallurgy; and Manufacturing Science, second edition by Amitabh Ghosh and Ashok Kumar Malik. So, this was one of the experiments. Let me try to pick another experiment.

Next, I will try to pick any of the automated welding processes. Let me, for example, pick metal inert gas welding. So, this is similar to shielded metal arc welding. Only the point is the wire is fed continuously, and there is a gas around. So, the theory here is this is how it works: a gas supply, contact tube, gas nozzle.

This is a mixed setup. And this is the mechanism within the nozzle. There is a gas diffuser, a gas nozzle, the wire guide, and a contact tube. The solid wire electrode comes out of the wire guide, and this gas diffusion tries to shield the welding zone from the outside atmosphere. So, weld metal is there, that is put here, and this is the base metal. A molten metal pool is there.

So, this theory about gas metal arc welding or metal inert gas welding is given. The kinds of metal transfer processes could be short-circuit transfer, globular transfer, spray transfer, or pulse transfer. This is given here. Different kinds of metal transfer processes are further explained here, and the constant voltage power source that is used—that we have discussed how the current varies with the fluctuation in voltage—is given here.

And let me come to the pre-test questions. Before talking about the simulation, what is gas metal arc welding or GMAW used for? Joining metal sheets, welding pipes, welding non-metallic materials.

C cannot be the answer. So, both A and B are the answers. That is joining metal sheets and welding pipes. What is the purpose of shielding gas in gas metal arc welding? Shielding gas protects the weld from atmospheric contamination.

C is the answer. Controlling temperature and providing filler metal are not the purposes. How is the heat used to weld in the GMAW process generated? How is heat generated? Heat is generated with the help of an electric arc.

So, B should be the answer. What is the gas used in MIG welding? The gas used here is mainly argon. What type of electrode is used in GMAW welding? The electrode that is used is the consumable electrode.

Which of the following gas is not used in GMAW? Argon is used. Helium could also be used. Acetylene is not used. Acetylene is used in the gas welding technique.

And we can only use the inert gas, argon or helium. Which of the following types of metal transfer provide lowest amount of heat to the workpiece? Spray transfer, short-circuiting transfer, globular transfer, pulsed arc transfer, short-circuiting provides the lowest amount of heat. In GMAW, what is the primary material of the consumable electrode for welding carbon steel? For welding carbon steel, mild steel electrode is used.

Submitting the quiz. And then coming to the procedure to understand how do we run the simulation, It is similar to what we did in the shielded metal arc welding, start button, then type of operation, type of joint, type of material, type of electrode, then again start. The mouse controls are the same as we saw in the previous setup. Simulation, coming to the start button, clicking type of operation, mig, type of joint per joint, type of material mild steel, type of electrode is again mild steel and I can start my simulation. So this is the simulation that is presented here. You can see here.

So this is the welding that is completed. This is the simulation here. This is the whole system or equipment kept here. So let me stop just to show you once again. I select the different variables and start the process. You can see the nozzle is supplying the electrode material and the welding material in the form of wire, and it is being transferred here.

And this is what we have gotten: slag over the weld. Next are the post-test questions. The post-test questions: What does GMAW stand for? It is gas metal arc welding. Which of the following metal transfer modes can occur during MIG welding?

Globular, short circuit, spray—all of these can occur. What is the main advantage of GMAW welding over other GTAW systems? The advantages are high metal deposition, lower cost, better penetration—all of these are advantages. What is the use of shielding gas in GMAW welding? It prevents oxidation.

Yes, increase the heat of the weld to make it stronger, then cool the weld. No, these are not the options. It prevents oxidation. Which of the following shielding gases is typically used to achieve shallower penetration in GMAW welding? For shallower penetration, we use carbon dioxide.

However, argon, carbon dioxide, helium, and oxygen are all used. Argon is mainly used, but for shallower penetration, if required, carbon dioxide is used. What is the effect of using higher voltage in MIG welding? When using higher voltage, a larger weld bead is created. How does using a larger diameter wire affect the MIG weld?

It improves penetration. Because if the diameter is larger, the overall bead size becomes bigger. What is the effect of using lower amperage in MIG welding? If the current is lower, we get a shorter weld bead. For consistent arc length, which type of power source is used by the GMAW process? This was discussed in the last lecture. A constant voltage power source for self-regulating is used to maintain a consistent arc length. In which of the following metal transfer modes is metal transferred in the form of large droplets to the workpiece? In the form of large droplets, that occurs in the globular transfer method. Which of the following shielding gases are used for welding various carbon steels? Argon or carbon dioxide. Submitting, got everything correct. Now, this is again developed using certain references, and contributors are from the developing team.

