/ Perfect Welding / Solar Energy / Perfect Charging

METAL INERT GAS WELDING (MIG)/ METAL ACTIVE GAS WELDING (MAG)

WELDSCRIPT

M1,02,0005,EN

USEFUL INFORMATION ABOUT THE HISTORY OF MIG/MAG WELDING

ca. 1948

Metal inert gas welding (MIG) was initially developed in the USA as the S.I.G.M.A welding process (Shielded Inert Gas Metal Arc). This project only used inert (non-reactive) gases during welding. Though other gases were used, helium was the preferred choice.

1953

At the Paton Institute in Kiev (then still part of the USSR), pure, 100-percent carbon dioxide (CO_2) is used instead of expensive inert gases for the first time.

1953

Of these two processes, Metal Active Gas welding (MAG) was far more popular in Europe. It is the counterpart of MIG welding and is used for ferrous metals.

From this moment on, MIG and MAG welding is continually adapted to changing industrial requirements.

Today

One of the major characteristics of MIG/MAG welding today is the use of mixed gases. The different gas compositions include mixtures of argon and carbon dioxide (CO_2) or oxygen (O_2) with considerable variations through to the still common use of pure CO_2.

TABLE OF CONTENTS

WELCOME!

We are pleased that you are interested in our training on MIG/MAG welding.

We would like to support you in your training with this training documentation. The following pages contain a great deal of helpful information about MIG/MAG welding. You can use it to look up useful information and find the right answers to questions.

We hope you enjoy your training program and wish you every success!

1. THE LEARNING OBJECTIVES

By the time you have completed our full "MIG/MAG welding" training course, you will know a great deal about these welding processes:

- You are familiar with the development history of MIG and MAG welding and the basic process principles.
- You can explain in detail the principles of MIG/MAG welding and the heating effect of the arc.
- You know the advantages and disadvantages of the welding processes.
- You know the parts of the equipment and their purposes and you can explain the functions of the different equipment parts.
- You have learned the details of process control and how to adjust an operating point.
- You are familiar with the arc types during MIG/MAG welding.
- You know about the filler metals of the welding processes: shielding gases, solid and flux core wires.
- You know the basics of welding different materials and are familiar with the associated work techniques.
- You know the different applications of the process variants.
- You know the suitable weld seam profiles for MIG/MAG welding, welding positions and possible welding faults and you know how to avoid them.
- You know about the qualification of welding processes and personnel.
- You recognize potential hazards and have learned about methods for safe handling and safe working.

Want to know more?
Great! Then the training can begin!

Let's go!

2. BASIC KNOWLEDGE: JOINING MATERIALS

There are various manufacturing processes, including forming, separating, coating and joining materials.

In accordance with DIN 8580 "Manufacturing Processes – Terms And Definitions, division", **joining materials** constitutes a main group encompassing all welding processes in which two or more solid objects with a geometrically-defined shape are permanently connected (joined) to one another.

When joining materials, a distinction is made between **separable** and **inseparable** joints.

Separable and inseparable joints

- Examples of **separable joints:**
  screws, pin and bolt connections, wedges.
- Examples of **inseparable joints:**
  welding, brazing, bonding, riveting.

Another way of classifying the joining of materials relates to the type of joint. Here a distinction is made between **cohesive**, **form-locking** and **force-fit** joints.

Cohesive, form-locking and force-fit joints

- **Cohesive joints** create a connection in the material itself. These include welded and soldered joints.
- **Form-locking joints** use the shape of the components to connect them. These includes hooks and eyes.
- **Force-fit joints** are held together by frictional forces.

3. GAS METAL ARC WELDING (GMAW)

3.1 Classification of the Gas Shielded Welding Processes

The term "gas shielded arc welding" covers all arc welding processes where shielding gases are used to protect the weld pool from unwanted contact with the oxygen in the ambient air.

Shielding gases protect the weld pool from oxygen in the ambient air.

Gas shielded welding processes are divided into different groups. They are **classified** (Figure 1) based on the following criteria:

1. Type of shielding gas used
2. Type of electrode used

Gas shielded welding processes are distinguished according to gas type and electrode type.

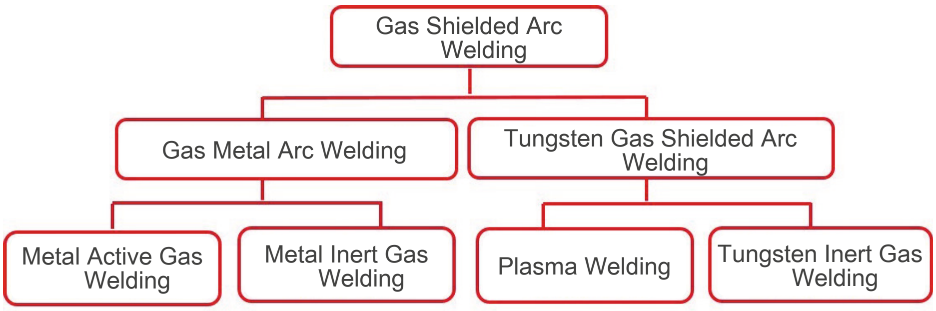


Fig.1: Classification of the gas shielded welding processes.

The shielding gases are divided into:

1. Active gases
2. Inert gases

Determining the correct shielding gas for a welding task is dependent on various criteria:

/ Type of material to be welded

/ Cost-effectiveness considerations

/ Suitability of the shielding gas for the welding process.

The **electrodes are divided into**:

1. Consumable electrodes for gas metal arc welding (GMAW)
2. Non-consumable electrodes for tungsten gas shielded arc welding (GTAW).

Gas metal arc welding covers

1. **Metal inert gas welding (MIG)**
2. **Metal active gas welding (MAG).**

Classification of GMAW.

3.1.1 Metal Inert Gas Welding (MIG Welding)

Inert gases

Metal inert gas welding (MIG) is so named because non-reactive (inert) gases are used during welding. Inert gases are argon, helium, and mixtures of these.

Arc types for GMAW (MIG)

During MIG welding, either a spray arc or a pulsed arc is used.

Materials for GMAW (MIG)

MIG welding is primarily used for the non-ferrous metals aluminum, magnesium, copper, and titanium.

3.1.2 Metal Active Gas Welding (MAG Welding)

During MAG welding, active shielding gases such as carbon dioxide (CO_2) or oxygen (O_2) are added to the carrier gas argon. It is however also possible to use pure CO_2 as a shielding gas for the weld pool.

For special applications, e.g. high performance welding or to weld thicker sheet metals, three-component gases are also used. These consist of argon, helium, and CO_2 . The shielding gases protect against contact with the ambient air.

Arc types for GMAW (MAG)

The arc range during MAG welding is large. MAG welding can be achieved through dip transfer, intermediate, spray, and pulsed arcs.

Materials for GMAW (MAG)

MAG welding is primarily used for unalloyed, low-alloy, and high-alloy steels. With high-alloy steels, the active gas range is limited to a maximum proportion of 3%.

3.1.3 Terms

The gas shielded welding processes are divided into different process variants according to ISO 4063 depending on the type of electrode and the type of shielding gas.

There are various terms (Table 1) for the MIG welding process:

SCOPE OF USE	NAME
Germany	Metall-Inertgasschweißen (MIG)
United Kingdom	Metal inert gas welding
USA	Gas metal arc welding

Tab. 1: The different terms for metal inert gas welding.

The global standard DIN EN ISO 4063 assigns different numbers to the MIG welding process depending on the type and electrode (Table 2):

Metal inert gas welding **with solid wire electrode**	Welding process with number 131
Metal inert gas welding **with welding powder filled wire electrode**	Welding process with number 132
Metal inert gas welding **with metal powder filled wire electrode**	Welding process with number 133

Tab. 2: Process variants of MIG welding.

There are also various terms (Table 3) for the MAG welding process:

SCOPE OF USE	NAME
Germany	Metall-Aktivgasschweißen (MAG)
United Kingdom	Metal active gas welding
USA	Gas metal arc welding

Tab. 3: The different terms for metal active gas welding

The global standard DIN EN ISO 4063 also assigns different numbers to the MAG welding process depending on the type and electrode (Table 4):

Metal active gas welding **with solid wire electrode**	Welding process with number 135
Metal active gas welding **with welding powder filled wire electrode**	Welding process with number 136
Metal active gas welding **with metal powder filled wire electrode**	Welding process with number 138

Tab. 4: Process variants of MAG welding.

Fig. 2: Manual gas metal arc welding.

3.2 Characteristics and Applications

Main areas of application of GMAW

Gas metal arc welding (GMAW) is used in virtually all areas of metal working. The main areas of application include vehicle construction and vehicle repairs, steel construction, bridge construction, and mechanical engineering. The process variants of gas metal arc welding are ideal for different material thicknesses. In vehicle construction, it is therefore possible to weld thin metal sheets, whilst large, thick-walled components can be welded in steel and heavy mechanical engineering applications.

Characteristics of GMAW

Gas metal arc welding is characterized by a whole range of features: It gives a high deposition rate and deep penetration. It is extremely cost effective, is easy to use, and can even be fully automated. Based on the consumption of filler metals, gas shielded arc welding is the most frequently used welding process.

Materials for GMAW

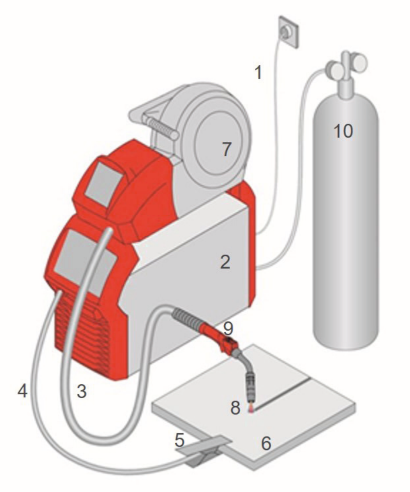
Over the past years, gas metal arc welding has been used more and more to weld unalloyed and low-alloy construction steels. Pulse technology has enabled gas metal arc welding to also be used to weld aluminum and high-alloy steels.

3.3 Set-up and Basic Principle

The set-up: Direct current is used for MIG/MAG welding. During MIG/MAG welding, the arc burns between the workpiece and a consumable wire electrode that is also the necessary filler material (Figure 3).

The arcs

During MIG/MAG welding, the heat is generated by an electric arc. An arc is a short section of air or gas through which the electrical current flows.



1 Grid connection
2 Power source
3 Hosepack
4 Welding current return
5 Grounding clamp
6 Workpiece
7 Filler metal
8 Arc
9 Welding torch
10 Shielding gas cylinder

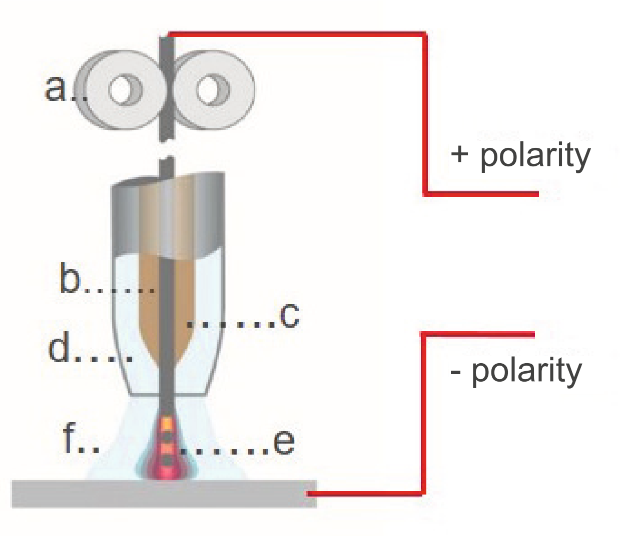
Fig. 3: Set-up for MIG/MAG welding.

Endless wire electrode

The basic principle: The wire electrode (Figure 4, b) is essentially endless. It originates either from a coil or drum and is fed to the contact nozzle (c) by drive rollers (a). The free wire end is relatively short, which allows a high amperage to be used in spite of the thin electrodes.

Shielding gas

The shielding gas (f) flows from a gas nozzle (d) that surrounds the electrode. The function of the shielding gas is to protect the arc (e) and weld pool against contact with the ambient oxygen.



a) Drive
b) Wire electrode
c) Contact nozzle/ contact tip
d) Gas nozzle
e) Arc
f) Shielding gas

Fig. 4: Detailed view of the arc during GMAW.

Gases for MIG and MAG welding

For MIG welding, the inert gases argon, helium, or mixtures thereof are used.

For MAG welding, gas mixtures with two, three, or four components from the constituents carbon dioxide (CO_2), argon, helium, or oxygen (O_2) are used. Pure carbon dioxide can also be used.

3.4 Advantages and Disadvantages of Gas Metal Arc Welding

Advantages

+ High deposition rate
+ No slag formation
+ Simple ignition of the arc
+ Very suitable for mechanized and automated welding
+ Constant wire diameter for thinner and thicker workpieces
+ Unalloyed, low-alloy, and high-alloy CrNi steels are MAG welded
+ MIG welding for aluminum, magnesium, and nickel-based materials, as well as copper and titanium
+ High attainable welding speeds with adequate weld quality
+ Well-suited to out-of-position welding (preferable in lower power range)
+ Free welding of roots with relevant joint preparation or with auxiliary equipment (pool safeguard)
+ Relatively low costs for filler materials

Disadvantages

- Welding outdoors or in drafty halls is not possible without equipment that maintain a shielding gas environment.
- GMAW is sensitive to rust and humidity.
- GMAW is in part slightly more susceptible to porosity and lack of fusion than other welding processes.
- Non-porous weld seams can only be achieved with higher CO_2 ratios in the shielding gas, which in turn increases the risk of spattering.
- The quality of the weld seam can be partially lower than for TIG welding.

3.5 Review Questions

/ What materials are mainly MIG welded?

/ Name four advantages of MIG/MAG welding.

/ How high should the active gas percentage be when welding high-alloy materials?

---

4. WELDING POSITIONS

4.1 Definition

The way in which the components are welded together leads to a fundamental difference in:

1. Butt welds
2. Fillet welds

With **butt-welded joints**, the components are at 180° to one another and are therefore welded on a plane. So that the weld seam passes through the whole workpiece, from a material thickness of approx. 5 mm upwards, the material is first machined with an angle grinder so that a V-shaped opening is created between the workpieces that are to be joined.

Butt welds

With **fillet-welded joints**, the components to be welded together are at an angle to one another (generally a right angle). Depending on the type of connection between the components, a distinction is made between various types of fillet weld, such as lap welds, edge welds, web welds, chord welds, or corner welds. The position of the workpieces to be welded and the position of the welding torch to the seam result in a very wide range of welding positions.

Fillet welds

Welding positions describe the position of the weld seam during the welding process.

Definition of welding positions.

