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Adapting quality of VET offer to the need of industry – manufacturing sector

European Training Module for metal sector – machine & systems operator

Working with a welding robot

Evaluation of welding assemblies

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bsw Bildungswerk der Sächsischen Wirtschaft gGmbH

Structure of the module

1 Check-in knowledge test

2 Self-study

2.1 Welding robots

2.2 Welding basics (MAG)

2.3 Welding seam defects

3 Application / work assignment

4 Check-out knowledge test

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Learning outcomes

Welding robots are industrial robots that work **flexibly, quickly and reliably**. They are classified as **automation technology**. The task of these robots is to automatically weld products in a wide variety of production environments.

The aim of this module is to provide participants with a basic overview of **how a welding robot works**, **how it is set up and how to work safely** with it.

Furthermore, the training serves to impart **basic welding knowledge**, in particular the recognition of **external welding seam irregularities**. The use of measuring equipment and images for target/actual comparisons should make it easier to recognize and evaluate welding seam defects. The causes of welding seam defects should also be localized, forwarded to the appropriate welding supervisor and rectified.

The **reasons for weld seam defects must also be localized**, forwarded to the relevant welding supervisor and rectified.

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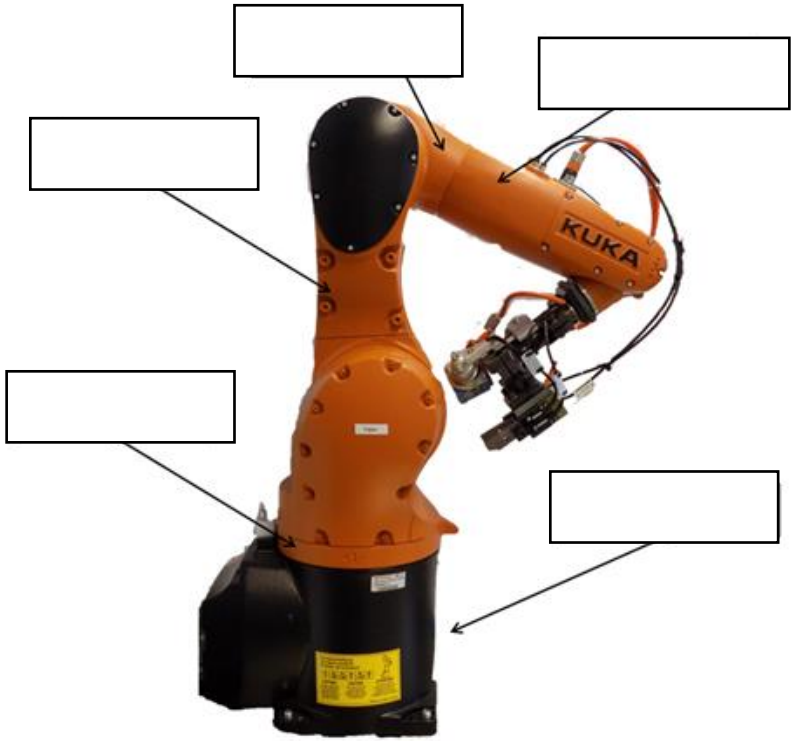
Check-in knowledge test

Assign the following components to the robot shown:

carousel, swing arm, base frame, arm, central hand



Let‘s see what you‘ve got! You get 1 point per correctly assigned component.