There are certain other experiments available, like tungsten and gas welding, and submerged arc welding. Those are similar to what we have seen now. Let me see something different now. Let me try to see the testing of the welding joints, the non-destructive testing. Here, the objective is to study and understand the various non-destructive tests of welded joints.

Theory: different kinds of tests. It is non-destructive testing that is there. Non-destructive means there will be no effect or impact on the welding or the welded material. Only the dye penetrant joint test could be there, which could be surface penetration, so that we see any voids, etc., in the welded joint. Penetrant application, removing extra penetrant—this is the procedure how it goes.

This is how it is penetrated here. The liquid is penetrated here. I mean, try to see or try to have the image while passing light through this. So, then ultrasonic testing is one of the methods using the ultrasonic principle because the pulse goes inside and comes out whenever a defect is there. So, for example, if a defect is here, the ultrasonic wave will come back early.

So, this is the ultrasonic testing method, then magnetic particle testing. Magnetic bar magnets are used; the flux leakage occurs whenever there is a crack, welding void, or something similar. So, these tests can be performed. This is a simple theory on welding tests. Pre-test questions. Which of the following testing techniques is non-destructive?

Metallographic, ultrasonic, hardness, tensile. Tensile, hardness, and metallographic are all destructive tests. In a tensile test, we break the pre-test. Ultrasonic testing is non-destructive. Non-destructive testing methods will not cause any damage to the sample being tested.

This is true. Which non-destructive test uses sound waves to detect defects in the material? As I have discussed or shown you in the theory, ultrasonic testing sends sound waves to detect any defect. Which of the following tests are not non-destructive? Radiography, hardness, acoustic, magnetic particle test.

Hardness is a destructive test because it creates an indentation on the workpiece, which hinders the surface roughness of the workpiece. Which of the following materials are ferromagnetic? Magnesium, molybdenum, copper, zinc, cobalt, nickel, silver, gold. Here, the copper-nickel combination is ferromagnetic. I submit.

Let me come to the procedure. They say start button, non-destructive testing, pick the test: ultrasonic testing, dye penetrant test, or magnetic test. For each of them, there is a separate set of instructions. For ultrasonic testing, we observe the transmission pulse flow.

We observe the ultrasonic device monitor, press the next button to go to the next case, and restart. In the dye penetrant test for a welded workpiece, we press the next penetrant bottle. Let me try to come to the simulation, and the instructions are already given here. I will start. I will first pick the ultrasonic testing. See, it is showing the ultrasonic waves coming and going.

So, transmission pulse. First pulse felt all good. Next, the second pulse is sent. While sending the second pulse, we saw that the time is reduced, so that is the defect echo here. Next, another pulse is sent. The transmission pulse defect echo comes in between, and the back wall echo is also there.

Again next, we start from the beginning; there is no defect echo in the second step or second sending of the wave. The ultrasonic device monitor shows the graph here, where intensity is given here and the time when the wave is sent is also given. It identifies a defect echo here. This is how it goes.

So this is ultrasonic testing. So let me take another test. I will now again start and I will now pick dye penetrant test. So I will click start and click next. So penetrant, this is a penetrant spray.

I will click on the penetrant and this penetrant would spray over the welded zone, the welded workpiece. So it is now being penetrated down to the crack. Now there is liquid penetrant there and there is a cleaner of the penetrant. I will click the cleaner. It will remove the excess penetrant.

And using the cloth, excess penetrant is cleaned. After excess penetrant removal, we put the developer over it. Let us know where the crack is. The crack indication is here. The developer comes out and shows that there is a crack. So this is how die penetrant test is there.

We can restart to understand it. So we click the penetrant. The penetrant is sprayed, then it is cleaned, and the developer helps us understand where the crack is. So this was the die penetrant test. Next, I will move on to magnetic particle testing.

Right. I will stop here and start magnetic particle testing again. Magnetic particle testing without a crack and with a crack. Both options are there. Let me first pick without a crack.

I will say next. These are ferromagnetic particles sprayed here, using a magnet. It is identified that no crack is there. That is, there is no disturbance in the magnetic field. Let me restart and pick the MPT with a crack and try to click next here.