Every welding position requires a specific work technique. In addition to this, the welding position also affects the following parameters:

- Amperage
- Welding torch
- Welding parameters
- Torch guidance
- Deposition rate
- Weld seam appearance

4.2 Classification

Welding positions are organized in accordance with international standard DIN EN ISO 6947. In line with this standard, an international classification of the various welding position is applied (Figure 6):

PA Flat position for butt and fillet welds
PB Horizontal vertical position
PC Horizontal position
PD Horizontal overhead position
PE Overhead position
PF Vertical up position
PG Vertical down position
PH Pipe position for welding upwards
PJ Pipe position for downwards

Classification of welding positions in accordance with DIN EN ISO 6947.

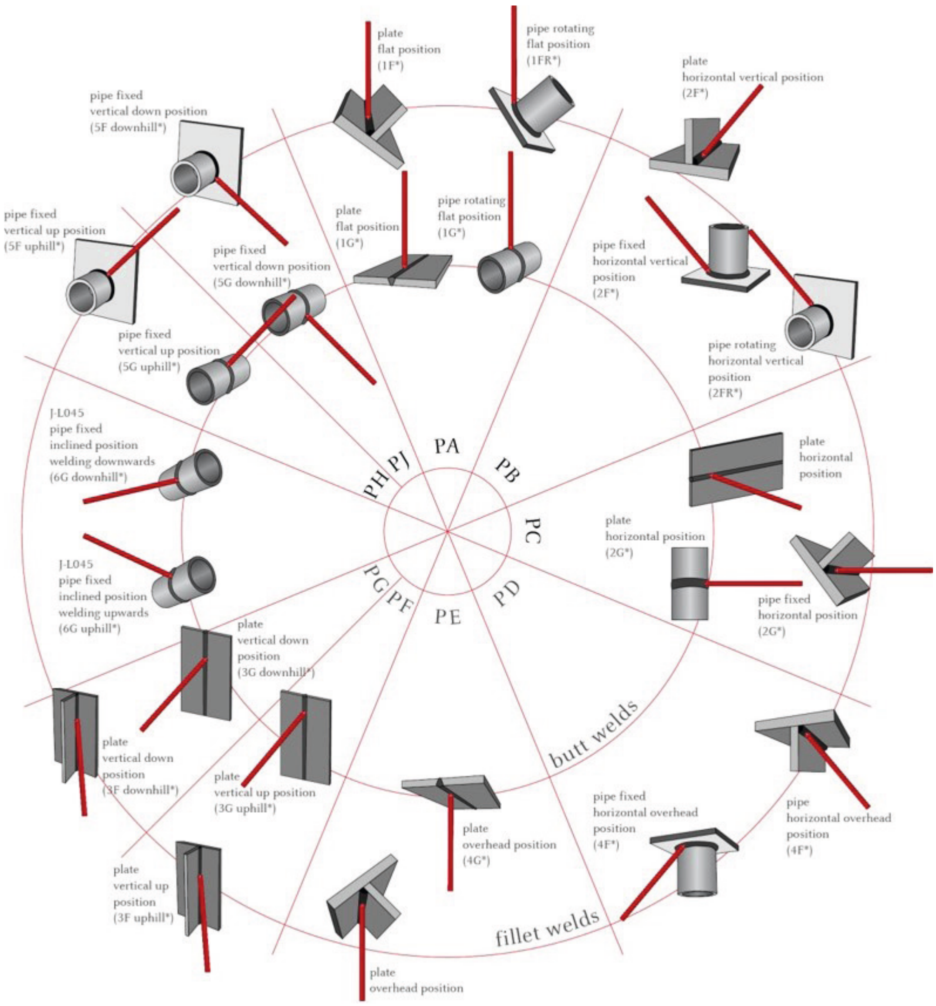


Fig. 5: Welding positions in accordance with DIN EN ISO 6947.

4.3 Review Questions

/ According to DIN EN ISO 6947, what is the abbreviation for the vertical up welding position on sheet metals and plates?

/ According to DIN EN ISO 6947, what is the abbreviation for the overhead welding position on sheet metals and plates?

---

5. ELECTRICITY AND MIG/MAG WELDING

For MIG/MAG welding, it is important to understand circuits and welding circuits, and to be aware of their similarities and differences.

5.1 Electrical Current

Formula symbol: I   Unit: Ampere (A)

Current is the directed movement of negatively-charged charge carriers (electrons). The formula symbol I describes the quantity of current that flows through the line within a given time period.

In order for current to be able to flow, it requires an electrical voltage. This is generated between two differently-charged poles and is the driving force causing the movement of the electrical charge, similar to water pressure. The higher the voltage, the more current that can flow.

Resistance is the "opponent" of voltage, as voltage is lost at each instance of resistance.

Atoms, protons and electrons

Atoms have protons and neutrons in their nucleus and electrons on the atomic shell that is made up of multiple layers. The **proton** has a positive charge, the **neutron** has no charge and the **electron** has a negative charge. Although the number of protons, neutrons and electrons differs for each material, it is always the case that the atomic nucleus is positively charged.

Technical and physical current direction

> The **technical current direction** (e.g. in drawings) runs from the positive pole to the negative pole. The actual **physical current direction** runs from the negative pole to the positive pole.

5.2 Electrical Voltage

Formula symbol: U   Unit: Volt (V)

Electrical voltage is generated between two points with different charge potentials, for example between a positive and a negative pole.

Differently-sized charges attempt to balance each other out through the flow of a current. This difference is known as the voltage. The higher the voltage, the greater the distances that can be bridged. It is only possible for current to flow as a result of voltage.

Electrical voltage gives rise to the current flow.

The formula symbol U indicates the size of the difference in electrical charge.

5.3 Electrical Resistance

Formula symbol: R **Unit: Ohm (Ω)**

Electrical resistance indicates how much the electrons are slowed down while the current is flowing. Resistance is therefore the reciprocal value for electrical conductivity: materials with high electrical conductivity have low resistance, while poor conductors have high resistance.

All substances display differing levels of resistance to the flow of electrons. A distinction is made between **conductors, semiconductors** and **non-conductors**. In the case of electrical conductors (metals, etc.), the electrical charge carriers are movable. In non-conductors (e.g. glass or rubber), they are fixed in their location.

Conductors, semiconductors and non-conductors

5.4 "Ohm's Law"

Ohm's law was named after Georg Simon Ohm, who discovered it. He established that there is a linear relationship between current, voltage and resistance:

1. The electrical amperage and the electrical voltage are dependent on each other.
2. At a constant resistance, the amperage and the voltage increase proportionately.
3. At a constant current, voltage and resistance are proportional to one another: the greater the resistance, the higher the voltage.
4. At a constant voltage, the amperage is indirectly proportional to the resistance: When the resistance increases, the current is reduced.

The formula for Ohm's law is therefore as follows: **U = R x I**

"Ohm's law".

5.5 Circuits

An **electrical circuit** consists of at least one power source and various electrical components that can be connected together.

The **basic components** of a circuit:
- Voltage and/or power source as a power generator (power supply, battery, dynamo, etc.)
- Power consumers, connected to one another via lines (motor, lamp, etc.)
- Switch
- Wires

Basic components of a circuit

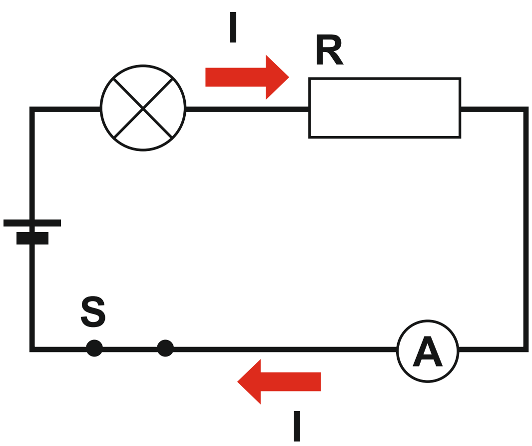
There are two different types of circuits:

1. Closed circuits

2. Open circuits

Circuit variants

In a closed circuit, the individual elements are connected to each other in such a way that charge can be transported: current flows (Figure 6).

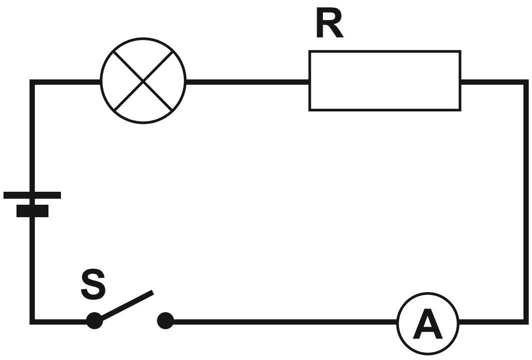


I: Current
Voltage source/power generator
⊗ Power consumer
A: Ammeter
S: Switch
R: Resistor/fuse
→: Direction of current flow

Closed circuit

Fig. 6: Closed circuit.

In an open circuit, the connection is interrupted, meaning that no current flows (Figure 7). The interruption can either be triggered deliberately using a switch or may happen unintentionally, for example due to a loose contact, a missing cable or similar.



- Voltage source/power generator
- ⊗ Power consumer
- **A:** Ammeter
- **S:** Switch
- **R:** Resistor/fuse

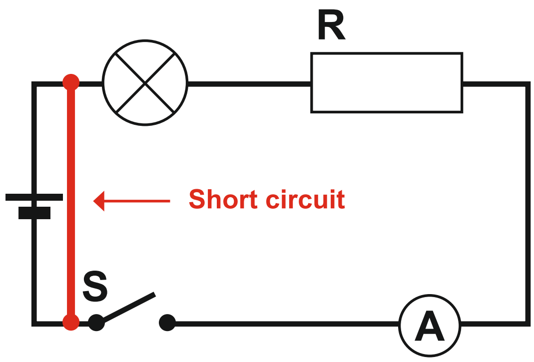
Open circuit

Fig. 7: Open circuit.

5.6 Short Circuit

An electrical short circuit (Figure 8) is an almost resistance-free connection of the two poles of an electrical power or voltage source. In the case of a short circuit, the voltage falls to almost zero.

With a short circuit, the current reaches its maximum value (initial short circuit current). This current is only limited by the resistance of the wire and the effective inner resistance of the power or voltage source.



- Voltage source/power generator
- ⊗ Power consumer
- **A:** Ammeter
- **S:** Switch
- **R:** Resistor/fuse

Short circuit

Fig. 8: Short circuit.

5.7 Voltage Types and Current Types

5.7.1 DC Voltage

Technically and in drawings, current always flows from the positive pole to the negative pole of a voltage source. If the assignment of the poles does not change and the current's direction of flow also remains the same, we refer to this as DC voltage.

DC voltage is an electrical voltage where the strength (value) and direction (polarity) do not change (Figure 9).

Definition of DC voltage

5.7.2 Direct Current

Variant terms:

GERMAN TERM	Gleichstrom
INTERNATIONAL TERM	Direct Current
ABBREVIATION	DC
SYMBOL	⎓

Tab. 5: Variant terms for direct current.

Direct current is an electrical current where the strength (value) and direction (polarity) do not change (Figure 9).

Definition of direct current

Direct current is used for MIG/MAG welding.

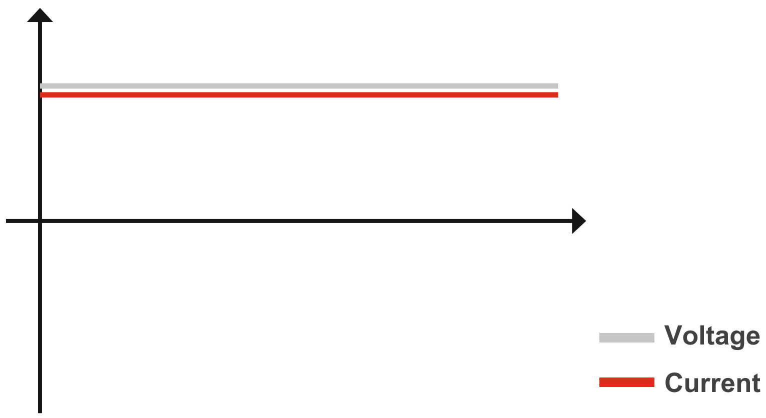


Fig. 9: Direct current and DC voltage.

Mixed current with a predominant share of direct current is also referred to as direct current, if the fluctuations that occur are insignificant for the intended use.

5.7.3 AC Voltage

There are voltage sources (e.g. sockets) where the polarity changes in a recurring rhythm. Due to the change of voltage, the current's direction of flow also changes. This is referred to as AC voltage.

AC voltage is an electrical voltage where the strength (value) and direction (polarity) change at regular, recurring intervals (Figure 10).

Definition of AC voltage

5.7.4 Alternating Current

Variant terms:

GERMAN TERM	Wechselstrom
INTERNATIONAL TERM	Alternating Current
ABBREVIATION	AC
SYMBOL	~

Tab. 6: Variant terms for alternating current.

Alternating current is an electrical current where the strength (value) and direction (polarity) change at regular, recurring intervals. Due to the periodical repetition of positive and negative values, the amperage over the averaged time is zero (Figure 10).

Definition of alternating current

There are various types of alternating current. The curved shape of the AC voltage describes the alternating quantity. Pure alternating quantities are the square wave voltage, sawtooth voltage, triangular voltage, sinusoidal voltage or a mix of all these variants.

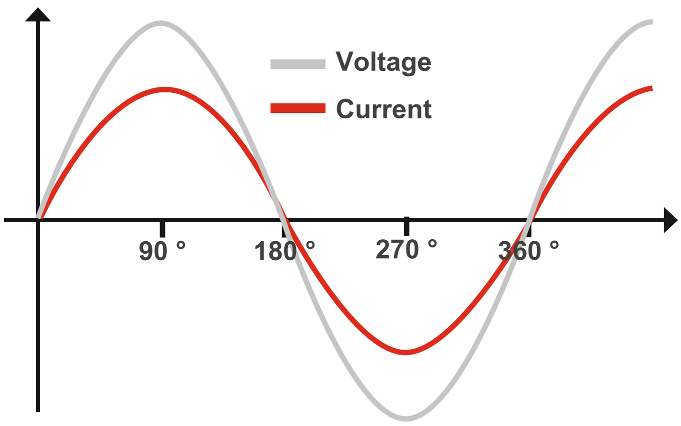


Fig. 10: Alternating current and voltage.

5.8 The Welding Circuit

A welding circuit behaves like an electrical circuit, meaning that Ohm's law also applies to the welding circuit.

However, a welding circuit is made up of different components than an electrical circuit.

The components of a welding circuit:

- Power source
- Welding torch
- Filler metal
- Workpiece

Components of a welding circuit

The welding circuit triggers the formation of the arc, without which MIG/MAG welding is not possible.

In the welding circuit, the formula symbol Is (A) is used for the welding current, while Us (V) denotes the welding voltage.

