

## Basics of Mechanical Engineering-2

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Lecture 28

### Basics of Welding (Part 5 of 7)

Welcome to the third lecture in basics of welding. Last time, the previous lecture when I closed it, I posted two questions. The question one was, why is it a big challenge to do stainless steel welding. And then I was also discussing about various open circuit and drooping curve. So, in the start of the lecture let me cover that and then I will move into resistance welding.

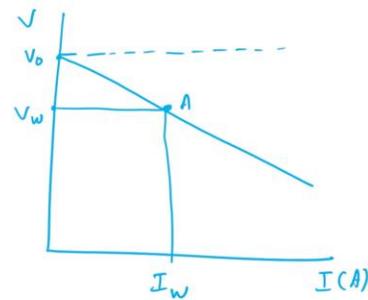
#### Power Source Characteristics

Constant Voltage or flat characteristics power source.

- the o/p voltage is not truly constant. It exhibits a slight downward or negative slope due to the presence of adequate internal electrical resistance and inductance within the welding circuit,  $\rightarrow$  minor reduction in the output volt-amp characteristics

Significance: arc voltage is establishing by setting the o/p voltage on the source

- Self regulating or self adjusting arc length system.
- electrode melts at the rate required to maintain the pre-set voltage.



$V_0$  = open circuit voltage  
 $V_w$  = welding Voltage  
 $I_w$  = welding Current



This is very important because when we try to look into auto feeding, auto cutting. All these things depend upon this power source characteristics. There are two characteristics.

One is called as constant voltage or it is called as flat characteristics power source. So, here we will have voltage and then here we will have current in amps.

So, the open circuit voltage will be  $V_0$ , the welding voltage will be  $V_w$  and the current will go. So, as the when voltage the current goes. So, when the welding happens it happens like this and you will see this will be the welding current ok. So, this is point A. So, this is called as a open circuit voltage. So,  $V_0$  is open circuit voltage  $P_w$  is welding voltage,  $I_w$  is welding current.

So, in constant voltage power supply. The output voltage is not truly constant. It exhibits a slight drop downward slight drop or downward or negative. Due to the, why does it show the negative? Due to the presence of adequate internal resistance, electrical resistance.

And inductance within the welding circuit. This results in minor reduction in the output voltage amperage characteristics. This is very important. So this talks about it. So what is the significance?

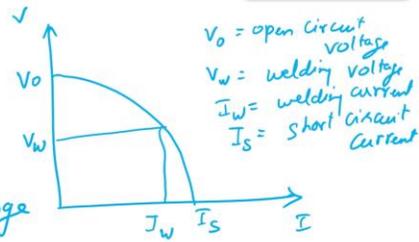
Significance is the arc voltage is established by setting. By setting the output voltage on the source. And this leads to self regulating or self adjusting arc length system. So here what happens is the electrode melts at the rate required to maintain. So, this curve clearly states about the flat response though the fall looks to be very high.

But the slope is very small. So, this talks about the flat characteristic power source or constant voltage power source. With this, we are trying to regulate the electrode melting rate by a preset voltage. In a similar way, we also will have a constant current mode.

## Constant current or drooping or falling characteristics:



- of characteristics of a constant current power source are drooper - downward or negative gradient of the curves.
- Addition to controlling of current, the power source may also adjust for OCV
- Variation in arc voltage, corresponding change in current is minimal, resulting in a relative stable electrode melting rate



Constant current mode  $\rightarrow$  thick welding plate/section



In the constant current mode, or it is called the drooping or falling mode, characteristic power supply. So, here the voltage is  $V_0$ , and the welding voltage is  $V_w$ . So, the drooping curve will be something like this. So, here it will be  $I_w$ , and this will be  $I_s$ . So,  $V_0$  is nothing but the open circuit voltage. So, this will be  $V$ , and this will be  $I$ .

Open circuit voltage  $V_w$  is the welding voltage, and  $I_w$  is the welding current. And  $I_s$  is the short circuit current. The output characteristics of a constant current power source are referred to as droopers. Why is that called droopers? Because there is a downward or negative gradient of the curves.