Here, after spraying, you see if the crack is there; there is a change in flux. The flow of the magnetic field lines is showing a change here, which indicates a crack. So, these were all non-destructive testing methods. So, these are taken care of or carried out using specific equipment.

That could be for magnetic testing, that could be for penetrant testing, or that could be for the ultrasonic testing system. These are generally used to identify cracks. When we try to do any testing on materials, if it is non-destructive, 100 percent testing can be performed. That is, all the systems, all the materials, and the components that are manufactured can be tested because there is no hindrance or destruction of the material.

If it is destructive testing—for example, tensile testing, hardness testing, and so on—we have to only pick some samples. Out of the thousand pieces manufactured, if a tensile test is to be performed on the welding, then some samples—say, 10 out of the thousand—must be picked because those will not be usable later. That is the difference between destructive and non-destructive testing.

Let me pick another experiment. Let me pick submerged metal arc welding. In submerged metal arc welding, the objective is to understand the working principle of submerged arc welding and its various parameters. The theory about submerged metal arc welding is that when the wire reel is there, the flux hopper is there, and there is a continuous supply of flux, the arc is completely submerged under the flux. See how it looks like: working on submerged arc welding.

Liquid weld metal, weld pool, and weld material are present. Solidified slag is present. This is a flux feed that is there separately, so that it is somewhat—and it is completely shielded from any impurities or effects of atmospheric conditions. So, there is equipment such as the electrode wire, wire feeder, welding charge, flux, etc. Applications include high deposition rates, deep weld penetration, and flux preventing weld spatter, resulting in clean and sound welds.

Edge preparation is not necessary. 50 to 90% of the flux can be recovered, repurposed, and utilized again. Submerged arc welding is easily automated, making it an ideal choice for high-volume welding applications. Let me come to the pre-test questions. Which of the following is the correct full form of SAW?

Submerged arc welding. A is the right answer. Which statement regarding submerged arc welding is correct? It uses a consumable electrode. Yes, it uses a consumable electrode.

It requires shielding gas. No, it is a form of gas welding. No, it produces high spatter. No, it uses a consumable electrode, and spatter is minimal because it is submerged. The arc is submerged under flux.

Which of the following industries commonly uses submerged arc welding? Automotive, aerospace, shipbuilding, electronics. Shipbuilding usually uses submerged arc welding. What is the purpose of granular flux in submerged arc welding? Granular flux is used because the weld needs to be protected from contamination. In submerged arc welding, is the welding arc exposed to the surrounding atmosphere?

No. Is it protected by shielding gas? No. Is it completely submerged under the flux layer? Yes.

Is it generated by a tungsten electrode? No. So, the answer is: completely submerged under the flux layer. I will submit this and now proceed to the simulation procedure. It says: press the start button, select the type of operation, type of joint, type of material, type of electrode, type of flux, and then start the simulation.

Click the next button to start the process of welding. Let me come to simulation. Let me click the start button. It asks me to click on the summer stock welding, butt joint, mild steel is the material, electrode is also mild steel. And type of flux is also picked, that is silicate based flux.

I start it here. I start the welding. So it is showing the whole equipment, the reel of the wire field, the flux supply and the system that controls, generator and everything. I click the next button to start the welding. So this is how the welding goes.

And it comes back to the original position. Now using the hammer the flux is removed and this flux could be reused here. In submerged arc welding the welding current is primarily responsible for generating heat to melt the base metal and filler wire. Yes, it is the primary purpose. Controlling the speed, providing shielding gas, controlling the arc length.

Now, generating heat is the primary purpose of welding current. Extremely low welding current may lead to issues. Extremely low welding current means insufficient penetration. A narrow weld bead increases porosity and cracks in the weld bead. Insufficient penetration is the answer that is closer.

The purpose of controlling the arc voltage in submerged arc welding is to regulate welding speed, maintain a stable arc, address the electrode size, and control electrode consumption. The right answer should be to maintain a stable arc and arc voltage. Submerged arc welding is suitable for welding thick metal plates. A larger diameter electrode in submerged arc welding produces a high deposition rate if a larger diameter is used. Deeper penetration—both of them should be correct.