5.9 Review Questions

- What is the unit of electrical voltage called?

- What is the unit of electrical current called?

- What types of current and voltage are there?

- Which type of current is used in MIG/MAG welding?

---

6. ARC TYPES

6.1 Heating Effect of the Arc

The basic prerequisite for the formation of the arc is a closed circuit. Every circuit has a positively and a negatively charged pole. The negatively charged pole has an excess of electrons.

Contact between the wire electrode and workpiece creates a short circuit. This short circuit causes the tip of the wire electrode to heat up to such an extent that negative-poled electrons can emerge. The voltage applied within the circuit causes the electrons on the way to the positive pole to accelerate to high speeds. If they encounter neutral gas atoms in the arc column, then additional electrons are released and the gas atom is converted into a positive ion (Figure 11).

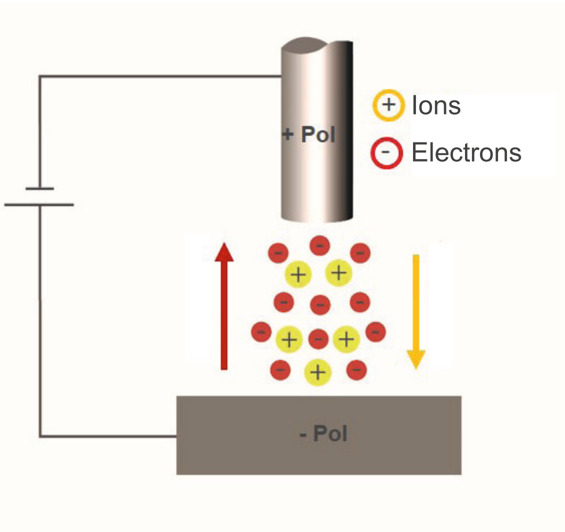


Fig. 11: The heating effect in the arc.

The temperature at the positive pole is always hotter than at the negative pole. The wire electrode during gas metal arc welding therefore has positive polarity.

The wire electrode always has positive polarity.

There are different types of arcs (Figure 12):

- CMT arc
- Dip transfer arc
- Intermediate arc
- Spray arc

- Pulsed arc
- High performance arc

The boundaries between these arc types are fluid

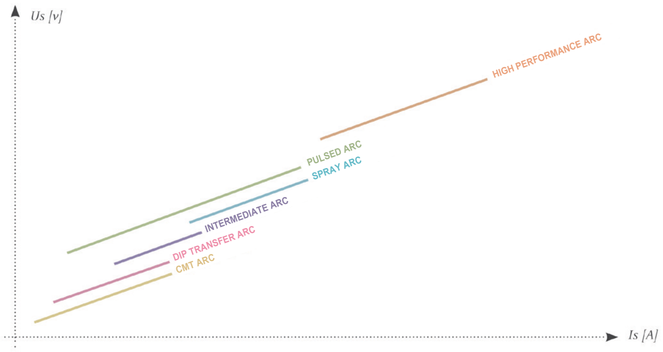


Fig. 12: The arc types.

During MIG/MAG welding, the material transfers dynamically from the consumable wire electrode to the workpiece during the arc phase. This can occur with or without a short circuit. The arc type used during the material transfer is dependent on the welding voltage (Us) and welding amperage (As).

If the welding amperage or voltage increases, the type of material transfer changes during MIG/MAG welding:

- As the **arc voltage increases**, the droplet volume increases and the material transfer becomes short circuit-free.
- As the **amperage increases**, the number of droplets increases. At the same time, the volume decreases.

Welding amperage and welding voltage affect the material transfer

6.2 Dip Transfer Arc

6.2.1 Uncontrolled Dip Transfer Arc

An uncontrolled dip transfer arc is an arc in the lower power range with a consumable wire electrode.

The dip transfer arc is ignited through brief contact between the wire electrode and workpiece. This produces a high, rapidly increasing short circuit current (Figure 13).

The heat causes the wire electrode to liquefy and the weld droplet detaches itself. Once the short circuit bridge breaks, the arc reignites.

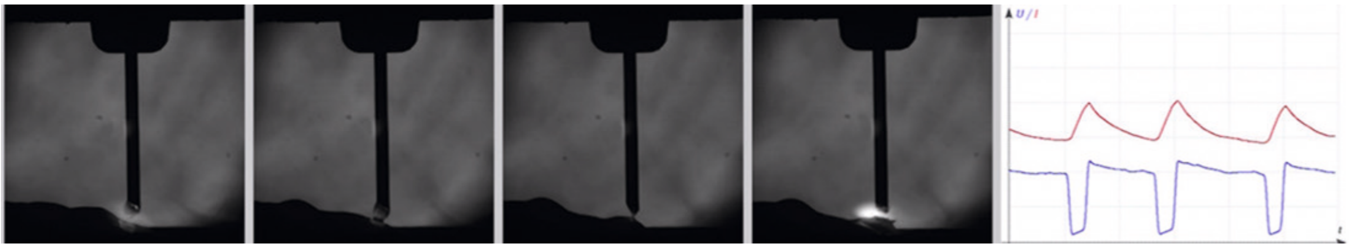


Fig. 13: Uncontrolled arc.

Fields of application of the dip transfer arc

With the dip transfer arc, welding is possible in virtually any position. However, the deposition rate of the uncontrolled dip transfer arc is low. The uncontrolled dip transfer arc is therefore ideal for welding thin components, out-of-position welding, root passes, and for bridging the welding gap.

6.2.2 Controlled (Modified) Dip Transfer Arc

With the Low Spatter-Control (LSC) function, a modified dip transfer arc is created with an extremely high arc stability. The LSC principle is based on the premise that the short circuit is dissipated at a low current level. This results in a gentle reignition and a stable welding process (Figure 14). This is quite different to the uncontrolled dip transfer arc.

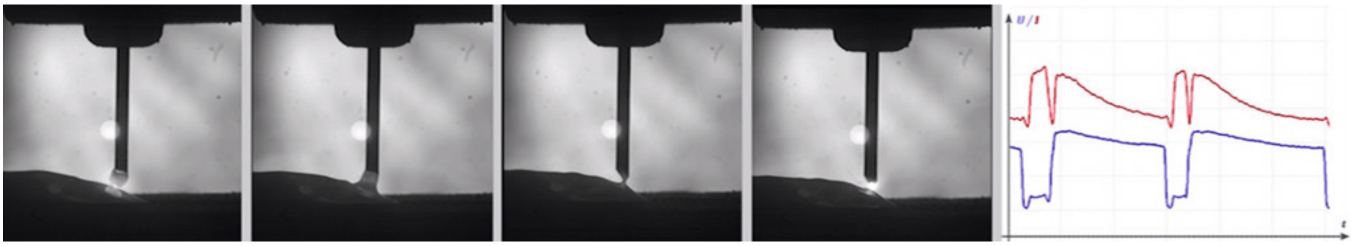


Fig.14: Controlled arc.

Effect of the controlled arc

With the controlled dip transfer arc, the user achieves high-quality weld seams with very little spattering and an increased deposition rate.

6.3 Intermediate Arc

With the intermediate arc, short circuits and spray transfers alternate (Figure 15).

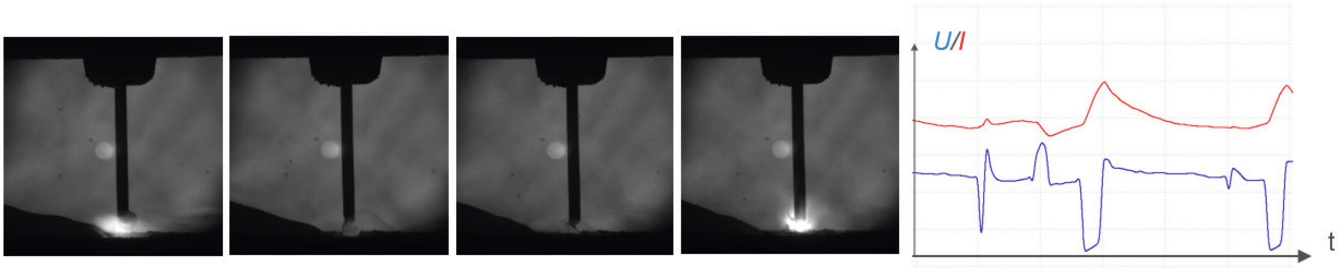


Fig. 15: The intermediate arc.

With the intermediate arc, the switch between short circuits and spray transfers occurs at irregular intervals. Furthermore, there is increased spatter as the comparatively high current has a forceful effect on the welding droplets. This is why an effective use of the intermediate arc is virtually impossible. **The intermediate arc should therefore be avoided at all times!**

Avoid intermediate arcs at all times!

6.4 Spray Arc

Features of the spray arc

The spray arc burns continuously without short circuit interruption (Figure 16). The filler metal therefore transfers at high speed and in fine droplets into the weld pool.

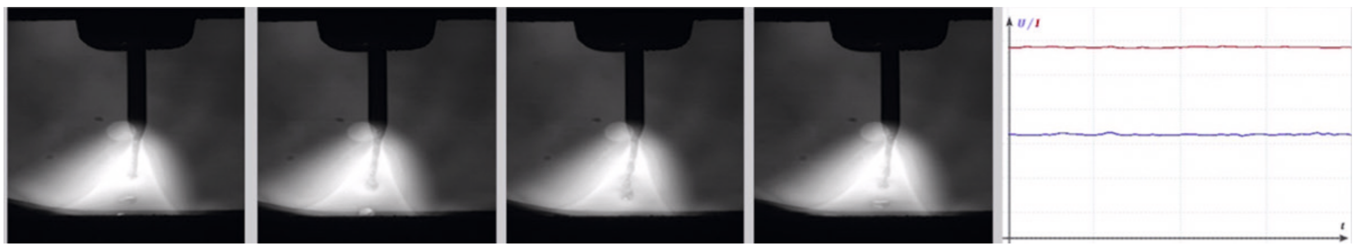


Fig. 16: The spray arc.

The high thermal energy of the spray arc creates a larger heat-affected zone than the dip transfer arc. This is why workpiece distortion is also greater with the spray arc.

Characteristics and fields of application of the spray arc

Characteristics of the spray arc include a high deposition rate and deep penetration. The spray arc is therefore ideal for welding thicker sheet metals.

6.5 Pulsed Arc

With the pulsed arc, the material transfer is precisely controlled by pulses (Figure 17).

Functionality of the pulsed arc

In the base current phase, the energy input is reduced to such an extent that the arc barely burns steadily and the surface of the workpiece is preheated. In the pulsing current phase, an accurately timed current pulse guarantees a precise detachment of the weld droplet.

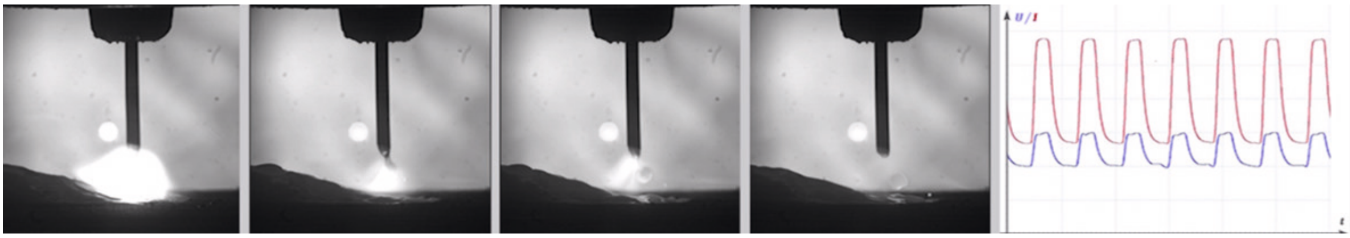


Fig. 17: The pulsed arc.

The pulsed arc almost completely eliminates unwanted short-circuits and simultaneous droplet explosions. As a result there is virtually no uncontrolled spatter with the pulsed arc.

Advantages of the pulsed arc:

+ Low-spatter welding across the whole power range
+ Control of penetration during overlay welding
+ Processing of thicker wire electrode diameters for thin sheet metal welding (e.g.: aluminum materials)

6.6 Combined Arcs

Combined arcs are often made up of pulsed arcs and dip transfer arcs (Figure 18).

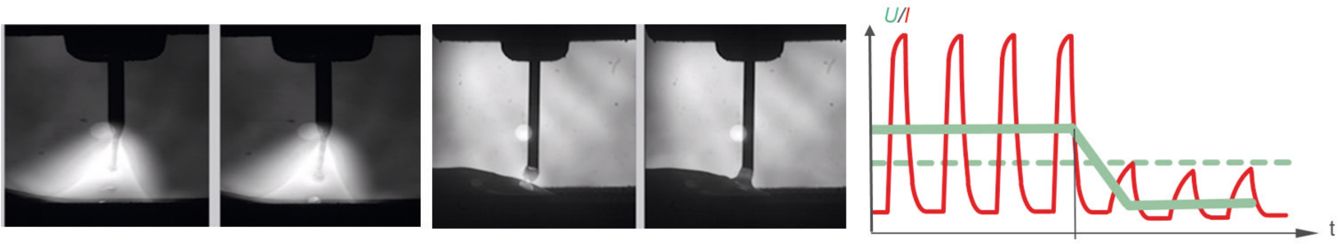


Fig. 18: Combined arcs.

The penetration and heat input needed are generated in the pulsed arc phase. The dip transfer arc phase takes care of the cooling in the weld pool, thus ensuring better controllability of the weld pool.

Combined arcs are often used for out-of-position welding (position PF).

Combined arcs are ideal for welding out-of-position.

6.7 Review Questions

/ What are the disadvantages of the dip transfer arc?

/ What are the characteristic features of the intermediate arc?

/ What distinguishes the spray arc?

/ What are the advantages of the pulsed arc?

/ How is the wire electrode poled during MIG/MAG welding?

---

7. EQUIPMENT

7.1 Power Sources

Metal inert gas welding and metal active gas welding require a high amperage and a low electrical voltage. This means a welding power source is required. Welding power sources transform the current available from the grid, with high voltage and low amperage, into a current that is suitable for welding. In addition, welding power sources are responsible for rectifying the AC voltage coming from the grid and regulating the welding current. Modern welding power sources are digitally controlled and permit infinitely variable welding amperage settings. This is important in order to be able to weld different thicknesses of sheet metal.

Tasks of a welding power source

7.1.1 Primary Switched Power Source (Inverter Power Source)

Inverter power sources (Figures 19 and 20) represent the state of the art. These devices transform low-voltage grid power into a high current welding arc using a switched frequency transformer.

Fig. 19: Compact inverter power source.

Fig. 20: Split inverter power source.

Inverter power sources are constructed in such a way that the welding transformer is in the end path behind the transistor.