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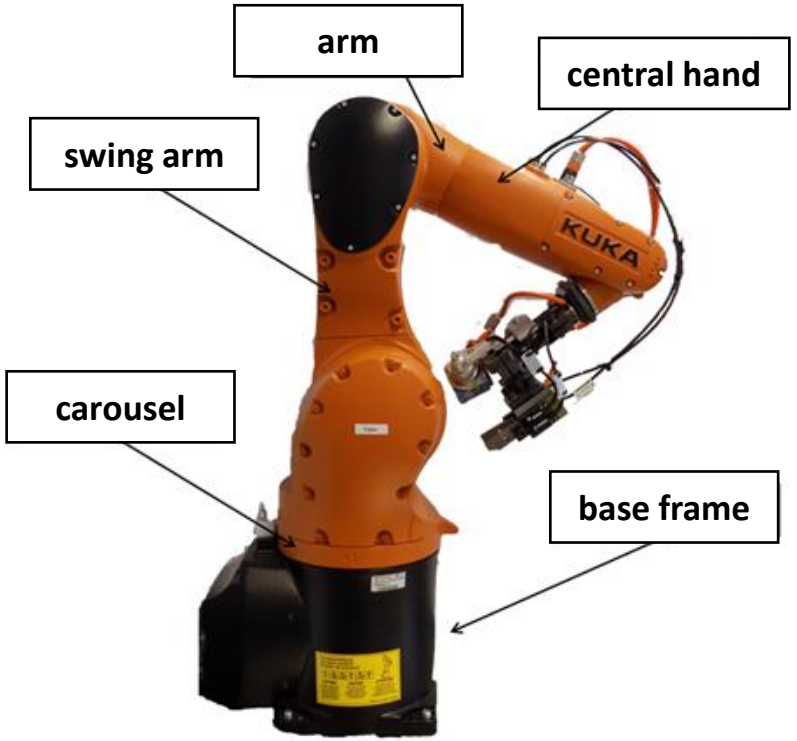
Check-in knowledge test

solution



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Check-in knowledge test

Name the main hazards when working with a robot!

- **A** explosion hazard
- **B** hazard due to electric current
- **C** risk of injury due to unpredictable and complex movements of robot

What is the role of shielding gas in welding?

- **A** protection of the weld pool against air ingress
- **B** cooling of the weld pool
- **C** shielding gas has no special function

Each correct answer is worth 1 point.

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Check-in knowledge test

Which rays can cause burns on uncovered parts of the body when welding?

- A X-rays
- B light rays
- C ultraviolet rays (UV rays)

How do pores form in a welding seam? (multiple answers possible)

- A amperage set too high
- B work piece not cleaned, dirty surface
- C incorrect amount of shielding gas

Each correct answer is worth 1 point.

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Your results

8-9 points: You already know a lot!
5-7 points: There are still some knowledge gaps!
3-4 points: OK, but it could be better.
0-2 points: Not the best results to be honest, but that‘s what our training is made for!

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Self-study automated welding (robotics)

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Composition and parts of a robotic system