So, both A and B are the answers. Copper coating of the electrode wire is done to increase heat and resistance, make it shiny, and increase conductivity and corrosion resistance. Yes, this is the right answer. Increasing conductivity and corrosion resistance because copper is highly conductive. So, copper coating of the electrode is done.

Extremely low welding speed leads to, in submerged arc welding, the inclusion of slag. Current density in submerged arc welding is determined by the electrode diameter. Which of the following factors determines the appropriate welding current for submerged arc welding? Thickness of base metal, welding position, type of flux used—all of these determine it. So, these are all marked correct.

So, this was submerged arc welding. Let me now pick another experiment. I will try to pick advanced welding techniques here. I will walk through the different techniques given here. In the theory, we have laser welding. The principle of laser welding is given. Then we have friction stir welding. Using the fixture, stir welding is done here. And we have the pre-test and post-test questions for them. What type of welding process is friction stir? It is a solid-state welding.

It is just due to friction—no fusion, no resistance, no gas is used. What is the main principle behind friction stir welding? It is heat generation through friction, that is, through rubbing. What is the temperature range during friction stir welding? The temperature range is not very high—that is, below the melting point temperature.

Next questions are all about laser. Which of the following is true with friction stir welding process? It is having minimal heat affected zone. It reduces residual stresses. It has both A and B that is has minimum heat affected zone and reduce residual stresses.

Which of the following defects in friction stir welding process is related to tool plunge depth? Porosity, cracks, distortion. Distortion is the right answer. So I can submit the quiz. The marks would be less.

Whatever questions I have marked are correct. I am missing here the laser welding because the laser will be discussed in the forthcoming weeks where we will discuss about the advanced processes. There the welding laser machining system would be discussed. For friction stir welding, we select the following steps. Rotation speed. We select the weld speed.

We click the submit button. We observe the torque calculated. We repeat the experiment with different values and try to understand how the friction stir welding is going on. Let me come to the simulation here. In the simulation, I will pick friction stir welding and here I can pick different options from the given rotational speed that is RPM 250, 2500, 710, 1400. This is rotational speed of the motor. Then weld speed.

The rotational speed of the motor is one parameter. Weld speed is the speed of the movement of the motor along the weld line. That is there. So, weld speed could be any range between 0 to 450. Suppose I pick a very small value here, for example, 50, and I submit it here.

You can see the motor speed is 250, and at the weld speed of 50 millimeters per minute, it is going on. It has started here because the speed is slow. It is taking time for the welding to go through. Let me now increase the speed. Let me say I increase the speed to 400 millimeters per minute, and also I will increase the rotational speed of the motor. Let me say I will put it to 1000. Let us submit. You can see now the motor is also rotating fast, and the welding is also proceeding at a faster speed, that is, at the speed of around 400 millimeters per minute. This is friction stir welding.

Now, let me come to the post-test questions only about friction stir. What is the purpose of the rotating tool used in friction stir welding? It helps to generate heat. It helps to generate pressure over the weld zone. It helps to generate friction.

All of these are the answers. In conduction welding, what is the main advantage of friction stir welding over traditional welding methods? It lowers the welding temperature. It happens at lower welding temperatures. Higher welding speed, higher quality, all of the above, no.

It happens only at lower welding temperatures. The size and shape of the weld material in friction stir welding depend on which of the following parameters. Size and shape of the weld material. Tool tilt angle. Tool plunge depth.

Tool rotational speed. Pin profile. Tool tilt angle determines the size and shape of the weld material. Then comes friction stir welding. What material is the tool made of?

It is made up of a material that is hard and wear-resistant because it has to generate heat using friction all the time. So, I will submit only the friction stir questions, and all these questions are marked right, and I can also see the explanation. For example, for the tool tilt angle, you see you are right. This is only the explanation given. So, this is regarding advanced welding techniques.

One last experiment I would like to walk you through is not any other welding process, but I will try to study the characteristics of the weld bead. Let me pick this experiment. Effect of welding parameters on weld bead. To understand the effect of different welding parameters on the weld bead profile: theory, weld bead, what is the construction of the weld bead, bead width, heat-affected zone, base material, reinforcement height, and penetration depth—all of the different dimensions are given here. So, theory about the welding bead that takes effect of welding current, effect of welding voltage, effect of welding speed, effect of electrode diameter.

These are the four parameters that determine the bead size, shape, and quality. Welding current, welding voltage, welding speed, electrode diameter. Let me come to the pre-test questions. Welding current controls the melting rate of the electrode. The change in welding voltage is determined by the change in arc length.