The design of the inverter power sources is related to the volume of the transistor and transistor frequency: According to electrical principles covering transformers, the weight and volume of a transformer is dependent on the frequency with which they are being operated.

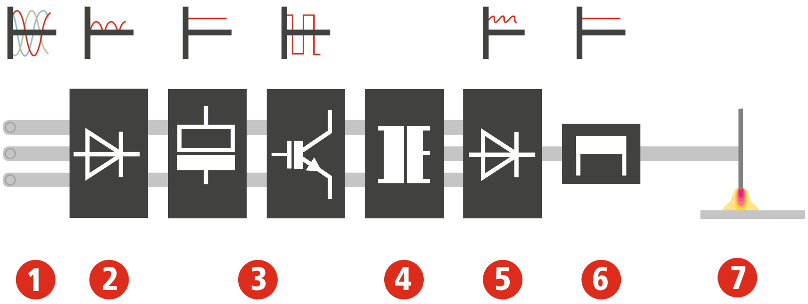
Weight and volume of transformers.

The following points apply: The higher the frequency, the lower the volume of the transformers. For IGPT transistors, the frequency is ~ 35-40 KHz.

High frequency - small volume

To ensure that a high switching frequency can be used, the AC voltage from the grid must first be rectified. This transformation (= inverting) is where the inverter power sources get their name from: The grid voltage is immediately rectified after the main switch. Once the primary rectifier has transformed the AC grid voltage into a DC voltage, a transistor switch is used to create a high frequency. The voltage from the transformer is then finally rectified once more (Figure 21).

The inverter principle



1 Input: sinusoidal alternating current
2 Primary rectification
3 Buffering and switching
4 Transforming
5 Secondary rectification
6 Smoothing
7 Output for welding

Fig. 21: The inverter principle in the block diagram.

Advantages of an inverter power source

On the basis of this configuration, inverter power sources are lightweight and small with unlimited performance capability. Inverter power sources are easy to transport and are therefore ideal for use on construction sites. Another advantage of inverter power sources is their high electrical efficiency, which can be as high as 90%.

7.1.2 Digitization and Automation

The potential for full digitization of the system that is now possible marks a revolutionary step in the ongoing development of power sources, since digitization enables the weld properties, i.e. the arc characteristics, to be presented by software.

Digitization also opens up undreamed-of possibilities for software to influence the welding process. At the same time, the digitally controlled process increases the accuracy and reproducibility of the welding results since the analog components affected by a temperature drift are eliminated.

Software can be used to influence the welding process.

Another advantage of modern hardware is communication between the power source and system components (wire drive, remote control, etc.). Data about the operating status can be read or parameter settings applied – and not just at the power source but also directly on the robot controller.

Device communication

Fig. 22: Inverter power source in conjunction with a robot and an external wirefeeder.

Important: When selecting a gas shielded arc welding system, it is important to make sure that the performance of the power source is sufficient. The performance data of a system is listed on the rating plate.

The power source must be sufficiently powerful.

7.2 Wirefeeder

Wirefeeders and the wire speed they produce are absolutely crucial in the MIG/MAG welding process. The wirefeeder influences the welding result straight away. Because the wire feed impacts so much of the welding process, the feeder must run safely, precisely, and as smoothly as possible.

The wirefeeder influences the welding result.

Wire feeding during manual (Figure 23) or mechanized welding (Figure 24) is usually realized by different wirefeeder systems.

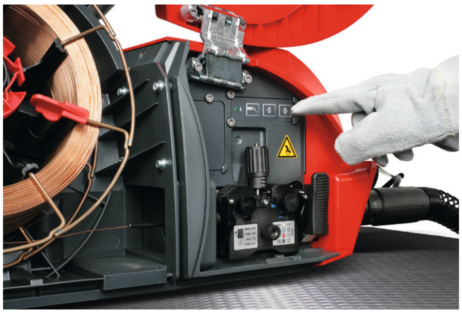


Fig. 23: Manual wirefeeder.

Fig. 24: Wirefeeder for assembly on a robot axis.

Drive systems with two and four rollers are used for the wirefeeder, whereby high-quality industrial devices always operate with a 4-roller drive.

The following points apply: The drive rollers are always matched to the wire diameter being used!

Drive rollers and wire diameter must be compatible.

The drive rollers are color coded (Figure 25) for easier identification.

Fig. 25: Color-coded drive rollers and their schematic diagram.

Wire shape and wire groove type

Drive rollers have different groove profiles. The groove profile used depends on the type of wire to be welded. Soft wires, such as aluminum wires, should be conveyed with a half-round groove profile. This prevents any deformation of the wire. Steel wires are successfully conveyed with a half-round groove profile, but also sometimes with a trapezoidal groove profile.

Travel speed

The travel speed setting of the wirefeeder is infinitely variable from 0- 30 m/min with a digitally controlled motor speed, thereby ensuring accuracy and a high level of reproducibility.

On compact systems, wirefeeders are integrated directly into the power source (Figure 19, p. 30). Alternatively, the wirefeeder can also be placed on the power source. Together with an intermediate hosepack, they then extend the operating range. For mechanized applications, wirefeeders are often placed directly on the robot axis (Figure 22, page 32).

7.3 Welding Torches

7.3.1 Welding Torch Variants

Types of welding torches

There are many variants of welding torches for MIG/MAG welding:

- Air-cooled welding torches
- Water-cooled welding torches
- Welding torches with exchangeable torch bodies

The welding torches for MIG/MAG welding must be optimally set up for the welding system. The choice of welding torch is therefore dependent on whether welding is manual (Figures 26 and 27), mechanized, or robotic (Figure 28).

The welding process determines the type of welding torch.

Torch lengths up to approx. 4.5 m guarantee stable wirefeed.

Push-pull welding torch

Push-pull welding torches (Figure 28) are also fitted with a wirefeeder. With these systems, the welding wire is pushed and pulled synchronously, thus making the wire feed extremely accurate. When welding aluminum in particular, this offers significant advantages.

Fig. 26: Manual welding torch.

Fig. 27: Welding torch with wire drive.

Fig. 28: Push-pull welding torch

Welding torch with JobMaster function

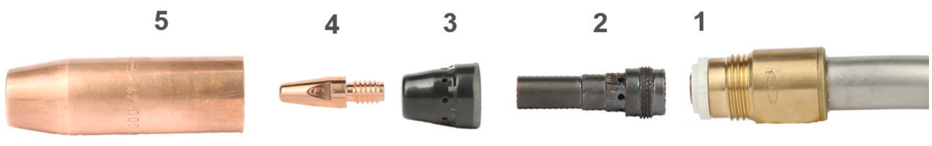
Welding torches with a JobMaster function are extremely convenient. With these, the user can use the remote control and three-digit color display that is integrated in the handle to get a quick overview of the most important welding parameters such as welding power, wire speed, previously stored jobs, and arc lengths, and can adjust them to the desired value.

In terms of occupational health and safety, the welding torches have also proven themselves when it comes to integrated welding fume extraction.

7.3.2 Replacement and Wearing Parts for Welding Torches

Welding torches for MIG/MAG welding are made up of several individual parts (Figure 29) that can become worn or damaged as a result of the extreme stresses they are exposed to.

Components of the welding torches can wear.



1 Insulation ring
2 Nozzle fitting
3 Spatter guard
4 Contact tip
5 Gas nozzle

Fig. 29: Replacement and wearing parts for welding torches.

Contact tip and contact surfaces

During welding, there is a constant power transfer in the contact tip of the welding torch to the filler metal. Contact surfaces are used for this power transfer that wear as a result of the constant demands.

The quality of the contact tip is also vital. Materials made from electrolytic copper (E-Cu), copper-chromium (CuCr), or zirconium-copper (CuCrZr) are often used here. The hole on the contact tip is matched to the wire diameter.

The wire electrode is fed through the hosepack by a component known as the **inner liner**. It is essential that the inner liner is made from a suitable material for the filler metal being welded.

Inner liner and filler metal must be compatible.

A plastic inner liner is recommended for aluminum. The inner diameter should be approx. 0.5 mm greater than the outer diameter of the filler metal.

The clamping piece of the torch connector (Figure 31) is color coded and is also matched to the diameter of the filler metal.

Fig. 30: Inner liner with color-coded clamping piece.

On the welding torch body, the selection criterion for the inner liner is based on whether it is a water-cooled or gas-cooled welding torch. Water-cooled welding torches do not heat up as much, which is why the inner liner can be made of plastic in this case. Gas-cooled welding torches heat up more, which is why the end piece of the inner liner is made from brass (Figure 31).

The type of welding torch influences the inner liner.

Fig. 31: Variants of inner liners on the welding torch body.

7.4 Cooling Units

In the case of a long arc time and high welding amperages, welding torches may overheat. Cooling units (Figure 32) are therefore used to protect the welding torches.

Fig. 32: Cooling unit.

Cooling units extend the duty cycle of the welding torches. This also allows them to be constructed much smaller. The cooling units are usually installed directly below the power source and are integrated into the overall set-up of the welding process and its digital control unit. This enables the power source to control and monitor the flow rate of the coolant and the coolant temperature, which is especially important for mechanized applications.

Coolant and coolant filter

The coolant used should be chosen to suit the system, be freeze-resistant, and non-corrosive. In addition to this, it is also important to use a coolant filter. This prevents any contamination of the cooling unit pump, thus ruling out any consequential damage.

Water-cooled welding torches must be used where the welding power exceeds approx. 250 A and the arc burns for a long time.

Water-cooled welding torches should be used from a welding power of 250 A upwards.

7.5 Remote Control

Remote controls are used to set and change welding parameters directly from the welding location. The operator can therefore control the welding process at all times without having to go to the power source.

Remote controls are integrated either directly in the welding torch (Figure 33) or are operated as a separate unit (Figures 34 and 35). Remote controls often have the same functionality as the control panel of the power source. Furthermore, welding parameters can also be saved as a job with a defined parameter set and then retrieved from the remote controls.

Fig. 33: Remote control on the welding torch.

Fig. 34: Remote control with display.

Fig. 35: Remote control with key card.

7.6 Operating Concept

Tasks and function of operating concepts

Power sources these days have numerous adjustment options. It is therefore essential that users can select the correct welding parameters for the relevant welding task as clearly and easily as possible. This task is realized by operating concepts, where different welding parameters are set automatically and in line with the selection made by the user (Figures 36 and 37). This makes the systems extremely user-friendly.

Operating concepts follow this sequence:

1. Select the welding process
2. Select the process variant
3. Select the filler metal to be welded together with diameter and shielding gas
4. Select the desired material thickness
5. Select various process parameters

The basic principle of operating concepts

The operating concepts are designed in such a way that the desired welding process is always selected first. A process variant can already be set at this stage too, e.g. MIG/MAG Pulse Synergic; MIG/MAG Standard Manual or MIG/MAG LSC.

The second step involves selecting the filler metal to be welded together with the respective diameter and suitable shielding gas. This sets the characteristic stored in the device. Then the desired material thickness is set, e.g. basic fillet weld in position PB, under the "Welding" menu item. The wirefeeder, resulting amperage, and the welding voltage are all configured based on these selections.

Under the "Process parameters" menu item, settings concerning the gas setup, the start of welding, the end of welding, and process control can all be applied.

The "Wire threading" and "Gas test" functions are helpful functions that can also be operated using their separate buttons.

Fig. 36: Operating concept TPS 270i.


Fig. 37: Operating concept with touchscreen.

7.7 Review Questions

/ What are the advantages of inverter power sources?

/ From when should cooling units be used?

/ What is meant by a push-pull welding torch?

/ What are the advantages of remote controls?

8. FILLER METALS

8.1 Solid Wires

Spool sizes of wire electrodes

Wire electrodes for MIG/MAG welding are usually wound onto a spool body (Figure 38). Depending on the intended use, the following spools are used:

- 1 kg
- 5 kg
- 15 kg

Drums are also available for large-scale consumers, from which the wire is pulled using a special device (Figure 39).

Fig. 38: Small spool, 15 kg.

Fig. 39: Drum coil, 300 kg.

Diameters of solid wires

Common wire diameters of solid wires:

- 0.6 mm
- 0.8 mm
- 1.0 mm
- 1.2 mm
- 1.6 mm

The surface of the solid wires must meet strict requirements in order to be able to optimally transfer the welding current in the contact tip to the wire.

Cast and helix

Cast and helix are also factors that affect an optimum wire feed. To determine these values, allow approx. 3 m of welding wire to drop onto a level surface. The resulting diameter is the cast and should be approx. 600-800 mm for a wire with a 1.2 mm diameter. If the wire leaves the floor, then this is the helix. This value should not be greater than 50 mm.

> **Important:** Welding wires for stainless and heat-resistant steels must not be copper-plated!

For certain types of steel, the welding wires must not be copper-plated!

Standardization of solid wires

Solid wires for unalloyed steels and fine-grained steels are subject to international standard DIN EN ISO 14341 A. It defines, amongst other things, how solid wires should be labeled (Figure 40).

Example of solid wire labeling for unalloyed materials:

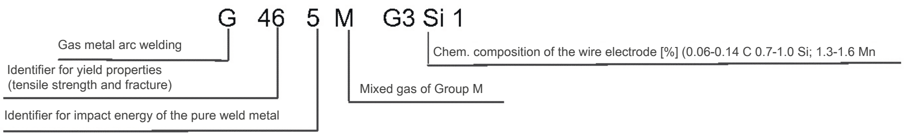


Fig. 40: Standardized designation for unalloyed materials.

8.2 Gas Shielded Flux Core Wires

Gas shielded flux core wires are mainly welded using shielding gas.

A flux core wire is a filled tubular wire (Figure 41).

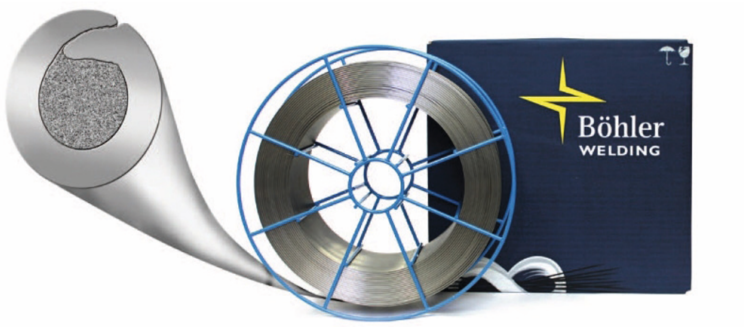


Fig.41: Tubular covered electrode.

Stick out

Flux core wires are primarily welded with shielding gas and are often used as an alternative to solid wire. Unlike solid wires, the free wire end of flux core wires is approx. 5-10 mm longer, i.e. 15-20 mm stick out.

The wire is manufactured by cold forming a ribbon that acts as a sheath material. At one of the production stations, the powdery filling is introduced into the strip that is bent into a U-shape. In the following stations, the strip is then sealed by means of folding or welding with a laser beam, and then calibrated to the final dimension.