The next thing is in addition to controlling. Apart from that, it also tries to have, in addition to controlling, the output current. The power source may also adjust interestingly. It also features and also adjusts for open circuit OC voltage. In addition to controlling the output current, the power source may also adjust for open circuit voltage.

Then there is a variation in the arc voltage. Which is corresponding to the change in current is minimal. And results in a relatively stable electrode melting. So, constant current mode is always used for thick welding plates or sections, okay. So, this talks about the constant current.

So, when we want to have a flat curve, it talks about this, which is For a constant voltage, there is a flat curve, and this is significantly very small. So, we try to control. The other

way around in the drooping curve. You will have a sudden fall in the negative gradient of the curve, as you can see.

So, you can see what the very small change in current is for a large drop in voltage. So, the next question I asked was about steel.

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- Steel
    - high thermal conductivity
    - high  $\alpha$  expansion
    - cracking / warping
  - Steel → multiphase → difficult in welding



NPTEL



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Why is it not possible, or why is AC used for welding steel? In steel, what happens is that it has very high thermal conductivity. So, it has high thermal expansion.

And this leads to cracking and warping. So, because of that, we always try to use an AC power supply for stainless steel. The other thing is that stainless steel, or steel, has multiple phases: austenite phase, multiple phases. So, this leads to difficulty in welding.

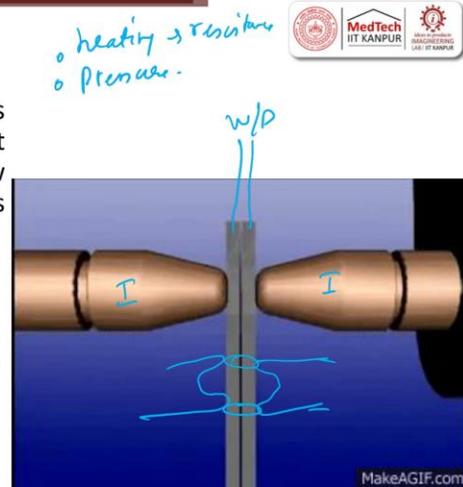
So, people always try to use AC current—or, sorry, AC voltage—for welding steel. These were the questions I asked. So, I thought I would write and explain it to you. You will remember it. So, now let us move to the next process.

# Resistance Welding

- Resistance welding is a group of welding processes where in coalescence is produced by the heat obtained from resistance of the work to the flow of electric current in a circuit of which the work is a part and by the applications of pressure.
- No filler metal is needed in this process.

## Principle of Operation

- Successful operation of a resistance welding process depends upon correct application and proper control of the following factors.
  - (i) The generation of heat at the place where a weld is to be made.
  - (ii) The application of pressure at the place where a weld joint is to be formed.



<https://makeagif.com/gif/resistance-spot-welding-how-it-works-zl3Lvf>

The next process is going to be the resistance welding process. You can see the animation here. Two electrodes. These two electrodes have a current passing through them. This is the workpiece.

The electrodes are brought close to each other and pressed with some pressure, and now the current is passed. So if you see through it, it comes closer, and you can even press it. And then you can start applying current, or simultaneously, you can apply current first and then press. Both are possible, but the second method is very easy to do. So we apply a very high current between the two electrodes, which softens the material there.

And then we press it. Resistance welding is a group of welding processes. Wherein coalescence is produced by heat obtained from the resistance of the work to the flow of electric current in the circuit. Where the work is part of the circuit and by the application of pressure. So, first bring the two electrodes close, apply current, then it softens, and then you slowly pressurize.

So, pressure is used, and heat is used. So, two components are used: heating by resistance, and then we also apply pressure, okay? So, when we look into it, no filler is used, so you can try to do it. So, here it is a spot welding process. You change the spot into a wheel, then it becomes a seam welding process. So, the principle of operation is this: the success of this resistance welding process depends upon the generation of heat at the place where the weld is to be made.

Then, the application of pressure is required. The electrodes can be flat. The electrodes can also have any contour you want. They can also have a contour shape. It is not a wheel but a contour. So, then what happens? Only this part and this part will have resistance welding happening, and then you can do it.

