Design of Connections in Steel Structures
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Module - 2
Lecture - 6
Structural Welding Process

Hello. Welcome back to this course on the design of steel connections. And in the lectures earlier, we had discussed the basic principles of bolted connections and also we had talked about basic design requirements for bolted connections. We are yet to go into the welded connections. And then, the subsequent parts, we will talk about how to design composite connections, which is basically a number of bolts or a number of welds or a combination of them that are used in a connection. So, in this lecture, we are going to talk about the basic principles of designing welded connections.

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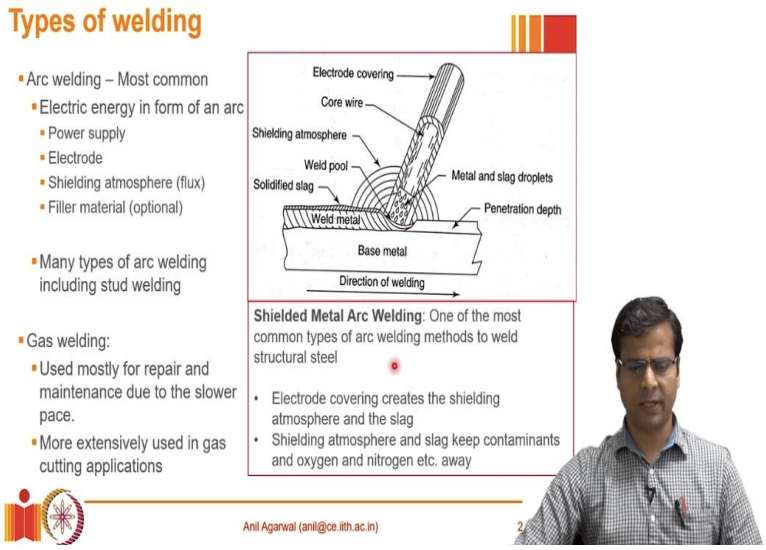

Welding is a very common technique of joining structural steel members, which is used very frequently in construction. The most common type of welding is the one which uses electricity, that is known as arc welding. And the other one which is relatively less used is gas welding. This is more frequently used for cutting operations in comparison to regular structure and steel welding.

We will talk about these things in some detail. So, arc welding usually requires power supply, that is electricity supply and of course in addition to that, we need an electrode. All of us must

have witnessed some type of arc welding in our lives. So, the electrode typically also doubles as a filler material which fills the gap between the 2 metals which are being joined. But there are other varieties of that also; that we will discuss in a minute.

So, the basic constituents that are usually used in an arc welding include power supply, an electrode, some kind of a shielding atmosphere. We require a shielding atmosphere because metals when they are melted, when they are at very high temperature, they are likely to oxidise. And oxidation can make them brittle and lose strength. And to avoid that kind of oxidation, we have to use some kind of a shielding atmosphere so that the metals do not contaminate.

And in addition to that, sometimes we have a separate filler material or sometimes the electrode itself acts as a filler material. And that is how a typical welding, arc welding operation is done. There are other types of arc welding also where we do not use a filler material separately. The 2 parent materials themselves, one of the parent materials acts as an electrode and then they fuse together without any additional filler material; such as when the shear studs are welded to the flanges of floor beams, they are often done through an arc welding process, but there is no filler material utilised.

Gas welding is rarely used for structural applications. This is mostly used for cutting or maintenance or repair type of operations, because first it has a very slow pace in comparison to the electric welding and the portability is also a challenge. Gas welding however is used most significantly, more frequently for cutting operations. When you want to get cut very thick plates of steel, gas torches are found to be very effective and that is the purpose that it is used.

So, we will not be focusing, these lectures will not be focusing on gas welding operation so much; we are primarily going to talk about arc welding. Now, arc welding of course, the majority of the arc welding actually relies on some kind of a shielded metal arc welding. What is a shielded metal arc? The shielding here refers to the shielded atmosphere wherein an inert gas atmosphere is created around the weld zone, and that shielded atmosphere actually prevents the oxidation or nitrogen to react with the molten metal.

So, how is that shielding material created? Generally, we require some kind of a flux, some kind of a compound which when burnt at such a high temperature, some kind of releases in gases, and those gases are inert gases and they do not allow the oxygen and nitrogen in the

atmosphere to enter the molten metal area. And after the flux compounds which have burnt already, their residue gets mixed with the molten metal.