The common wire diameters of flux core wires are:

- 1.0 mm
- 1.2 mm
- 1.6 mm

Diameter of gas shielded flux core wires

Due to the more complex manufacturing process, flux core wires are more expensive than solid wires, but in certain applications they do offer many advantages.

Advantages of flux core wires

+ Excellent mechanical properties and corrosion resistance in the weld metal
+ Reliable constant weld properties
+ Smooth weld surface
+ Little or no spattering
+ Minimum weld reworking
+ Increased productivity

Welding behavior of solid wires and flux core wires

The differences in the welding behavior between a solid and tubular covered electrode are essentially down to the differing structures. With the solid wire electrode, the welding current passes across the whole cross sectional area of the wire, whereas with the tubular covered electrode, the majority of the current is transferred across the significantly smaller cross sectional area of the ring formed by the outer sheath.

The powder filling inside a tubular covered electrode is barely electroconductive. This physical effect causes tubular covered electrodes, with the same diameter, to have a considerably higher current density than solid wire electrodes. Since the droplets on the outer sheath of the tubular covered electrode are also pinched off, this creates a significantly wider arc and also creates a wider penetration profile than with the solid wire electrode.

Gas shielded tubular covered electrodes are classified by the current European standard DIN EN 758 as follows:

1. B = basic tubular covered electrodes
2. R = rutile tubular covered electrodes with slow freezing slag
3. P = rutile tubular covered electrodes with fast freezing slag
4. M = tubular covered electrodes with metal powder

This classification applies to M, R, and P types, and for stainless CrNi-alloyed additions.

Classification of gas shielded flux core wires

The various flux core wire types differ with regard to the material transfer:

Properties of the types of flux core wire

Rutile and **basic flux core wires** create a good penetration and a smooth weld surface, with minimum spattering. In addition to this, these two types of flux core wire form slag that supports the weld pool when welding out-of-position. When using rutile and basic flux core wires, it is therefore possible to apply a greater deposition rate.

Metal powder wires do not produce slag during welding. They offer maximum productivity with the general advantages of the flux core wires.

8.3 Self-Shielded Flux Core Wires

Self-shielded flux core wires develop gases, metal vapors, and slag in the arc that protect the weld pool from contact with the ambient air. When using these flux core wires it is therefore not necessary to use a shielding gas. The material transfer is in the form of very coarse droplets. Furthermore, the generation of smoke with self-shielded flux core wires is often very high, which is why this type of flux core wire is primarily used for welding outdoors.

With self-shielded flux core wires, no shielding gas is needed.

With self-shielded flux core wires, the torch's gas nozzle is not used. The flux core wires are usually welded using direct current and by connecting the electrode to the negative pole.

8.4 Review Questions

- What are the common wire diameters for solid wires?

- What are the advantages of flux core wires?

- Which flux core wires do not need shielding gas?

- Which flux core wires do not generate slag during welding?

9. SHIELDING GASES

With MIG/MAG welding, the primary function of the shielding gas is to the protect arc and the weld pool from nitrogen and oxygen in the ambient air. Without a shielding gas, the weld pool would react with the oxygen and nitrogen, thereby causing welding faults such as pores, inclusions, or embrittlement.

Functions of shielding gases

In addition to this, the shielding gas also affects the material transfer (coarse or fine droplets), surface tension, and flow in the weld pool. The penetration and spattering are also greatly affected by the shielding gas.

9.1 Standardization and Classification of Shielding Gases

Classification of shielding gases

Shielding gases are standardized in accordance with standard DIN EN ISO 14175 (AWS A5.32) and are classified into **seven main groups**:

I:	Inert gases and inert mixed gases
M1, M2, M3:	Oxidizing mixed gases with oxygen and/or carbon dioxide
C:	Very oxidizing gases and very oxidizing mixed gases
R:	Reducing mixed gases
N:	Non-reactive gases or non-reactive mixed gases with nitrogen
O:	Oxygen
Z:	Mixed gases that cannot be classified in accordance with the aforementioned criteria.

These seven main categories are classified into subgroups according to their manner of reaction (Table 7):

Welding process	Symbol		Components in volume - percent				
	Main group	Sub-group	Oxidizing		Inert		Reducing
			CO_2	O_2	Argon	Helium	H_2
MIG	1	1					
		2				100	
		3			Residual	$0.5 \leq He \leq 95$	
MAG	M1	1	$0.5 \leq CO_2 \leq 5$		Residual[1])		$0.5 \leq H_2 \leq 5$
		2	$0.5 \leq CO_2 \leq 5$		Residual[1])		
		3		$0.5 \leq O_2 \leq 3$	Residual[1])		
		4	$0.5 \leq CO_2 \leq 5$	$0.5 \leq O_2 \leq 3$	Residual[1])		
	M2	0	$5 < CO_2 \leq 15$		Residual[1])		
		1	$15 < CO_2 \leq 25$		Residual[1])		
		2		$3 < O_2 \leq 10$	Residual[1])		
		3	$0.5 \leq CO_2 \leq 5$	$3 < O_2 \leq 10$	Residual[1])		
		4	$5 < CO_2 \leq 15$	$0.5 \leq O_2 \leq 3$	Residual[1])		
		5	$5 < CO_2 \leq 15$	$3 < O_2 \leq 10$	Residual[1])		
		6	$15 < CO_2 \leq 25$	$0.5 \leq O_2 \leq 3$	Residual[1])		
		7	$15 < CO_2 \leq 25$	$3 < O_2 \leq 10$	Residual[1])		
	M3	1	$25 < CO_2 \leq 50$		Residual[1])		
		2		$10 < O_2 \leq 15$	Residual[1])		
		3	$25 < CO_2 \leq 50$	$2 < O_2 \leq 10$	Residual[1])		
		4	$5 < CO_2 \leq 25$	$10 < O_2 \leq 15$	Residual[1])		
		5	$25 < CO_2 \leq 50$	$10 < O_2 \leq 15$	Residual[1])		
	C	1	100				
		2	Residual	$0.5 \leq O_2 \leq 30$			
	Z	Mixed gases with components that are not listed in the table or mixed gases with a composition outside the specified ranges□)					
For the purposes of this classification, argon can be replaced either in part or fully by helium. Two mixed gases with the same Z-classification must not be interchanged.							

Tab. 7: Classification of shielding gases in accordance with DIN EN 14175.

The purity of the shielding gas is another quality criterion. A designation of 4.6 indicates a level of purity of 99.996%.

Important: Different materials require different shielding gases!

Different materials require different shielding gases!

Selecting the correct shielding gas for the welding task is based on the following criteria:

- Type of material to be welded
- Consideration of cost effectiveness
- Suitability for the welding process

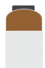
Shielding gas recommendations for various materials can be found in Table 8:

Welding process in accordance with DIN EN ISO 4063	Material	Chemical reaction of the shielding gas	Shielding gas classification according to DIN EN 14175
MIG (131)	- All metals except for steel - Aluminum and copper - Aluminum and copper	Inert	I 1 I 2 I 3
MAGM (135)	- Stainless and high-alloy steels - Stainless and high-alloy steels - Low-alloy steels	Less oxidizing	M 11 M 12 M 13
	- Unalloyed and low-alloy steels, flux core wires - Unalloyed and low-alloy steels - Unalloyed/low-alloy and stainless steels		M 21 M 22 M 23
	- Unalloyed and low-alloy steels - Unalloyed and low-alloy steels - Unalloyed steels	More oxidizing	M 31 M 32 M 33
MAGC (135)			C

Tab. 8: Shielding gases for various materials.

Gas cylinders have color-coded shoulders in accordance with DIN EN 1089-3 (Table 9). The most common gases used in welding have the following color codes:

Color coding of gas cylinders

Gas type	Identification color	RAL No.	Illustration
Pure argon	Dark green	6001	
Oxygen	White	9010	
Forming gas Nitrogen/hydrogen	Red	3000	
Helium	Brown	8008	
Mixture argon/CO2	Bright green	6018	
Carbon dioxide CO2	Gray	7037	
Nitrogen	Black	9005	
Acetylene	Maroon	3009	

Tab. 9: Color coding in accordance with DIN EN 1089-3.

Individual cylinders are now supplied with a filling pressure of 200 or 300 bar.

9.2 Shielding Gas Consumption at the Gas Nozzle

The consumption of shielding gases is specified in l/min and is dependent on the following factors:

- Gas nozzle diameter
- Standoff distance to workpiece
- Arc type
- Environmental conditions
- Weld seam profile and join profile

To determine consumption, use the rule of thumb **wire diameter x 10**. Accordingly, a consumption of 12 l/min would be set as the standard value on the pressure regulator for a 1.2 mm wire diameter.

Rule of thumb for determining the consumption of shielding gas

9.3 Review Questions

- What are the functions of shielding gases?

- On what does the consumption of shielding gas at the gas nozzle depend?

- What is the color code of a pure argon cylinder?

---

10. PROCESS CONTROL

MIG/MAG power sources can be easily configured based on the relationship of power source characteristics and standardized arc characteristic, as detailed in DIN EN 60974-1. The static power source characteristics present the relationship between the welding amperage and arc voltage in a current-voltage diagram, called the U/I diagram.

Power source characteristics clarify the relationship between welding amperage and arc voltage.

For step-switched power sources, the number of static power source characteristics is identical to the number of different adjustment levels. Nowadays, continuously variable devices are mainly used. They have almost limitless voltage levels and therefore also limitless static characteristics.

10.1 Adjusting the Operating Point

For MIG/MAG welding, a voltage must always be preselected on the device first. The wire speed (m/min) needed for this voltage is the second variable to be set. Based on this wire speed, the U/I diagram then shows the required intensity of the welding current.

The operating point is the intersection between the power source characteristics and the standardized arc characteristics. At the operating point, the arc is neither too short nor too long and therefore burns optimally (Figure 42).

The operating point

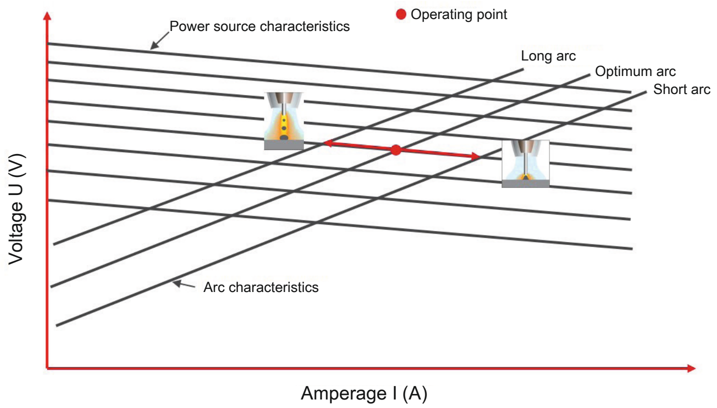


Fig. 42: Setting the operating point.

If the wire speed is increased, the arc shortens and the reduced resistance of the arc column causes the amperage to increase. The voltage barely changes since the power source has virtually constant voltage characteristics. Consequently, the operating point drifts to the right (Figure 43).

If the arc is too short, short circuits may occur and increased spatter.

A short arc can cause spatter.

Vice versa, a reduction in the wire speed results in a longer arc and reduced amperage as the resistance in the arc column increases. The operating point drifts to the left (Figure 43).

If the arc is too long, this can cause undercuts and the formation of pores.

A long arc can cause undercuts and pores.

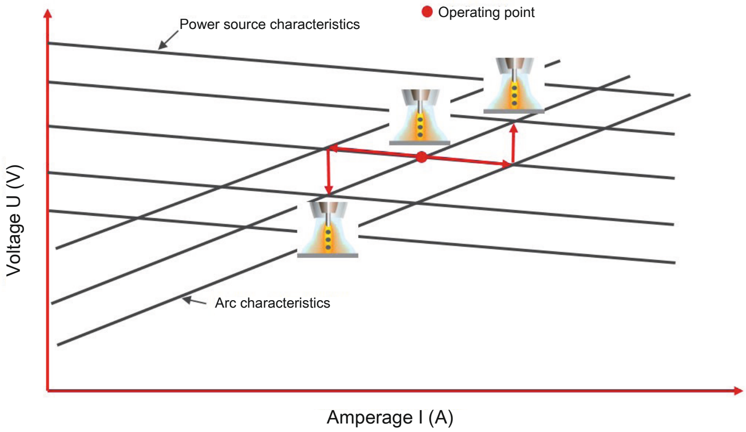


Fig. 43: Changes to the operating point.

The interplay between voltage and amperage is vital in order to create the operating point with an optimum, constant arc length.

The following points apply:

- If the amperage is increased, then the arc voltage must also be increased at the same time.
- If the amperage is reduced, then the arc voltage must also be reduced.

Both are controlled by selecting a different arc characteristic on the power source.

Voltage and amperage are related.

10.2 Inner Control

To achieve an optimum welding result, it is useful to have a constant arc length across the entire welding area. The inner control system supports a constant arc length.

For the inner control, constant-voltage characteristics or slightly drooping characteristics are used. The result is that when the welding amperage is changed, the voltage barely changes or does not change at all.

For the inner control, the voltage remains virtually unchanged.

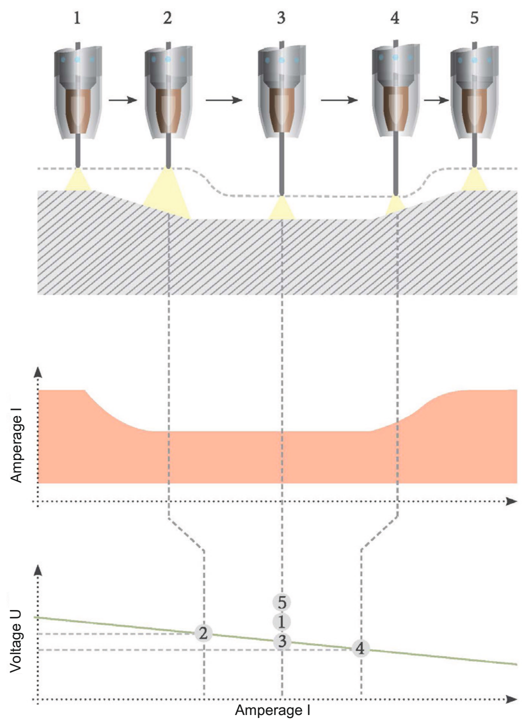


Fig. 44: Presentation of the inner control system.

Functionality of the inner control system

Functionality of the inner control system: A selected operating point and corresponding voltage and wire speed is preselected and remains constant during the welding process (Figure 44, welding torch no. 3). Changing the distance between the welding torch and the workpiece during welding will change the resistance in the arc (welding torches 2 and 4). The inner control system now balances out the arc length via the amperage.