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## Resistance Welding



### Heat (H)

The heat H, for electric resistance welding is generated by passing a large electrical current (of the order of 3000 to 100,000 Amps with a voltage between 1 and 25 volts) through two pieces of metal that are touching each other.

$$H = I^2 RT$$

where H is the heat generated in joule.

I is the current in root mean square ampere.

R is the resistance in Ohm.

T is the time (from fraction of a second to few seconds) of current flow through the pieces to be welded.



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So, here heat is generated. The heat for electric resistance welding is generated by passing a large electric current, which is somewhere around 3000 amps to 100,000 amps, depending upon the requirement.

So the voltage which is applied is very low, 1 to 25 volts. When the two pieces are in contact. Then the  $H = I^2 RT$ , the Joule heating effect. Where I is the current, R is the resistance in ohms, and T is the time period which is applied. Generally, the time period will be in fractions of a second, or seconds.

Within that small time, a huge current is passed through the thin sheet. Whatever it is, it has its resistance through which we try to generate heat. So this heat tries to soften the material.

## Resistance Welding

### Current (I) :

- With other parameters kept constant, the temperature in resistance welding is regulated by controlling the magnitude and timing of the welding current.
- The current is obtained from a step down transformer.
- Generally, three types of current supply are used in resistance welding
  - AC systems
  - DC systems
  - Stored energy current systems



The current, whatever we are trying to discuss, with other parameters kept constant. The temperature in resistance welding is regulated by controlling the magnitude of current and the timing of the welding current.

So, controlling magnitude and time. So, generally we use a transformer, which is a step-down transformer. Again, here we have three types of power supplies. So, one is AC supply, DC supply, and stored energy current supply. All three are used for the resistance welding process.

## Resistance Welding

### Resistance (R)

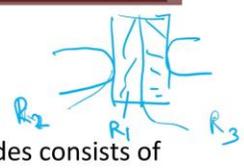
The total resistance of the system between the electrodes consists of

- (i) The resistance of the work piece  $R_1$ .
- (ii) The contact resistance between the electrodes and the work,  $R_2$ .
- (iii) The resistance between the surfaces of the two metal pieces to be welded together,  $R_3$ .

### Time (T)

Four definite segments or periods of timing are set up on a resistance spot welding machine during one welding cycle.

- (i) Squeeze time    (ii) Weld time    (iii) Hold time    (iv) Off time.



Resistance, the total resistance of the system between the electrode consists of resistance of the workpiece is 1. The contact resistance between the electrode and the work. So, what am I trying to say? 1. This is the workpiece. The resistance of the workpiece is  $R_1$ .

The contact resistance between the electrode and the work, this is  $R_2$ . And the resistance between the two metal pieces, this is  $R_3$ . So, there are three types of resistance. So, generally what we do is we try to take the higher resistance and between the three. And then we do it or we try to do  $R_1 + R_2 + R_3$  whatever it is we try to solve it.

The time whatever is required there are four different segments or periods of timing at setup on the resistance spot welding process. Squeezing time, welding time, holding time and off time.

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## Resistance Welding (EGW)



### Squeeze time

- It is the time between the initial application of the electrode pressure on the work and the initial application of current to make the weld.
- During this period the upper electrode comes in contact with the workpiece and develops full electrode force.
- At the end of the squeeze time, the welding current is applied.

### Weld time

- During this period the welding current is through the circuit i.e., it enters from one electrode, passes through the workpieces and goes out from the second electrode.

### Hold time

- It is the time during which force acts at the point of welding after the last impulse of welding current ceases.



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So what is squeezing time? Pressing time is a squeezing time. You squeeze and wait for some time, then you start applying the current. So that is the welding time. Then after it is welded, immediately if you release, it will try to detach or delaminate. So now what you do is, after it is joined, you try to hold it for some time; that is the holding time. And once the holding time is done, then you remove it off. So there are four sequence times which are there.

So four times, which are squeeze time, weld time, hold time and off time. What is squeeze time? The squeeze time is the time between the initial application of the electrode pressure on the work and the initial application of current to make the weld.