However, since it has a very different density than the molten metal, it tends to get deposited on the surface of the weld. Now, that deposited flux material, consumed flux material is known as slag. And that slag actually has 2 purposes. 1, it separates the metal, so the metal inside remains pure. And secondly, it also keeps the weld metal hot for longer, because this is not a very good conductor of heat, this material that forms a thin layer on the top of the welded joint.

It has a low conductivity of heat and therefore it keeps the welded portion hot for a long time, which in a way has an annealing effect so that the stress or the rapid rise of stressors can be prevented.

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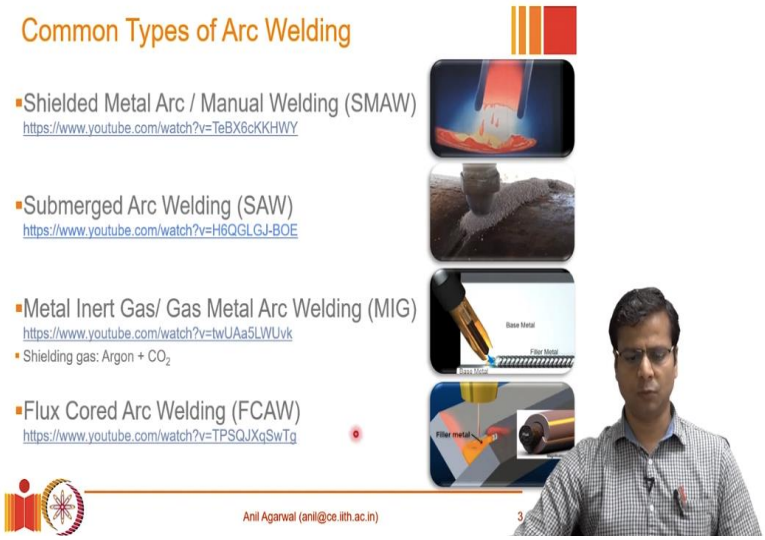

Here I would recommend in order for us to understand the different types of arc welding processes, I would strongly recommend all students to go through these 4 videos. These are all YouTube videos. I do not have the authority to share them here, but however, I have given you the link. We will also share these links to the 4 videos in the description of this video. So, please pause this video here and go through these 4 videos of 4 welding processes.

The first welding process that I am going to talk about is the shielded metal arc that we briefly discussed. It is also typically known as manual welding. So, whenever you see a worker holding an electrode and welding with his or her hand, that is usually the manual welding process. Also

briefly it is referred to as SMAW. So, this process we have already discussed. What you see here is an electrode which has a cover of flux material around it.

So, it is coated with flux material. And as the electrode, as the arc is formed, the current flows through this plasma and arc is formed and this electrode starts to melt. Along with that, the flux material also starts to get consumed and creates a shielding atmosphere. So, both of these, the electrode as well as the flux material gets consumed simultaneously and gets deposited on the target area.

As the arc continues to burn, the material gets deposited and basically because of the forces, that the flow of this material is such that it forms kind of beads or waves of welding. And there are ways to understand that how good the weld quality is by looking at how regular the beads are. The beads should be very regular in order for a weld to be of a good quality. And the slag that is deposited on the surface, which is basically the consumed flux material, once it is deposited on the surface, it has to be chipped off, and then the inspection should be done on the quality of the weld.

The other one, the one variation of this SMAW which is basically manual welding is the SAW, which is known as Submerged Arc Welding. So, in this process; fundamentally the 2 processes are similar; however, this process is much more suitable for automated welding. In an automated welding, what happens is that the electrode does not have any flux material coated on it.

However, the flux material, the beads, the tiny beads of flux material what you can see here in this image are deposited. So, there is a nozzle. In that nozzle, a wire is passing. That wire is actually the filler material as well as the electrode. And around it, these beads are also deposited. And the nozzle pushes both of these things together. So, this deposited bead material provides the flux around the welded area.

And then, it oxidises and creates that atmosphere which is required. So, again, please go to these videos. And in such a process, we can control the pace of welding very accurately and it helps us create a very good quality weld. The next one in this line is an MIG welding. MIG welding is again very useful for automated welding. Now, it is robotic arms are very easily deployable or CNC type of operations can be done.

And because of these operations, all these 3, see SAW, MIG and FCAW, these have become more common. However, at site, still we have to use SMAW type of welding. So, in MIG welding, instead of depositing a flux material, we directly release the inert gases, the shielding gases. The shielding gases typically contain argon and carbon dioxide. So, this is how a typical nozzle looks like.