10.3 Contact Tip to Workpiece Distance (Stick Out)

The contact tip to workpiece distance, also called "stick out", influences the process sequence tremendously (Figure 45).

The contact tip to workpiece distance affects the following elements of the welding process:

- Amperage
- Voltage drop
- Penetration
- Spatter
- Heating of contact tip

Impacts of the contact tip to workpiece distance

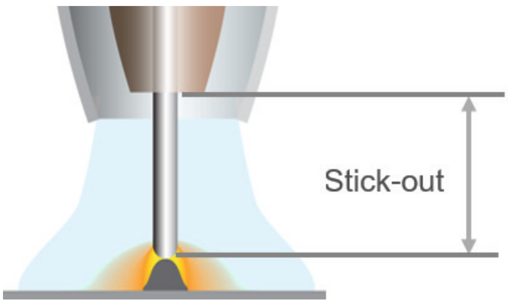


Fig. 45: Stick out.

Contact tip to workpiece distance

If the contact tip to workpiece distance increases, this has the following effects (Figure 46):

- The amperage becomes weaker.
- The voltage drop increases.
- The penetration is less.
- More spatter.
- Reduced heating of the contact tip.

Impacts when contact tip to workpiece distance increases

If the contact tip to workpiece distance decreases, this has the following effects (Figure 46):

- The amperage increases.
- The voltage drop decreases.
- The penetration is greater.
- Less spatter.
- Increased heating of the contact tip.

Impacts when contact tip to workpiece distance decreases

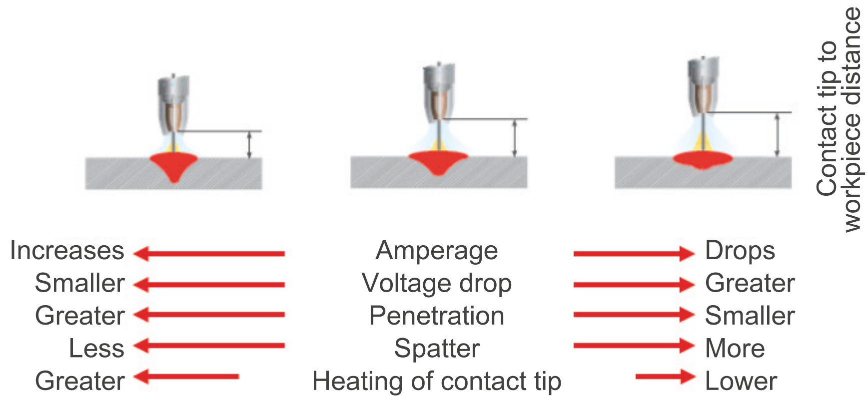


Fig. 46: Effects of a changed contact tip to workpiece distance.

In practice, the contact tip to workpiece distances are set in the lower current range at approx. 10–15 mm and in the upper current range at approx. 15–20 mm.

A longer distance relieves the thermal stress from the contact tip and gas nozzle in order to prevent overheating. The contact tip to workpiece distance also affects the welding amperage and penetration depth.

10.4 Synergic Welding

Expert knowledge and experience is needed to configure an operating point. Besides the two variables of "voltage" and “wire speed", there are also other parameters that influence the quality of the arc and therefore also the welding result.

Single-button operation

Synergic operation is the single-button operation of the power source. The function helps the user to achieve optimum welding results. This is realized with preprogrammed parameters for any wire-gas combination.

With single-button operation, the original equipment manufacturer (OEM) undertakes the task to first define specific parameters for a variety of base metal, filler metal, and shielding gas combinations. These knowledge-based results are electrically stored in the form of a database. Special welding programs can be directly transferred to the power source using electronic data transfer.

For synergic welding, the parameters are preprogrammed.

With synergic welding, the user simply selects the filler metal on the power source. An indication of the sheet thickness helps the user find the appropriate welding parameters. The microprocessor integrated in the device then guarantees a continuous welding performance selection that extends from the minimum to maximum range.

10.5 Inductor Effect

An inductor smooths current peaks in the welding circuit through additional inductance. The correct setting of the inductor is dependent on the following factors:

- Type of shielding gas
- Welding data
- Welding task

Inductor and inductor effect

> The size of an inductor is dependent on the physical value of the inductance. The larger the inductor, the more it damps the increase or reduction of the current flow. Damping is symmetrical, i.e. the additional input energy is fully delivered again later on.

Big inductor – big effect

With a dip transfer arc, droplet transfers occur through short circuits. During the short circuit, amperage peaks occur that are limited by the inductor (Figure 47).

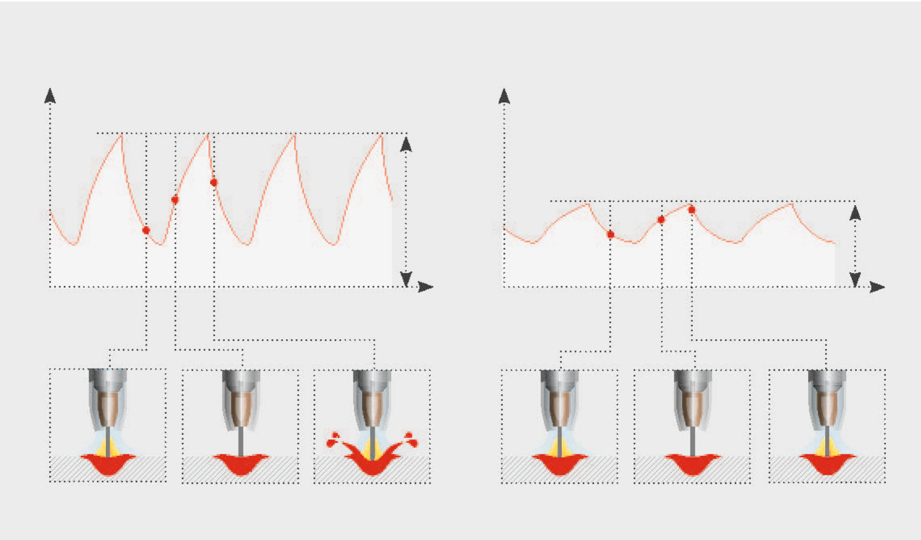


Fig. 47: Functionality of the inductor effect.

If the amperage increases sharply, this creates a hard, stable arc. A slight increase in the amperage creates a soft, unstable arc.

Important: When igniting the arc, it is advantageous if the amperage increases quickly and the inductor effect is low.

Low inductor effect when igniting the arc

Impact of a slight inductor effect:

Impact of a slight inductor effect

- Increased spattering
- Coarsely rippled weld surface
- Stable, immediate arc ignition
- Many short circuits

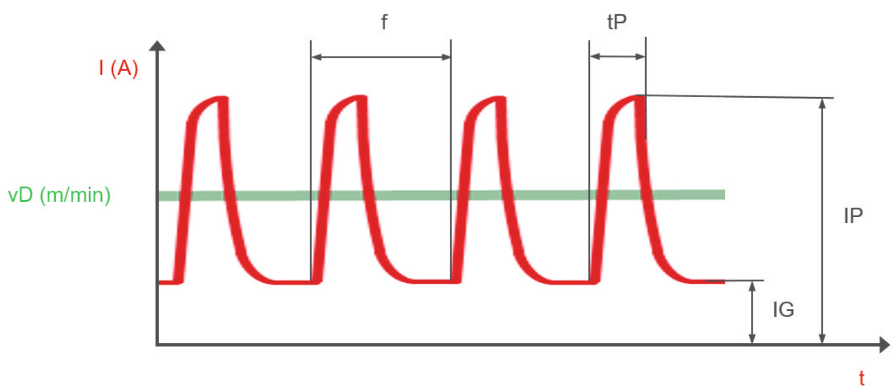
Impact of a significant inductor effect:

Impact of a significant inductor effect

- Minimal spattering
- Finely rippled weld appearance
- Delayed arc ignition, irregular droplet transfer
- Few short circuits

10.6 Pulsed Arc Welding

As the name "pulsed arc welding" already suggests, the current is increased to high values through pulses during this welding process (Figure 48).



tP: Pulse duration
f: Pulse frequency
IG: Base current
IP: Pulse current
vD: Wire speed

Fig. 48: The current flow during pulsed welding.

The filler metal is transported into the weld pool by these current pulses.

In practice, there are many additional parameters that influence the stability and dynamics of the pulsed welding process. These parameters are:

- Pulse duration
- Pulse frequency

/ Base current

/ Pulse current

/ Wire speed

Schematic sequence of pulsed-arc welding (Figure 49):

1. The arc burns at a low base amperage.
2. The pulse causes the amperage to increase. This in turn melts the wire end slowly.
3. The current has reached the pulse current value. The wire end is melted intensely and a droplet forms. It is constricted by the pinch effect.
4. The current is reduced to a lower value. The droplet continues to be pinched and accelerated towards the weld pool.
5. The droplet has detached from the wire end
6. The current is reduced again to the base current

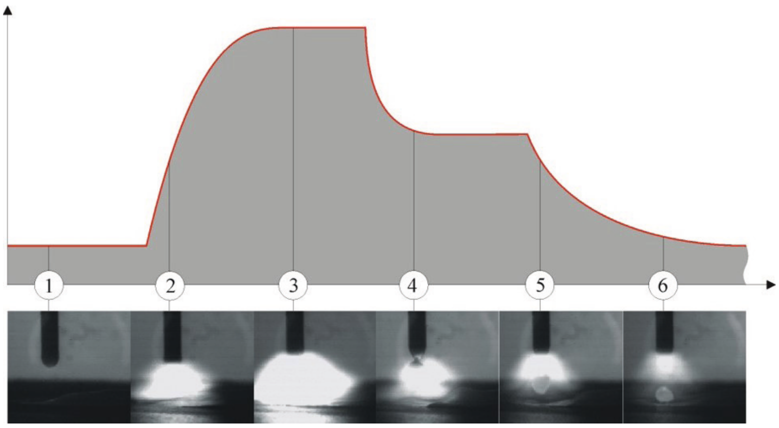


Fig. 49: Periods during pulsed-arc welding.

10.7 Review Questions

/ What is meant by adjusting an operating point?

/ What regulates the inner control system during MIG/MAG welding?

/ What impact does a significant inductor effect have?

---

11. PROCESS VARIATIONS DURING MIG/MAG WELDING

11.1 CMT Welding

CMT is the abbreviation of "Cold Metal Transfer" and describes a welding process with a low heat input.

Cold Metal Transfer: low heat input

The CMT process combines a new type of droplet detachment with a reversing wire electrode movement (Figure 50).

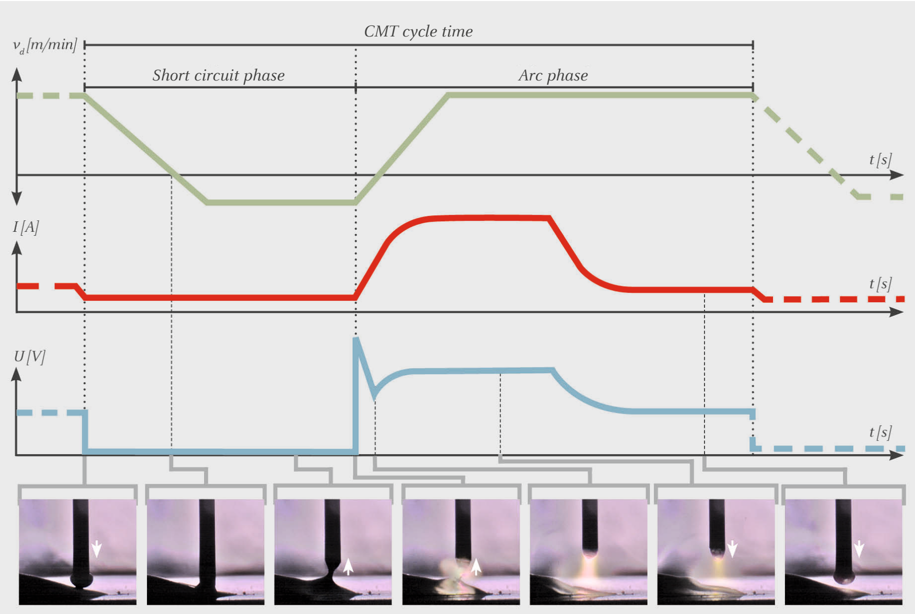


Fig. 50: The principle of CMT welding.

With the conventional dip transfer arc process, the wire is continuously fed to the workpiece. If a short circuit occurs, the current is increased to break up the short circuit and to ignite the arc again.

With the CMT process, the droplet detachment and reignition is controlled by a backward movement of the wire electrode: The wire is fed to the workpiece until a short circuit occurs and the arc goes out. The direction of the wire movement is then reversed, i.e. the wire is pulled back from the workpiece. This causes the short circuit to break and the arc is reignited. Subsequently, the wire movement is reversed again and the process described here starts from the beginning again.

Sequence of the CMT process

Depending on the characteristic for the filler metal, shielding gas, and electrode diameter, this reversing movement takes place within a frequency range of 50 to 160 Hz.

11.2 Tandem Welding

With tandem welding, two completely isolated power sources are always used along with a welding torch with an isolated power feed (Figure 51).

Tandem welding

With tandem welding, all common arc variants (dip transfer, spray, pulsed arc) are combined in one system. With tandem welding, the respective arc voltage can also be measured separately and as used as a controlled variable.

Fig. 51: Tandem welding system connected to a robot.

"TimeTwin" welding process

With the advanced tandem welding process "TimeTwin", both arcs are synchronized to each other during pulsed welding with a phase shift of 180° in order to achieve the best possible stability. Spreading the travel speed is essentially possible, but with very strict limits. Due to the phase shift, the weld pool remains quieter with the TimeTwin process; however, this process variant is only possible as a fully mechanized variant.

Difference between tandem welding and double-wire welding

Tandem welding is different to double-wire welding in that each wire electrode has a separate power source and a separate process control (Figure 52). The deposition rate of tandem welding is therefore greater than for double-wire welding.

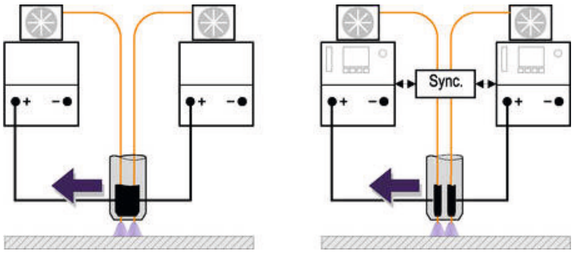


Fig. 52: Schematic presentation of double-wire welding (left) and tandem welding (right).

11.3 LaserHybrid Welding

LaserHybrid welding combines a laser welding process with MIG/MAG welding (Figure 53). This ensures that the advantages of both processes are optimally used and synergies are created.

LaserHybrid welding combines laser welding and MIG/MAG welding.