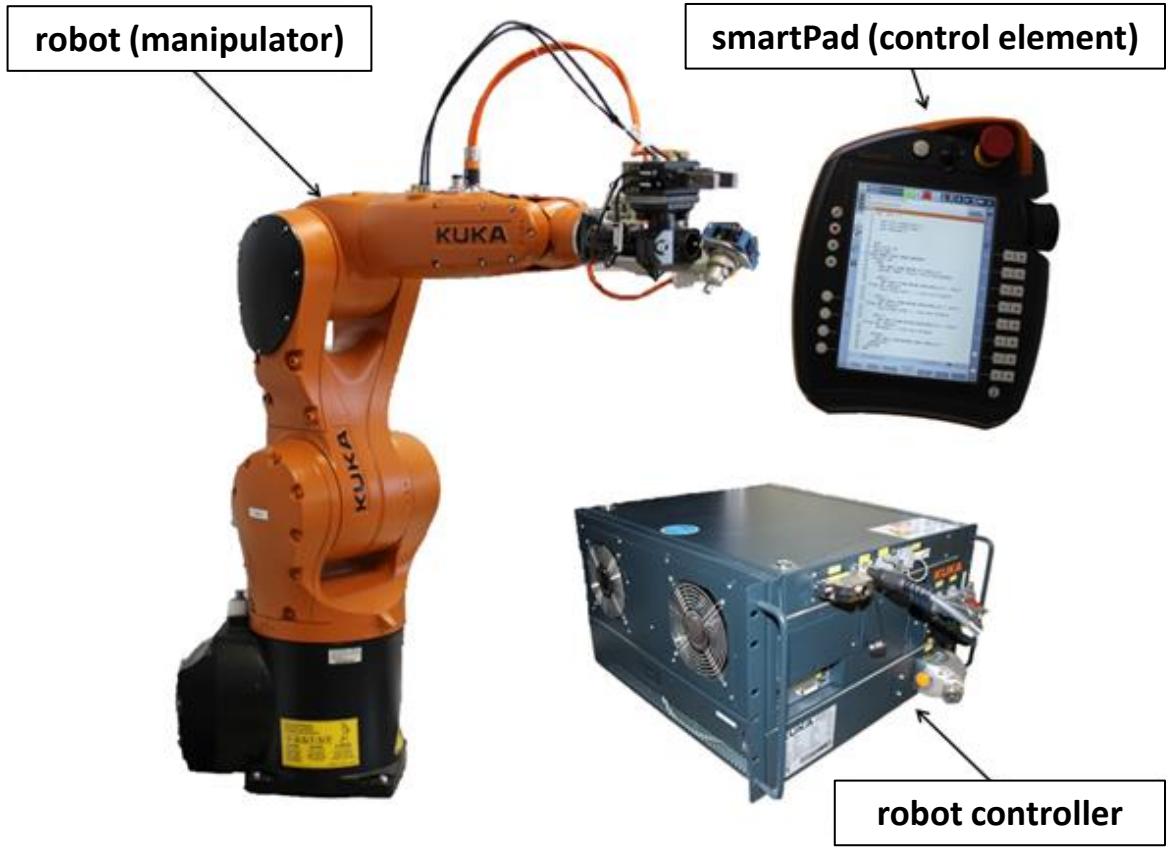
Learning objectives

- Gain an overview of how a robot works
- Correctly name the parts of a robotic system

Composition of a robotic system

First, the composition of the robotic system and the individual parts will be explained.

The robotic system consists of three main components. These are shown in the picture on the right:



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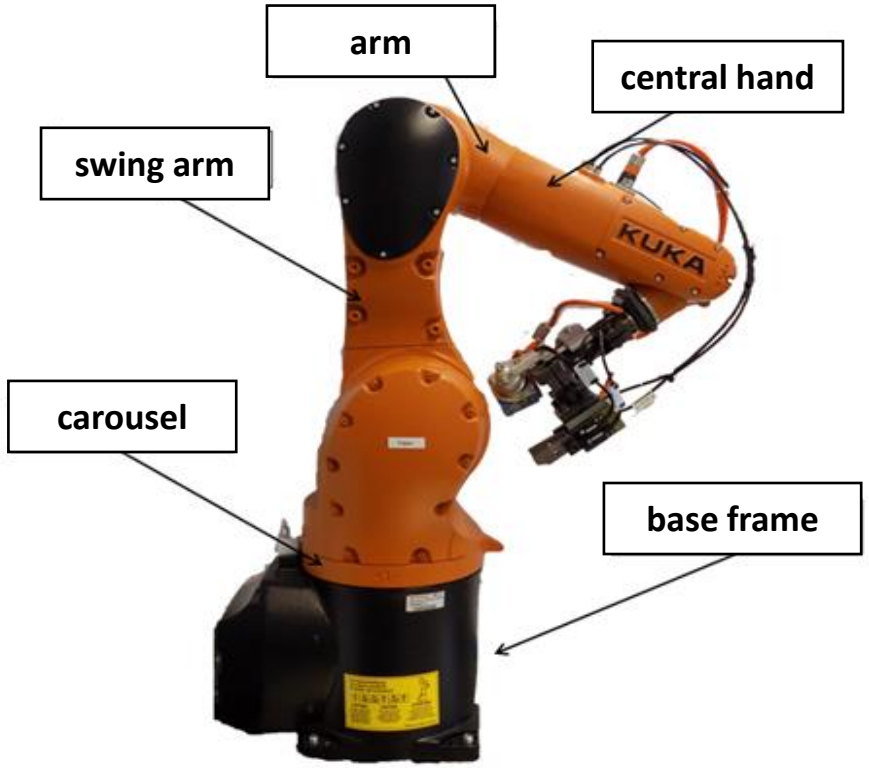
Parts of a robot

The robot itself has various **main assemblies**, which are shown in the following picture:



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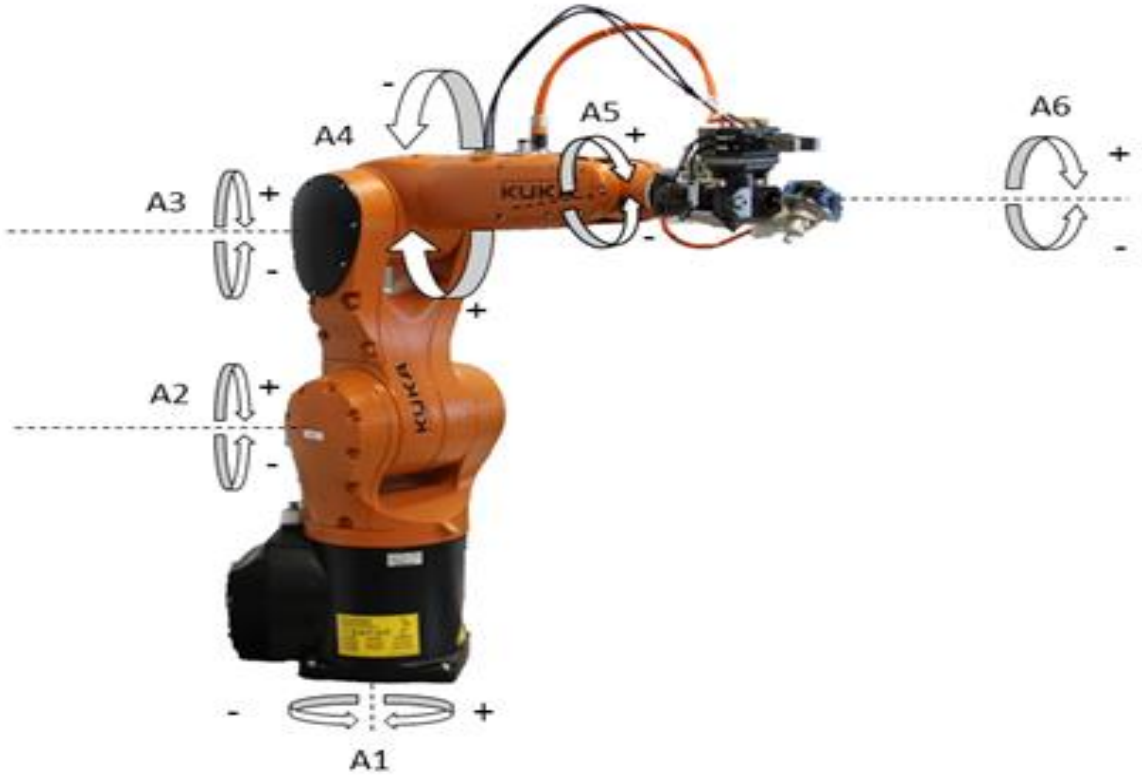
Parts of a robot

The central hand of the robot comprises **three axes** (A4, A5, A6) and forms the end of the robot arm. There are **three 5/2-way solenoid valves** and a **CAT5 data cable** on the central hand, which can be used to control tools.

In front of the mentioned parts is the arm, which is moved by axis A3. The **arm is the connection between the central hand and the swing arm** of the robot. The swing arm contains the power supply cables for axes 2 to 6. The **carousel is responsible for the rotary movement of the robot** (axis A1) and is connected to the base frame via a gearbox. The base frame forms the basis of the robot. The **interfaces between the robot mechanics and the control system are located on the base frame**.



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Parts of a robot

Each robot has both **mechanical limit stops** and **electronic limit switches (software limit switches)**. Among other things, this mechanically **prevents the robot from turning more than 190°.** The robot program can also be used to limit the range of movement. If one of these end positions is reached, a **fault (workspace error)** is reported so that no damage can occur to the robot.
The individual **axes of robots are driven by servomotors**. These are much quieter and more flexible than hydraulic motors. Furthermore, the work is more precise and well suited for **high repetition accuracy**.
There are various **options for equipping the robot's hand** (**effector**). In the case of the BBS2 robot, a pneumatic gripper is installed. This is controlled via one of the 5/2 directional control valves in the central hand.
Inductive sensors have been installed **to detect the current status of the gripper (open; closed).** Furthermore, an **optical component check** has been integrated to determine whether the robot has picked up the work piece correctly.

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Work safety (robotic systems)

Learning objectives

- Know the hazards of working with robots
- Know and apply safety measures when working with robots

General information

- The **operation of a robot without external safety measures is not permitted** and also prohibited by the manufacturer! Operating a robot without protective measures can have **fatal consequences**!
- Overconfidence or gross negligence **can injure not only the operator but also others**!
- If protective devices are bypassed or deactivated, the operator can move freely in the danger zone. In the event of ill-considered movements in manual mode or automatic start-up of the drives, **the human operator is completely at the mercy of the robot**. In most cases, there is no collision detection, so that everyone is dependent on the **additional protective devices** (safety fence, light curtain, safety door, etc.).