It has 2 chambers or 2 nozzles within it. One nozzle releases the electrode which is basically an electrode wire which gets deposited at the weld location. And the outer cavity releases these 2 gases, a mix of these 2 gases which because they are released, they create a shielding atmosphere near the weld joint and prevent the weld from getting contaminated. One variation of MIG welding is known as FCAW welding.

In this process what happens is that, we have an electrode and that electrode may sometimes have a core which is made of flux. So, this is basically an inverse of the SMAW welding. So, in this one, the electrode, the filler material is inside and the flux is on the outside. However, in case of a Flux Cored Arc Welding, the flux is at the core and the filler material forms the sleeve.

In addition to this, the nozzle may also have provisions of releasing some of the shielding gases. So, you may have a core which is fluxed and also you may have some kind of a shielding gases available. So, this is basically a combination of in a MIG welding and SMAW.

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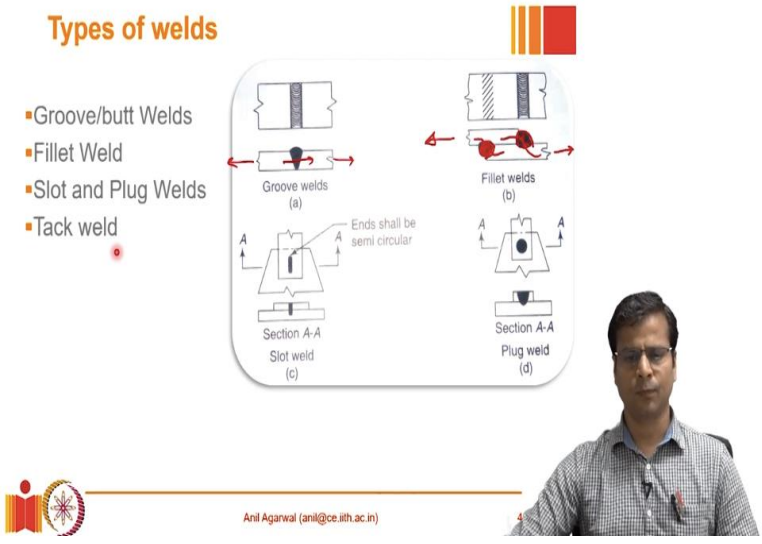

In typical structural applications, geometry wise we can classify welds into these 4 categories. The first one is the groove weld, also known as butt weld. So, here you can see some examples of a groove weld. These are the 2 plates of equal thicknesses. They need to be equal thicknesses. Here is just an example. So, if these 2 plates are to be joined using a groove weld, basically we fill the gap between the plates with a weld.

So, these are the 2 views of the same plates being weld. This is known as butt weld or a groove weld. It is obvious to see why we call it a groove weld, because we are creating a groove which is getting filled with a welding material. Or, the 2 plates are placed in a butt position, facing each other; so, therefore, it is called a butt weld. Another type of commonly used, much more commonly used weld is known as fillet weld.

In a fillet weld, we require 2 surfaces which are almost perpendicular to each other before we weld them. So, a lap joint which would be done; if I wanted to splice a plate, one option was to go with the groove weld, where we would just butt the 2 plates against each other. Other option would be to provide a lap joint, and an example of that is like here. So, this is not really a butt but a lap.

Here again, these 2 corners or these 2 edges are welded. And what happens in the process is that, as the filler material gets deposited, it fuses the parent material along with it because of the high heat, and that produces a monolithic zone of welded material. And that is how the force; if we applying force here, that force gets transferred. Let us take example of this weld. So, if these forces are applied, it gets transferred between these 2 plates through this fused material, and same thing here.

Whereas, in case of a groove weld, the path of stress transfer was straightforward. Another alternative of welding which is used much less frequently is known as slot or a plug weld. These are used in certain conditions; we will talk about them. Generally, we use them only when we want to prevent shear type of a deformation, or we want to join 2 plates resisting shear. We will talk about them later in more detail.

So, an example for that is what is shown here, wherein you have these 2 plates. One of the plates, the upper plate for example, has a slot or a hole. And what we do is that, we can fill that entire hole with a weld filler material. And in that process, we also fuse the 2 plates together,

as shown here and here. So, these welds are known as slot or a plug weld. There is another way of welding which is known as tack welding. Tack welding is not really structural welding. The tack welding is used only in situations where we want to just hold 2 members together until we do the final welding.