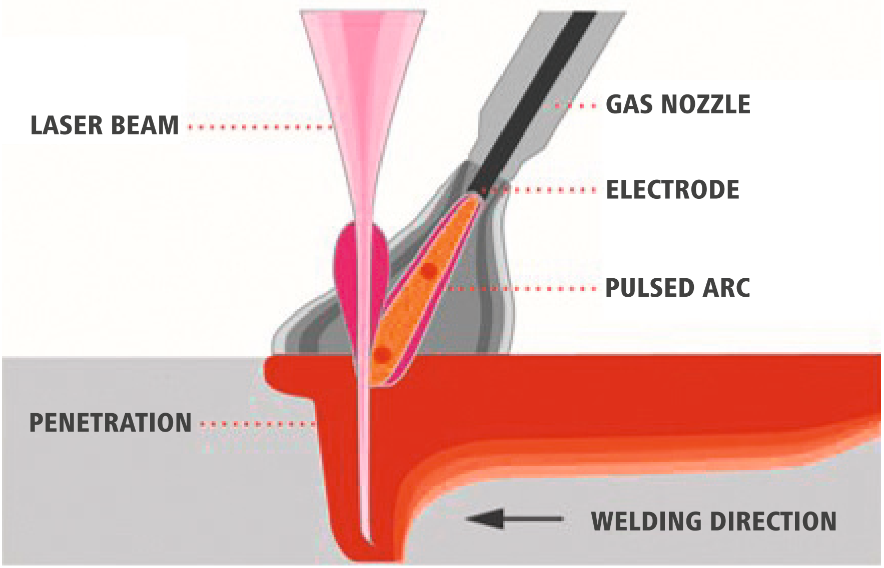


Fig. 53: The principle of LaserHybrid welding.

Features of LaserHybrid welding

Elements of MIG/MAG welding in LaserHybrid welding:

- Excellent gap-bridging ability
- Simple edge preparation

Elements of laser welding in LaserHybrid welding:

- High welding speed
- Low heat input
- Deep penetration

The high welding speed and concentrated energy of the laser in conjunction with the MIG/MAG arc can be used in two ways with LaserHybrid welding:
1. High welding speed when joining thin metal sheets
2. Maximum welding depth for thicker materials

Applications of LaserHybrid welding

In addition to this, LaserHybrid welding facilitates the automated joining of different aluminum and steel parts at a speed of up to 8 m/min and to high-end quality. LaserHybrid welding is however only used as part of a mechanized system (Figure 54).

Fig. 54: The system setup during LaserHybrid welding.

11.4 GMAW Brazing

During gas metal arc brazing (GMAW brazing), the base material is not fully melted, but is only slightly melted, similiar to a conventional brazing process.

Differences between GMAW brazing and GMAW welding

GMAW brazing is different to GMAW welding in that copper-based wires with a low melting temperature of 910–1040 °C are used as the filler metal. The low heat input reduces the amount of distortion and zinc burn-off. Copper-based wires also have the advantage of corrosion resistance.

With GMAW brazing, gases from the main group I or M are used as shielding gases. This process variant can be used in all welding positions, whether manually or mechanized.

Applications of GMAW brazing

GMAW brazing is usually performed with a dip transfer or pulsed arc. GMAW brazing is used for galvanized thin and very thin metal sheets, as is predominantly found in the automobile industry (Figure 55).

Fig. 55: GMAW brazing in the automobile sector.

11.5 Review Questions

/ What does the abbreviation "CMT" stand for?

/ What is the difference between tandem welding and double-wire welding?

/ What are the advantages of the LaserHybrid process?

---

12. WELD SEAM TYPES AND THEIR PREPARATION

There are different types of weld seams (Figure 56).

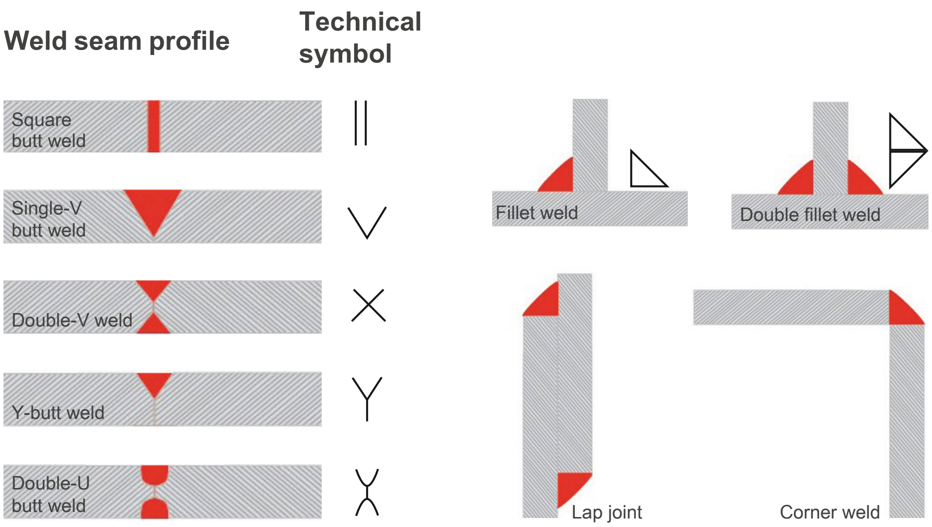


Fig. 56: Weld seam profiles and their technical depiction.

> The weld seam profile determines two key aspects of the welding process:
> 1. The preparation of the join.
> 2. The profile of the weld seam.

The weld seam profile influences the welding process.

The weld seam profile to be considered for the relevant task depends on various factors:

- Material type
- Material thickness
- Welding process

12.1 Joint Preparation

The selection of join profile is dependent on:

- Welding position
- Accessibility
- Susceptibility to weld seam faults

The most common weld seam profile is the fillet weld. When, in the case of a butt weld, a complete, single-sided full penetration weld is required, edge preparation is necessary from a wall thickness of approximately 4 mm upwards (Figure 57).

Edge preparation from a material thickness of 4 mm

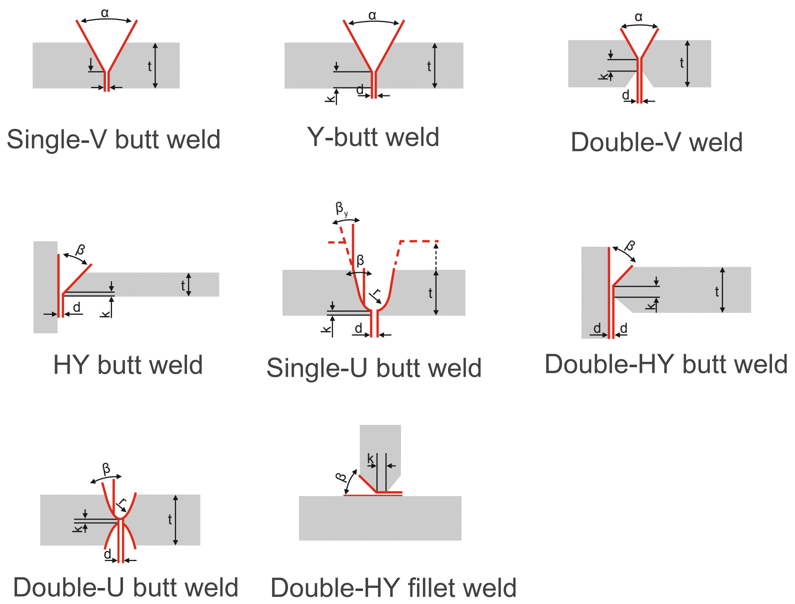


Fig. 57: Welding edge preparation.

Edges must be free from rust, cinder and other contaminations.

Edges must be clean!

To ensure there is no angular shrinkage, it is helpful to pretension the components. For thicker workpieces, it is advisable to use run-in and run-off plates.

12.2 Weld Seam Thickness

The thickness of weld seams is indicated by "a" (Figure 58).

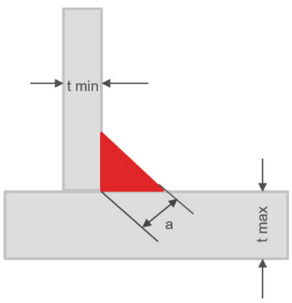


Fig. 58: Weld seam thickness "a".

With butt welds, the calculated weld seam thickness "a" is usually set the same as the component thickness "t". The weld reinforcement that usually exists is not taken into account here.

Where different sheet metal thicknesses are being used, the smaller size is determinative.

The smaller sheet thickness is determinative.

With fillet welds, weld thickness "a" is the same as the height of the isosceles triangle measured up to the theoretical root point.

Important: If a weld seam is not fully penetrated, then only the throat thickness actually obtained may be included in the calculation!

Only the actual throat thickness counts.

The throat thickness is dependent on the sheet thickness. To avoid any disparity between the seam cross-section and the connected components, for component thicknesses of t ≥ 3 mm the following limit values for fillet welds must be observed:

- "a min" ≥ 2 mm
- "a min" $\geq \sqrt{t\ max} - 0.5$
- "a max" ≤ 0.7x t min

Limit values of fillet welds

12.3 Review Questions

- What factors influence the weld seam profile?

- From what wall thickness is weld edge preparation required for a single-sided full penetration weld?

- What is the most commonly used weld seam profile?

---

13. WELD SEAM FAULTS

13.1 Overview of Weld Seam Faults

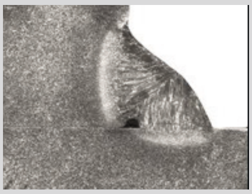
There are many types of weld seam faults. They are classified and the permissible limit values are specified in standards.

Weld seam faults impede the welded construction and are often categorized as:

- Inner weld seam faults (Table 10)
- Outer weld seam faults (Table 11)

Classification of weld seam faults

13.2 Inner Weld Seam Faults

Fault type	Picture	Cause(s)	Remedy
Pores		- Faulty shielding gas cover - Humidity - Contaminations - Impeding coating	- Improve shielding gas cover - Keep workpiece and filler metal dry - Clean the workpiece - Use clean filler metal - Remove coatings
Slag entrapment		- Welding power too low - Arc too long - Poor joint preparation - Forward slag during flux-cored wire welding	- Increase welding power - Shorten arc - Clean joint preparation - Correct welding torch position
Faulty penetration		- Unsuitable joint preparation - Welding power too low - Arc too long - Welding speed too high	- Enlarge root opening - Increase power - Shorten arc - Reduce welding speed
Cracks/heat cracks		- Unfavorable ratio between weld seam width and weld seam depth - High internal stresses in the component - Incorrect filler metal - Coolant escape	- Observe normal ratio between weld width and weld depth 1:1 (unalloyed steels) - Tack component without tension - Select suitable filler metal - Check welding torch

Tab. 10: Inner weld seam faults – causes and remedies.

13.3 Outer Weld Seam Faults

Fault type	Picture	Cause(s)	Remedy
Unsymmetrical weld		- Incorrect work angle of the welding torch - Weld pool too large - Incorrect welding parameters	- Correct welding torch position - Reduce welding power - Shorten arc length - Correct parameter selection
Weld rein-forcement		- Too much filler metal in relation to the welding speed - Wire diameter too large - Incorrect welding torch position	- Increase welding speed - Use less filler metal - Select suitable wire diameter - Correct welding torch position
Undercuts		- Arc too long/voltage too high - Welding power too high - Excessive weaving - Incorrect welding torch position	- Reduce arc length/ voltage - Reduce welding power - Correct welding torch position
Crater cracks		- Severe shrinking when the weld pool freezes - Welding power reduced too quickly	- Lower the welding power before the end of welding - Leave welding torch for gas post-flow at the end of welding
Welding spatter		- Incorrectly set welding parameters - Incorrect polarity - Poor quality filler metal - Inferior shielding gas	- Set the correct welding parameters - Select the correct polarity - Test the filler metal - Check the shielding gas supply
Edge misalignment		- Poor fixing or tacking of workpieces - Distortion during tacking - Breaking of tack welds before welding over	- Fix workpieces securely - Use correct weld sequence - Dimension stitch welds adequately
Cracks/heat cracks		- Unfavorable ratio be-tween weld seam width and weld seam depth - High internal stresses in the component - Incorrect filler metal - Coolant escape	- Observe normal ratio between weld width and weld depth 1:1 (unalloyed steels) - Tack component with-out tension - Select suitable filler metal - Check welding torch
Excessive penetration		- Heat input too high - Air gap too large - Root pass too thin	- Reduce welding power - Reduce air gap

Tab. 11: Outer weld seam faults – causes and remedies.

13.4 Review Questions

- What are the possible causes of welding spatter?

- How are undercuts created?

- What can cause crater cracks?

---

14. WORK TECHNIQUES

MIG/MAG welding offers many possibilities to influence the seam geometry. Besides adjustment options on the power source, how the welding torch itself is handled and guided also has a significant influence on the seam geometry.

Work techniques

When guiding the welding torch, a distinction is made between the following work techniques:

- Neutral guidance of welding torch
- Pull technique
- Push technique

14.1 Pull Technique

Pull technique

With the **pull technique**, the welding torch is angled in such a way that the arc pressure forces back the liquid weld pool (Figure 60).

Fig. 59: Neutral guidance of welding torch.

Fig. 60: Pull technique.

Impact of the pull technique

The pull technique allows the arc to fuse the base material more deeply. As a result, the penetration is greater, and a higher and narrower weld seam is created.

Applications of the pull technique

A backhand technique should be applied up to a sheet metal thickness of approx. 3 mm and in the dip transfer arc. Flux core wires with slag are also processed with a slightly backhand technique. This assures better weld pool control and sufficient penetration.

Vertical down welding

Slightly backhand to neutral is also the welding torch position for vertical down welding (PG). Vertical down welding is only used for thin sheets, since thicker sheets present the risk of fusion faults due to the advancing weld pool.

14.2 Push Technique

Push technique

With the **push technique**, the welding torch is angled in the opposite direction to the welding direction. The arc pressure then pushes a pad of liquid weld metal in front of it (Figure 61).

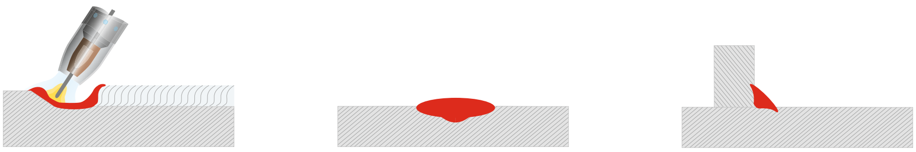


Fig. 61: Push technique.

The push technique is the preferred technique for root passes.

Applications of the push technique

For a material thickness exceeding 5 mm, welding should be carried out with a slight forehand to neutral technique, as this makes the weld seams of fillet welds flatter. To improve the penetration and wetting of the weld edges, the wire end used for welding should be as short and free as possible.