During this period, the upper electrode comes in contact with the workpiece, and the development of full electrode force happens. At the end of the squeeze time, the weld current is applied. Squeeze applied. Weld time is the period where the current is passed into the circuit.

So, naturally, between the electrode and the workpiece—workpiece and the electrode—you try to apply the current. So, that is called the welding time. The time will be short, as I said, in seconds or a fraction of a second. It enters from one electrode, passes through the workpiece, and goes to the second electrode. Holding time: after the welding is done, the softening operation is done, and we try to hold it. If the time during the force acting at the point of welding, after the last impulse of the current ceases. Then that is what the holding time is.

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## Resistance Welding



### Pressure or Electrode Force

Electrode force is the force applied to the workpieces by the electrodes during the welding cycle. Pressure exerted on the workpieces by the welding electrodes does the following;

- Brings interfaces into contact, affecting contact resistance.
- Completes the electrical circuit between electrode and workpiece.
- Enables welding at lower temperatures.
- Provides forging action, reducing weld porosity.

### Off time

It is the interval from the end of the hold time to the beginning of the squeeze time for the next (resistance) welding cycle.



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So then, we try to apply pressure or electrode force. So, here, the electrode force is the applied force to the workpiece by the electrode during the welding cycle. So, bring the interface in contact, complete the electrical circuit, and then enable the weld at low temperatures.

And then provide the forging action, reducing the weld porosity. So, all these things are done with the pressure or electrode force. Off time: it is the interval from the end of the holding time to the beginning of the squeeze time for the next welding cycle.

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## Resistance Welding



### Advantages:

- Faster production, high reliability, reproducibility and reduces distortion..
- Welds similar and dissimilar metals without filler rods or flux.
- Requires minimal skill, is easily mechanized, cost-effective.

### Disadvantages:

- High initial equipment cost.
- Limited to thin materials, lap joints.

### Applications:

Joining sheets, rods, tubes, and components in industries like automotive aircraft, and metal furniture manufacturing.



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So, the advantages and disadvantages are faster production, higher reliability, reproducibility, and reduced distortion—all achieved in this process. So, that is the biggest advantage.

So, it requires minimal skill to do it. However, the initial cost is very high, and the thickness of the sheet is limited, unlike in the metal arc welding process. You can go up to 75 millimeters or 100 millimeters, but here you can hardly go beyond 4, 5, or 6 millimeters thick. So, joining sheets, rods, tubes, and components in automobiles is done by the resistance welding process.

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## Resistance Spot Welding



- Spot welding is a resistance welding process where overlapping sheets are joined by local fusion at spots.
- The heat generated from the resistance to electric current flow causes the fusion.
- The workpieces are held under force by two electrodes, one above and one below the sheets.

### Principle of Operation

- In spot welding, the resistance to current flow raises the temperature of the metal between the electrodes to welding heat.
- After current is cut off, mechanical pressure is applied to forge the weld. Finally, the electrodes open. Thinner sheet settings used for unequal thickness.
- Currents range from 3000A to 40,000A. Modern systems are computer-controlled and robotic.



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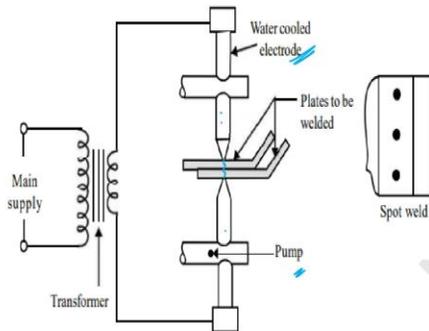
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If you look at the car body, the sheet metal operation attached to the frame is done by the resistance spot welding process. You will have a gun where the sheet and the frame are placed, and it tags. It is called the spot welding process. Spot welding is a resistance welding process where The overlapping sheets are joined by local fusion at a point. So, you can see here, here is a ring.

So, between the ring, whatever it is, two electrodes are applied. So, you can see here there is a joining happening. So, here we do not use any filler. The heat generated from the resistance to electric current flow causes fusion. The workpieces are held under force between the two, one above the other, to get the sheet done.