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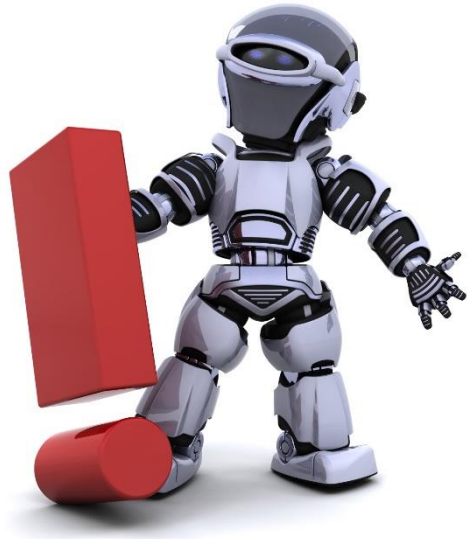
Work safety (robotic systems)

Safety measures

Special safety instructions or training courses are just as necessary as a very good understanding of the safety regulations of the respective industrial robot. An **assessment of the potential hazards** must also be carried out before starting work. The operator of the system in which the robot is installed, provides support here. Both the **duty to monitor and the duty to instruct** must be complied with. Among other things, attention must be paid to **safety-compliant integration**, in which, for example, the following points are addressed:

Provision of an operating manual for the system
Carrying out of a risk assessment
Use of the necessary safety functions and protective devices
Selection of persons who are fit and qualified for the work with the respective robot



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Self-study conventional welding

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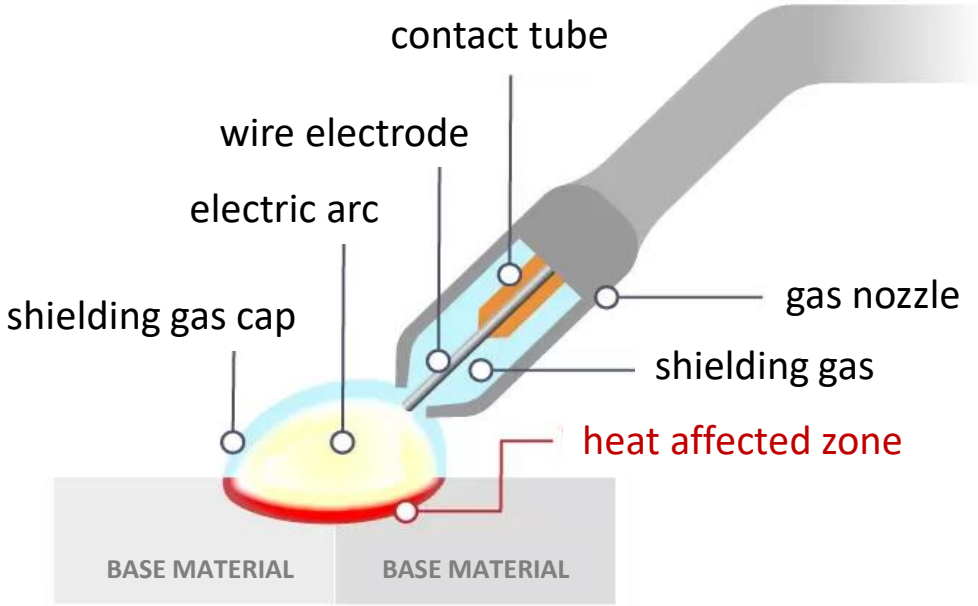
Welding and welding seam assessment (MAG)

Learning objectives

- Know the set-up and functioning of a MAG welding system
- Assessment of welding seams based on external irregularities

MAG (metal active gas) welding belongs to the group of **gas-shielded metal arc welding** processes in which **a wire electrode is melted under shielding gas**. It is particularly common in industrial production for **joining metallic materials**.

MAG welding involves the permanent joining of metals using **strong heat and welding consumables**. The **heat input** for the fusion welding process is **provided by an electric arc**. The used **wire electrode** flows together with the molten base material as **filler metal** and contributes to the **formation of the welding seam**. The process is characterized by **a high processing speed** and the **possibility of automation**. It is therefore particularly **suitable for industrial applications**.