When welding in a vertical up position (PF), overhead (PD), and horizontal position (PC), the welding torch position is still slightly forehand.

14.3 Spot and Interval Welding

Spot welding

A special gas nozzle is used for **spot welding**. Pressure is applied to the component so that the shielding gas can still escape to the side. The arc is ignited on the metal sheets lying one above the other and welding is carried out for a preset time (up to 2 sec).

To ensure there is full penetration with spot welding, the top sheet must not be thicker than 4 mm. The air gap must also be smaller than 1 mm.

With **interval welding**, a welding program of recurrent intervals is run, where the welding and pause phases alternate.

Molten mass is created during the welding phase and no arc burns during the pause phase. This alternation allows the resulting molten mass to cool down and freeze in a controlled manner during the pause phases.

Interval welding

14.4 Review Questions

/ What is the preferred welding torch position for thin sheet metal up to 3 mm during the horizontal welding of fillet welds (position PB)?

/ How does a shorter free wire end influence the penetration behavior?

---

15. WELDING MATERIALS

15.1 Unalloyed and Low-Alloy Materials

When welding **unalloyed** and **low-alloy materials**, mixed gases from group **M 21** or **M 22** are primarily used. In individual cases, pure carbon dioxide (CO_2) is also used for cost reasons, as it has very good properties in terms of porosity.

Gases of group M21 and M22

Pure CO_2 must not be used if unalloyed or low-alloy steel is to be welded with a pulsed arc. The reason for this is that the arc formation under the droplet prevents the reliable droplet detachment with pure CO_2.

15.2 Austenitic Materials

Austenitic steels are the largest group within stainless steels. Their main alloy components are chrome and nickel. Austenitic steels are distinguished by high corrosion resistance that can be further increased with molybdenum.

Main alloy components of the austenitic steels

When welding **austenitic steels**, it is essential to remember that these materials have a higher thermal expansion. The workpieces should therefore be tacked more often and welded with as little energy input per weld as possible.

Frequent tacking and low energy input per weld

Fully austenitic materials are susceptible to heat cracks, which is why it is essential to select the correct filler metal.

Gases of group M12 and M13

For **austenitic steels**, mixed gases of the group **M 12** or **M 13** are used as shielding gases. CO_2 or oxygen percentages of 1-3% are standard.

Mixed gases with higher percentages of oxygen or carbon dioxide are not recommended as this can lead to the burn-off of alloy elements and excessive oxidation.

15.3 Aluminum Alloys

Inert gases

When welding aluminum alloys, selecting the correct shielding gas is vital. **Only inert gases** should be used.

Avoid humidity

Aluminum can release large quantities of hydrogen when in a liquid state, but not when in a solid state. During freezing, this previously released hydrogen wants to escape from the molten mass and therefore forms pores. Humidity should therefore be avoided where possible when welding aluminum. It is also important that the filler metal is stored correctly and in a dry place.

Thermal expansion is twice as high for aluminum materials than for steels. This also makes the expansion and shrinkage stresses for aluminum much more pronounced. To avoid heat cracks, it is therefore important to already have a suitable construction. Welding torch guidance for fillet welds should always follow the forehand technique.

15.4 Review Questions

/ What gases should be used for MIG aluminum welding?

/ What gases are used for unalloyed and low-alloy materials?

/ What form should the welding torch guidance take for fillet welds on aluminum materials?

---

16. OCCUPATIONAL HEALTH AND SAFETY

When welding, a few essential hazards must be taken into consideration:

Hazards when welding

- Optical radiation
- Electrical hazard
- Handling errors
- Fire caused by flying sparks
- Pollutants

Important safety instructions!

Important: Clothing that covers the body adequately must be worn for welding work!

If there is the risk of injury from sparks, metal spatter, or darting flames, protective welding clothing must be worn that meets the specification requirements of European Standard DIN EN 470 (Figure 62). This must be evident from both the wash care label and Operating Instructions.

Fig. 62: Protective welding clothing: jacket and gloves.

16.1 Hazards Posed by Arc Radiation

Visible and non-visible radiation is emitted by the arc and weld pool.

The intensity of this radiation is dependent on:

- Input energy or amperage
- Arc size
- Arc temperature
- Arc type
- Temperature distribution

The following types of rays are emitted by the electrical arc: **Visible radiation, invisible infrared radiation,** or **heat radiation**, and also **invisible ultraviolet radiation**. However, the electric arc does not emit any radiation similar to X-rays during MIG/MAG welding.

Types of rays in the arc

/ Visible light rays

Visible light rays

Potential risk:
If there is no protection, or insufficient protection, visible light rays cause glare that is unpleasant for the eyes. If a person's eyes are exposed to visible rays of light repeatedly, frequently and over a long period of time, this may impair their vision in the long term – particularly at twilight.

Protective measures:
In order to provide protection from visible rays, welders use visors or helmets with standardized and suitably dark-tinted protective glass (welding filters).

/ Infrared radiation or heat radiation

Infrared radiation and heat radiation

Potential risk:
Infrared radiation can result in burns. Above all, the invisible infrared or heat rays heat up the parts of the body that are directly adjacent to the point to be welded, i.e. particularly the hands and the upper body. There is also a risk of injury to the eyes. If unprotected eyes or eyes without sufficient protection are exposed to this invisible radiation over a long period of time, this could result in clouding of the lens (heat cataract).

Protective measures:
In order to protect against the heating effect of radiation, the welder wears heat-resistant protective clothing (Figure 63) and special welding gloves. The eyes are protected against infrared radiation or heat radiation with standardized protective glasses. (Figure 80).

/ Ultraviolet radiation

Potential risk:
Ultraviolet radiation poses the most danger to eyes. "Flash burns" cause sore eyes, tears, painful sensitivity to light, and swollen eyelids. Most affected are usually the conjunctiva, in severe cases also the cornea. Ultraviolet radiation can also burn the skin (sunburn effect).

Protective measures:
Heat-resistant protective clothing, consisting of protective overalls and gloves,

prevents burns. Standardized protective glasses protect the eyes against possible flash burn. The eyes are protected by protective helmets with protective glass that darkens automatically in accordance with DIN 4647 (Figure 63). Welding filters are optical screens that filter the rays that occur. Protective filters are divided into different levels of protection, to which specific radiation transparencies (shading) are assigned.

Fig. 63: Visor with integrated forced ventilation.

If flash burn of the eyes has occurred during welding due to a lack of protective measures, it helps to place cold compresses on the eyes and, after consulting a doctor, to use eye drops.

16.2 Hazards in Connection with Electrical Current

Possible sources of danger:

- Defective grid connection (e.g. socket pulled out)
- Defective power source (missing switches or cover)
- Defective welding current lead or hosepack
- Faulty workpiece clamp
- Defective welding current return lead

Important: All maintenance work must be carried out by specially trained personnel and only when the power source is switched off and in an electrically isolated state.

Important safety instruction!

16.2.1 Open Circuit Voltage

Dangers from open circuit voltage

The greatest electrical risk is posed by the open circuit voltage UL. When no arc is ignited, this is the highest voltage that is applied to the power source at the connector. The open circuit voltage can be life-threatening if the welder touches the connector with bare hands. The open circuit voltage becomes even more hazardous if the welder's skin is damp, as moisture conducts electricity. Effective protection against the existing open circuit voltage consists of insulation by means of shoes, work clothing and leather gloves.

After igniting the arc, the voltage is lower and generates a welding voltage of approximately 10-20 V. In accordance with standard UVV VBG 15, power sources for direct current may have an open circuit voltage peak value of max. 113 V in normal operation. In the case of alternating current systems, the peak value is also 113 V, but the maximum effective value is 80 V.

OPERATING CONDITIONS	RATED VALUE OF OPEN CIRCUIT VOLTAGE
Increased electrical risk	Direct current 113 Volt peak value Alternating current 68 Volt peak value and 48 Volt effective value
No increased electrical risk	Direct current 113 Volt peak value Alternating current 113 Volt peak value and 80 Volt effective value
Mechanically-guided arc welding torch with increased protection for the welder	Direct current 141 Volt peak value Alternating current 141 Volt peak value and 100 Volt effective value

Tab. 12: Dangers from current.

There is an increased electrical risk while welding in cramped rooms. Here a peak value of 68 V and an effective value of 48 V applies for alternating current. The identifier "S" must be attached to the device:

S

This label is required to be able to use the welding system to perform welding subject where there is an increased electrical risk.

CE

The CE label indicates that this product has been tested in accordance with the technical standard.

Due to the electrical conductivity of wetness and moisture, you must **NEVER** sit or lie directly on the workpiece in work clothing that is damp, soaked with sweat or soaking wet!

Important safety instruction!

16.2.2 Protective Measures when Working with Electrical Current

In order to protect yourself from the dangers of electrical current during MIG/MAG welding, it is vital that you apply the following **safety measures**:

Safety measures with TIG welding

- Only work with leather gloves.
- Never weld with a bare upper body, even if the weather is very hot.
- Never clamp the welding torch under your armpit.
- Do not wear shoes with nailed soles.
- Never sit or lie down on metal without a base layer of wood or felt mats.
- In containers and cramped rooms, do not lean against the metal walls without an intermediate layer made of wood or felt.
- Do not use damaged cables.
- In containers, large housings, box girders, etc., never weld with the usual transformers and, in these locations, do not use any standard hand-held lamps with mains voltage, but instead only those with a maximum of 42 V.

16.3 Pollutants and Vapors

Welding fume

Welding fumes contain special toxins that can become extremely dangerous to human health. These toxins must therefore be removed from the room air using the respective filters.

Danger from ozone and argon

One gaseous harmful substance is ozone, which is formed through UV radiation during the melting of aluminum filler metals. The shielding gas argon is heavier than air and therefore displaces the atmospheric oxygen in depressions. There is a risk of suffocation for the welder!

Extraction

When welding alloyed steels with chrome and nickel and galvanized materials, pollutants that are hazardous to health are also produced. These must be vacuumed up by mobile or fixed extraction systems without exception (Figure 64).

Among other things, extraction systems protect against these dangers:

- One gaseous harmful substance found in MIG/MAG welding is ozone, which is formed through UV radiation during the melting of aluminum filler metals.
- The shielding gas argon is heavier than air. It therefore displaces the atmospheric oxygen in depressions, meaning that there is a risk of suffocation for the welder.
- When welding alloyed steels with chrome and nickel and galvanized materials, pollutants that are hazardous to health are also produced and must be vacuumed up.

Fig. 64: A mobile extraction system.

Minor accidents cannot be ruled out even when the accident prevention regulations are observed. Everyone should therefore know the immediate measures to be taken at the site of the accident in order to provide First Aid!

16.4 Review Questions

/ What are the sources of danger during MIG/MAG welding?

____

/ Who can carry out repairs to MIG/MAG power sources?

____

/ What type of radiation causes "flash burns"?

____

17. QUALIFICATION OF WELDING PROCESSES AND PERSONNEL

17.1 WPS (Welding Procedure Specification)

Contents of the WPS

Welding following a WPS (Welding Procedure Specification) means that welding is performed in accordance with tested parameters and defined preconditions. This determines how the weld seam should be structured and what welding parameters the welder must set on the device. The WPS also provides information that is needed to prepare and rework the welded joint. Details of additives and welding position as well as weld seam sizes are also documented.

17.2 Procedure Qualification

Preliminary WPS

A preliminary welding procedure specification (pWPS) is needed first for the procedure qualification. This welding procedure specification describes the most important welding parameters and the preconditions for a successful weld. The test pieces are then welded and undergo destructive testing.

If the test results meet the requirements, a report showing approval of the welding process (WPQR) can be created. Following this, the pWPS can then be renamed as a WPS. Approval and qualification of the welding processes is vital and should therefore be treated with great care.

It is the responsibility of the manufacturer of welded components to prove that the selected welding parameters meet the standard.

17.3 Welder Certification in Accordance with DIN EN ISO 9606

Welder tests prove know-how and manual skills.

International Standard DIN EN ISO 9606 "Qualification testing of welders" defines rules for the testing and qualification of manual welders. One successfully completed test in accordance with this standard proves the manual skill of the internationally recognized welder.

The qualification of the welder is based on the ability to master essential welding variables such as:

- Welding process
- Product form (sheet; tube)
- Weld seam profile (butt or fillet weld)
- Material group of the filler material
- Dimensions of sheet and tube
- Welding position
- Detail (pool backing, gas backing)

In areas regulated by law (e.g. pressure tank, boiler, or rolling stock construction), the use of successfully tested and qualified welders is preconditioned on the basis of the respective product and application standard and other rules.

Continuous proof of qualification

The qualification of the welder for a welding process must be confirmed every six months, either by a company's welding co-ordination personnel or by the examiner or examining body. An extension is granted following a welding process defined in the standard. The test must be repeated at the latest after three years.

17.4 Review Questions

- What does the abbreviation WPS stand for?

- The qualification of the welder in accordance with DIN EN ISO 9606 is based on what welding variables?

- After how many years does a welder qualification in accordance with DIN EN ISO 9606 have to be repeated?

GLOSSARY

A

Arc characteristic
The arc characteristic indicates the relationship between the arc voltage and the arc current.

Arc length
The arc length is the distance between the point where the arc starts on the wire electrode until reaching the workpiece.

D

Deposition rate
The deposition rate describes the amount of filler metal that melts per time unit.

H

Heat input
The energy that is introduced into the weld area during welding.

I

IGPT transistors
IGPT transistors are a semiconductor element that is used in power electronics.

Inert gas
Inert gases are non-reactive. Inert gases are argon, helium, and mixtures of these.

J

JobMaster
The JobMaster is used to change the welding parameters on the handle of the welding torch.

O

Oxide formation
Formation of oxides on the weld seam surface through reactions in the weld pool.

Ozone
Ozone is a molecule made up of three oxygen atoms.

P

Penetration
The depth of the area in which the filler metal fuses with the parent material is referred to as penetration.

Pinch effect
In welding, the detachment of the droplet at the wire end by the effect of a constriction is called the pinch effect.

Pore formation
Pores are welding faults that are caused by contaminations or lack of gas.

Power source characteristic
The standardized value of a required voltage for a specific welding process.

GLOSSARY

R

Robot controller
The robot controller provides the necessary processing power so that the robot arms can move.

Root pass
The first bead that is introduced into the join in the case of multirun welding.

S

Synergic welding
With synergic welding, the necessary welding parameters are coordinated in synergy by the power source.

T

Tacking
The joining of the components prior to the actual welding process.

Torch to workpiece distance
The torch to workpiece distance is the distance from the gas nozzle to the workpiece.

U

Ultraviolet radiation
Ultraviolet radiation is an electromagnetic radiation with wave lengths that are shorter than visible light and that are invisible to a person.

W

Welding sequence
The sequence in which the weld seams of a construction are created.