So, it can go like this, and you can do the resistance welding process or like this; you can also try to do it. So, the principle of operation, whatever we have discussed now, I have written it in the same way. The resistance to current flow raises the temperature of the metal between the electrodes and the weld heat. Again, the squeezing time, welding time, holding time, and off time—all these things are involved. And then you get resistance spot welding, meaning finally, you get a spot that is getting welded.

# Resistance Spot Welding



## Advantages:

- High production rate
- Economical process
- Low skill requirement.
- Ideal for welding sheet metals.
- No edge preparation needed.
- Can weld dissimilar metals.
- Small heat-affected area.

## Limitations:

- Suitable for thin sheets only.
- High equipment cost.

## Applications:

- Spot welding is used for fabricating sheet metal products which forms a cheap and satisfactory substitute for riveting.
- Low carbon steel, high speed steel, stainless steels, brass, Al, Cu, nickel, nickel are joined



<https://tristatefabricators.com/types-of-welding/>

So, this is how the machine looks. So, two electrodes—top and bottom—two sheets, then there is pressure applied between the two sheets. So, then you have welding softening happening, and then you will have welding occurring. Plates to be welded are two, and then you can try to get it done. So, here it is water-cooled, then you have a pump.

So, these are all the advantages; these are all the limitations. So, you can see here, spot welding is used for fabricating sheet metal products. It forms a cheap and satisfactory substitute for rewelding.

## Resistance Seam Welding

- Seam welding is a resistance welding process where coalescence occurs due to heat generated from resistance to electric current.
- The workpieces are held under pressure by electrodes. The weld consists of overlapping resistance seam welds made progressively along a joint by rotating circular electrodes.

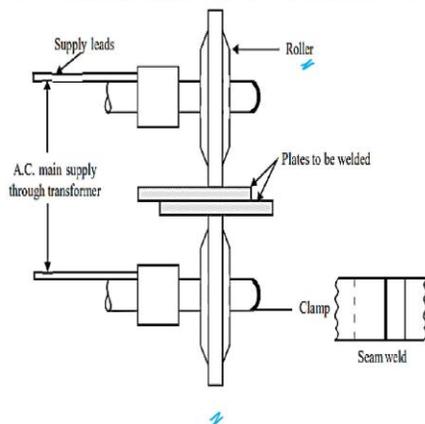
### Principle of Operation:

- Seam welding uses roller electrodes and moves work perpendicular to the roller axis, with current interrupted 300-1500 times per minute.
- Welding is done under water to reduce heating, maintenance, and distortion, with currents from 2000A to 5000A and forces between 5 KN to 6 KN.
- Typical welding speed for thin sheets is 1.5 m/min.



The resistance seam welding process is almost the same, except for the electrode.

## Resistance Seam Welding



### Advantages

- Produces gas-tight or liquid-tight joints.
- Overlap is less than spot or projection welds.
- Multiple seams can be produced simultaneously.

### Disadvantages

- Welding is limited to straight or uniformly curved lines.
- Difficult to weld materials thicker than 3 mm.
- High equipment cost compared to spot welding.

### Applications:

- Used for pressure tanks, oil switches, transformers, refrigerators, evaporators, condensers, aircraft tanks, paint, and varnish containers.



Look at it—the electrode is a roller, right? It is a roller. So it rolls; you have two sheets of metal, and then the electrode rolls. So you will have electrode rolling, and when it is rolling, it applies pressure and also passes current. So what you get is not a spot but a

continuous seam joining. So that is what resistance seam welding is. So all other parameters, whatever is done in spot welding, are also used here.

So, it is used for pressure tanks, oil switches, transformers, refrigerators, evaporators, condensers, aircraft tanks, etc. The process is the same.