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Work safety (welding)

Learning objectives

- Know and detect hazards of welding
- Know and apply safety measures during welding process

General information

The different welding processes are classified according to the energy source used, such as gas, electricity, laser or friction. The electrical processes are of great importance, for example metal active gas welding (MAG). If you want to implement measures to promote safe welding, it is important to bear this in mind:

Each process involves different risks, such as **optical radiation**, **electric current**, **fire and explosion** hazards, the **release of gases and fumes** that are hazardous to health or the **displacement of oxygen in the air** we breathe.

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Work safety (welding)

Electrical hazard

An electrical hazard begins when:

A **voltage higher than 25V AC** (effective value) or **60V DC** can be touched and a sufficiently **high current** could flow. Therefore, an **initial protective measure** must be implemented as basic protection (e.g. insulation).

Hazardous substances

There is a chain of physical and chemical processes behind the formation of welding fumes. The pollutants in welding fumes are also formed from very different elements during the welding process. **Welding fumes are produced when an arc or flame strikes a material at high temperatures**. This involves **physical and chemical processes** such as **vaporization, condensation, oxidation, decomposition, pyrolysis (thermal-chemical decomposition) or combustion**. Pollutants are produced, which can be formed from:

Filler materials - Base materials - Protective gases - Coatings - Contaminants - Ambient air

The **concentration** of all these hazardous substances in the air at the workplace **must be determined by measurings**. According to **occupational health and safety regulations** the employer is obliged to take the necessary measures against these hazards. Accordingly, the correct **extraction units** must be installed depending on the process, material and resulting welding fumes.

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Work safety (welding)

Optical rays (UV rays)

The human body has **no sensory organ for ultraviolet radiation**. It needs small amounts of UV radiation to produce vitamin D. However, **excessive doses are harmful** to humans.

UV radiation causes, among other things, **blinding of the eyes** by causing inflammation of the outer eye (conjunctivitis). Other effects of UV radiation are not felt until it is too late. Short-term high doses of UV radiation lead to **sunburn** like the so-called "welder's tie" (the burn of the uncovered area between the shirt and face protection). Long-term exposure to high doses can lead to **skin cancer and cataracts** (clouding of the lens of the eye).

Safety measures

To avoid skin and eye damage, **the entire body must be protected** from the effects of radiation.

Face protection is required. A **protective helmet** for welding is preferable to a protective shield so that the temples are also adequately covered. **Covers for the skull, neck and throat** should also be attached to this helmet. All areas of skin not covered by the protective clothing must be protected, e.g. if necessary by the **protective hood** and by using a **UV skin protection cream** specially made for welding. In this way, people at welding workstations are not only protected against radiation from neighboring workstations, but also against **radiation reflected from the walls or workpieces**.

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	Electrical hazard	Pollutants	Optical radiation	Fire hazard
Description	Not all energised parts of electric welding equipment are insulated. The electrical insulation at the welding point is interrupted to close the circuit for melting the metals.	Welding fumes are produced when an arc or flame strikes a material at high temperatures. The concentration of hazardous substances in the air at the workplace must be determined by measurements.	During the welding process, the arc generates ultraviolet radiation. Excessive doses are harmful to humans.	Experience has shown that welding and flame-cutting work is often the cause of fires, particularly during conversions or extensions, repair work, refurbishment work, etc., which result in extensive damage to property and sometimes even loss of life.
Consequences	The voltages present on the welding equipment can cause life-threatening or fatal injuries.	Inhaling toxic welding fumes can damage the lungs and lead to cancer	BurnsInflammation of the eyes Cataracts Skin cancer	Can cause extensive damage to property and sometimes result in loss of life.
Security measures	Insulation to the floor (mat), to the welding machine (gloves) and to the workpiece Insulate the welding torch, the cables and the person themselves with dry and clean clothing and, if necessary, additional insulating mats Ensure safe welding current return (direct connection to the welding piece or welding table and return to the welding machine)	Depending on the process, material and the resulting welding fumes, the **correct extraction units** must be installed 	Face protection (hard hat) Protective hood Special UV protection cream Welding booths 	Welding and flame-cutting work may only be carried out by reliable persons over the age of 18. Written authorisation, a so-called welding permit, is required to carry out the work.If the fire hazard cannot be completely eliminated for operational and structural reasons, welding and flame-cutting work may only be carried out with the written authorisation of the plant management or their representative and only under supervision.

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Welding seam defects

Welding seam defects in a welded joint are an expression of **low manufacturing quality**. No statements can be made about the **suitability for use of the manufactured product** if defects are detected.