Increased welding speed reduces heat input. Yes, it reduces heat input. Increased heat input does not affect the heat input. The correct answer is it reduces the heat input. Variation of electrode diameter.

It does not impact the weld bead geometry, not correct. Impact weld bead shape, yes. Variation of electrode diameter for the more diameter or bigger diameter, weld bead shape would be a larger. Welding parameters effect weld quality, weld shape, both A and B. Heat affected zone is majorly depending upon which of the welding parameter. Heat affected zone is majorly depending upon the welding current.

What type of power supply has higher heating rate? For higher heating rate, DC power supply is used. Melding the base material increases as the welding current increases. The welding current decreases does not happen on the variation of welding current. As the welding current increases, the melting of the base material increases.

I submitted the quiz. And now I'll proceed to the procedure. It says to choose an arc voltage between 16 and 21. Choose an arc speed in millimeters per minute between 0.3 and 0.5. Choose an arc current in amperes between 320 and 400.

And click the submit button. Simulation. Start. I'll pick the arc voltage. Let me say I'll just pick the voltage as 19 volts.

I'll pick the speed or set the speed as 0.4. So, I'll set the arc current in amperes. I can also click this button. To set the current that I would like to input here, I will set the current in amperes, maybe, let me say, only very small, 30 amperes, and submit. So, it will show how the weld bead geometry is generated.

Right? The reinforcement zone is blue. The penetration zone is orange. Now, if I change the parameters—for example, if I increase the arc current to 300—I submit. You see, this is how the weld bead is generated.

A bigger bead has formed. If I set this value to 400, increasing the current, and submit, you can see a larger bead is generated. It shows exact dimensions here: plate width. That is, the bead size is around 10 plus 20 plus approximately 24 millimeters in diameter. So, the exact bead dimensions are given here.

For instance, if it is from point number 28.2 to 51.5, then around 24 millimeters of bead width is present. The bead depth is also there—a thickness. For example, if I try to see this parameter, this point is 30.0097 (the yellow color you can see), and the above point (the blue color you can see) is 42.51.

That means around 12 millimeters of bead depth is present. So, for different parameters, this is simulated while taking experiments at varying parameters or while using the theory; the formula is used to develop this simulation. So, let me now take the post-test questions here for the weld bead parameters and then close this lecture.

The post test questions are also giving the understanding about whatever we have understood about the arc welding throughout the last two weeks. So welding issues due to weak welding current are poor penetration, unstable arc. Both of them are the issues. Arc voltage beyond optimum value generates. If it is beyond optimum value, it will generate a broader bead.

Increased welding speed can cause reduction in amount of filler metal, undercutting, narrower weld bead, increased welding speed can cause all of these. Reduced welding voltage. Generates intense arc, deeper penetration. Both of them are generated with reduced welding voltage. Intense arc could be there, deeper penetration could be there. Slow welding speed allows molten gases to escape, lowers porosity.

Both of them are the output. If the slow welding speed is there, it allows molten gases to escape the porosity lowers. Faster welding speed. Exactly contrary to the slow welding speed, the faster welding speed generates smaller heat affected zone. Unreasonably high welding voltage can result in, if the voltage is very high, that is unreasonably high, then cracking could be there.

More difficult slag removal could also be there. Reduced porosity by rust on steels could also happen. That is all of these are the correct answer. Low welding current can cause, it can cause unstable arc, it can cause poor penetration. These defects could be there.

For welding thicker material, the electrode diameter should be larger for welding thicker material. Because the material is thicker, obviously the diameter should be larger. Which of the following is the reason for cracks and undercut in the weld bead? Higher welding voltage. Cracks and undercut occur because of higher welding voltage, and there is not enough current to compensate. The bead is not properly formed, and a void or crack is generated.

When welding thin sheets, a key parameter to control to avoid burn holes is welding current and travel speed for thin sheets. Travel speed has to be optimal so that no burn hole is generated. I submitted the case and got full marks here because I practiced this quiz before as well. These are the references. Certain books, handbooks, and research papers might have been referred to develop this whole simulation. So this was about the virtual simulation of welding.

In the coming weeks, we will cover metal cutting, that is machining. Then we will go through the advanced manufacturing processes. And then some concepts of sustainability would also be discussed in manufacturing.

Thank you.