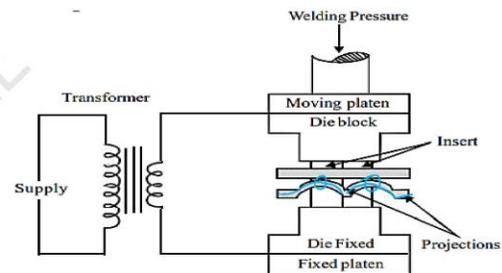
## Resistance Projection Welding

- Projection welding is a resistance welding process where coalescence occurs due to heat generated from the resistance to electric current flow.
- The work pieces are held together under pressure by electrodes.
- Welds are localized at predetermined points, created by projections and intersections on the work pieces.

### Principle of Operation:

Electrodes are flat and larger; higher power and pressure are needed compared to spot welding.

Projections (0.8 mm) concentrate heat for fusion, formed by embossing, stamping, or machining.



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Then, the next one is called projection welding. In projection welding, what happens? We will have the sheet. So, this is one sheet. This is one sheet. And then, you have projections on the workpiece. So, these are projections. So projection welding is a resistance welding process where coalescence occurs due to heat generated from the resistance of electric current flowing.

The workpieces are held together under pressure by the electrode, and here the weld is localized—it happens only here on the projection only where it is present. So, the projection welding process is also gaining a lot of importance. The projection thickness is around 0.8. So instead of this, you will have a projection—you will have a projection. So, this is the projection.

So now, only at the projected point will you see the welding happening. So the projection point 0.8 concentrates heat for fusion formed by embossing, stamping, or machining.

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## Resistance Projection Welding



### Advantages

- Multiple welds at once with precise location, better heat balance, and reduced shrinkage.
- Can weld thicker metals than spot welding, with less electrode wear and overheating.
- Lower current and pressure requirements, minimizing distortion.
- Less interference from scale, rust, and coatings.

### Disadvantages:

- Limited to embossable metals with uniform projections.
- Weak metals cannot support projections.

### Applications:

Welding fasteners, nuts, condensers, wires, and alloys.



So again, advantages and disadvantages are listed. This is for you to go through and read.

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## Resistance Butt Welding



- This is also known as upset butt welding, where two pieces are tightly held together.
- Current generates heat across the entire abutting surface, and pressure is applied during the heating period, resulting in coalescence over the entire area.

### Principle of Operation:

- One work piece is clamped in a stationary block, and the other in a movable clamp.
- The work pieces are brought together by pressure, forming a butt joint, and high current is passed through them.
- Heat is generated from resistance to the current, and pressure is applied until the desired temperature is reached.
- Pressure is increased for proper joining, then current is cut off, and pressure is released once the weld cools to normal temperature.

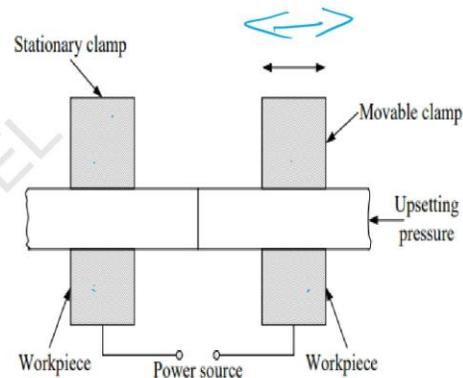


So now, the next welding is the butt welding process. It is also known as the upset butt welding process. Here, the two pieces are tightly held together. Current generates heat across the entire abutting surface, and pressure is applied during the heating period, resulting in coalescence over the entire area.

# Resistance Butt Welding

## Applications

- Wires, bars, strips and tubes are butt welded.
- Joining small strips of ferrous and non-ferrous metals and longitudinal butt joints in tubes and pipes.
- Metals welded include copper alloys, low carbon steels, stainless steels, Al and Ni alloys



So, in the butt welding process, here is a stationary clamp. So here is a workpiece. So, you can have upset pressure, which is there. So then, this tries to hit and then it tries to join. So, here is the upsetting pressure; here are the workpieces. This is a workpiece; this is a workpiece. So, one workpiece is clamped in a stationary block and the other in the moving block.

Stationary clamp; the other one is moving. So, this will be moving like this. So, this is stationary; one will move like this, right. The workpieces are brought together by pressure, forming a butt joint. A high current is passed through them.