Geometric irregularities in metallic welded joints are described in **DIN EN ISO 6520** Parts 1 and 2. A distinction is made between **internal and external** defects. Welding defects that are **visible or detectable** through non-destructive testing are divided into **six categories**:

Cracks | **Cavities** | **Solid inclusions** | **Shape and size defects** | **Lack of fusion and penetration**

+ Other irregularities

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Welding seam defects

Cracks are localized **separations** in the solid state of the material and **occur during cooling or later** as a **result of tension** in the welding seam or in the heat-affected zone. A distinction is made between **different types of cracks** depending on the **direction** of the crack and the **location** where the crack occurs.

Cavities can be caused by **gas inclusions**. **Spherical cavities are called pores**, which can be **evenly distributed** in the solidified weld metal or occur as **pore cells** or **pore nests**. Cavities **also occur as gas channels** parallel to the weld seam axis. If the cavity reaches the seam surface at the moment of solidification, i.e. is open to the surface, it is referred to as **surface pores**. A cavity created by material shrinkage during solidification of the weld metal is called a **blowhole**.

Solid inclusions are **foreign material deposits in the weld metal**. These can be slag, flux residues or oxides in different arrangements. These irregularities also include **inclusions of foreign metal** (e.g. tungsten in the electrode during TIG welding). **Undesirable oxide film deposits** due to inadequate protection against air ingress are also irregularities that fall into this main group.

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Welding seam defects

Lack of fusion defects occur when there is no firm bond between the weld metal and the base material or, in the case of multi-layer welding, between the individual layers. If the actual penetration is less than intended, this is referred to as **insufficient penetration** welding.

Shape and size defects include inadequate geometries of the weld seam and all forms of **penetration notches**. This also includes **excessive elevation of the seam and seam root**, a too **abrupt seam transition**, weld metal overflow on the surface or seam root and burning through the weld seam, resulting in a continuous hole. This main group also includes any type of **seam offset** as well as the **undercutting** of parts of the weld seam.

Irregularities that cannot be classified in the five main groups are referred to as **other irregularities**. These can be **ignition points** or **spatter** that occurs during welding and sticks to the welded work piece. Notches that can occur during reworking, such as grinding or chiseling notches, are such irregularities. **Discoloration** caused by tarnishing is also often undesirable, as are **flux residues**, **slag** and **scaling**.

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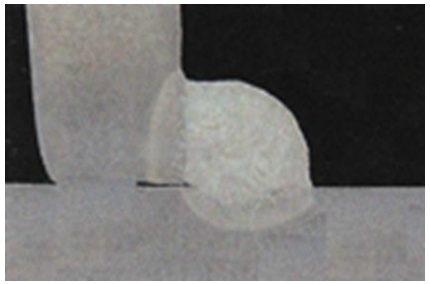
Welding seam defects - examples

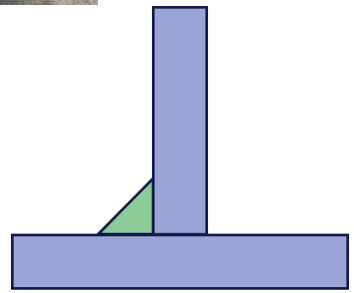
Cracks

Cracks often occur due to an **unsuitable base material** or the selection of the **wrong filler material**. **High tension** in the welded assembly can also lead to cracking. A crack in a weld seam is an **unacceptable irregularity**, as it often **results in component failure**.

Overfill / Excessive reinforcement

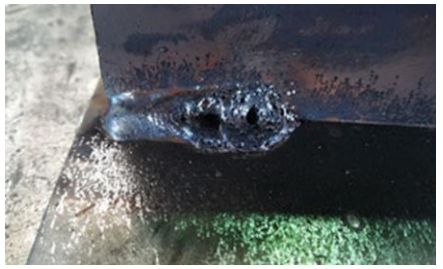
A seam overfill is a geometric irregularity and is **tolerated up to a certain deviation**. The cross-section of a fillet weld (see pic) should ideally correspond to an isosceles triangle. Excessive camber has **disadvantages in terms of strength**. The height or fillet weld dimension is calculated in advance and shown in technical documents.