Heat is generated from resistance to the current, and pressure is applied until the desired temperature is reached. The pressure is increased for proper joining; then, the current is cut off. So, this is the process. Wire, bar, strip, tubes can be done by resistance butt. This is the butt welding process. So, joining small strips of ferrous and non-ferrous can also be done.

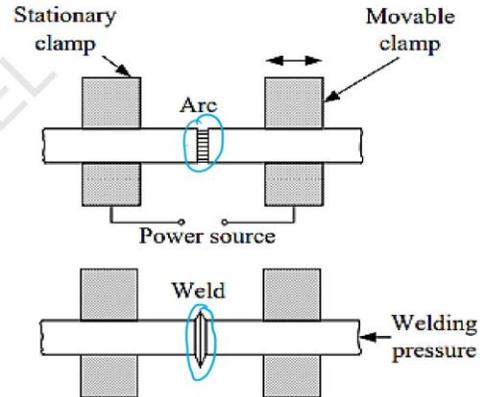
## Flash Butt Welding



- Flash butt welding has largely replaced resistance butt welding. It is similar to upset butt welding except that the heat required for melting is obtained by means of an arc rather than the simple resistance heating.

### Principle of Operation

- Work pieces are clamped in stationary and movable blocks with a small gap.
- When current is applied, it jumps through the gap, creating a flash that generates heat.
- Once sufficient heat is produced, pressure is applied to join the workpieces.
- The current is cut off, and the workpieces are unclamped after joining.



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When we are trying to talk about the flash butt welding, this is resistance butt welding. The other one is flash butt welding process. In flash butt welding process, what do you do is, there is a stationary clamp, there is a moving clamp.

So, when there is a pressure which is, when there is a old power supply which is there, there is an arc which happens. Once the arc is happened, then this portion is softened. Then you try to apply pressure, there is a flash which is getting created. So, that is why it is called as flash butt welding process. It has largely replaced resistance butt welding process.

It is similar to upset butt welding except the heat required for melting is obtained by means of an arc. It is getting replaced what? It is getting replaced upset forging or resistance butt welding. So the workpiece are clamped in stationary and moving. Everything else is the same like your resistance butt welding.

So in resistance butt welding, there is no flash. So here, there is a flash arc created. Pressure is created. So there is a flash which is present.

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## Flash Butt Welding



### Advantages:

- Flash butt welding offers strength factor upto 100% and consumes less welding current than upset butt welding process.
- The process is cheap, faster and no weld surface preparation is required.

### Disadvantages:

- Concentricity and straightness of workpieces during welding is difficult to maintain.
- There is possibility of fire and health hazards due to the flash.

### Applications:

- Welding bars, rods, tubes (low carbon steels, alloys, stainless steel, Al alloys, copper, magnesium, Ni alloys).
- Welding saw blades, taps, reamers to alloy steel shanks.
- Common in the automobile, aircraft, refrigeration, and farm implement industries.



Again, the advantages and disadvantages are figured out.

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## Flash Butt Welding



### Differences between Resistance Butt welding and Flash Butt welding

- No flashing takes place in resistance butt welding.
- The movable platen in flash butt welding keeps on moving constantly towards the stationary platen which is not so in case of resistance butt welding.
- Less current is consumed in flash welding but the application time is more
- Application of heat precedes pressure application in flash welding whereas in resistance butt welding constant pressure is applied during heating.



So, what is the difference between resistance butt welding and flash butt welding? No flash occurs in resistance butt welding. It is only when you come closer that you create it. The moving platen in flash butt welding keeps moving constantly toward a stationary platen, which is not. So in the case of resistance welding, there has to be an arc created.

Less current is consumed in flash butt welding, but the application time is longer. The application of heat precedes the pressure application in flash. But in resistance butt, constant pressure is applied during heating. This is the difference. First arc, then pressure.

So, here the pressure is applied, and then heating is done. So, these are the major differences in the process. You should understand the difference between resistance butt and flash butt. It is completely different.

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So, these are the references we have used for preparing this lecture.

Thank you very much.