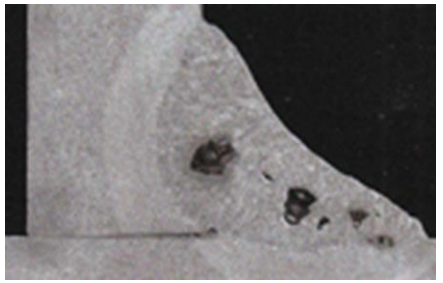




Pores

Pores are **cavities** usually located **inside the weld seam**, but can also appear **on the surface**. They are often caused by **dirty workpiece surfaces** or problems with **shielding gas coverage**. Surface pores are not permitted, while **pores inside the weld seam are tolerated depending on their size and frequency**.





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Weld seam gauges - examples

A weld seam gauge is a measuring device for quick and easy checking of the seam thickness and seam length of a completed weld seam. It can also be used to measure various weld seam irregularities and determine their admissibility in accordance with standards and regulations.

Weld seam gauge with vernier or digital display

Suitable for measuring fillet welds.
Condition: Flat or hollow design.

It is also suitable for measuring seam protrusions on butt welds.

The legs of the gauge are designed so that opening angles on V-seams can also be checked.

Weld seam gauge with three or four scales

Universally suitable and easy to use for measuring the edge offset, the fillet thickness of an unequal fillet weld, the seam camber and the fillet weld thickness with cover layer camber.

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Application example

Situation

You have inserted a welding assembly into the robot system, fixed it with the clamping device provided and closed the safety doors. After the automatic production process, you open the safety door and remove the assembly.
Carry out a routine visual inspection of all existing welding seams!

Which irregularity do you recognize?

A Pore

B undercut

C Overfill / Excessive reinforcement

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Application example

Situation

You have inserted a welding assembly into the robot system, fixed it with the clamping device provided and closed the safety doors. After the automatic production process, you open the safety door and remove the assembly.
Carry out a routine visual inspection of all existing welding seams!

What could be the cause of this irregularity?

A disrupted shielding gas supply

B dirty workpiece surfaces

C amperage too high

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Application example

Situation

You have inserted a welding assembly into the robot system, fixed it with the clamping device provided and closed the safety doors. After the automatic production process, you open the safety door and remove the assembly.
Carry out a routine visual inspection of all existing welding seams!

The picture shows a defect at the end of the welding seam.

A unclean workpiece surfaces

B poor fit of the parts to each other

C amperage too high

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Check-out Wissenstest

1. How is the welding torch stressed?

1 only mechanical

2 only thermal

3 it is subjected to high mechanical and thermal stresses

4 it is subjected to low mechanical and thermal stresses

2. What influence does the shielding gas have on the welding process?

1 The shielding gas only protects and has no other function.

2 It influences the processes in the arc, droplet detachment and the shape of the weld seam..

3 It only influences the processes in the arc.

4 It only influences the droplet detachment and the weld seam shape.

What effect does the absorption of increased levels of harmful substances have on the human body?

1 Burning of the sole of the foot

2 Blindness

3 Damage to the respiratory tract

4 None

4. Which statement is correct?

1 There is no danger from aerosol cans or disposable lighters.

2 Only disposable lighters must not be stored in protective clothing.

3 Aerosol cans may be stored in protective clothing.

4 Aerosol cans or disposable lighters must not be stored in protective clothing.

OK, now do your best for the final test! You can do it!

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Check-out Wissenstest

5. Which weld seam irregularity can occur if the torch is held incorrectly?

1 None

2 Cracks

3 Weld wire inclusions

4 Bonding defects

6. The welder suddenly notices extreme pore formation. What could be the cause?

1 The process gas has run out.

2 The welding machine has exceeded its duty cycle.

3 The welding procedure specification (WPS) has not been approved.

4 The welder has an incorrect welder's qualification.

7. What are the tasks of the carousel on the robot?

1 Control of the movement sequence

2 Optical component control

3 Connection between centre hand and swing arm

4 Responsible for rotary movement (axis 1)

OK, now do your best for the final test! You can do it!

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Check-out Wissenstest

8. How many axes does an industrial robot have?

1 two axes

2 five axes

3 six axes

4 ten axes

9. name the 3 main assemblies of an industrial robot

Solution: Robot (manipulator) / operating element (smartPad), robot controller

10. What are the tasks of safety devices on an industrial robot?

1 Controlling the motion sequences

2 Gripping the workpieces

3 Protecting the operator from serious injuries

4 Controlling the speed

OK, now do your best for the final test! You can do it!

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