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MODULE H
Welding arc

The principle of the electric arc

Summary arc

- Arc welding is a welding process extension, basically it is the electrical discharge in gases.
- The essence welding is a variation of electric energy to heat energy, welding requires a large current intensity to 2000 A, welding voltage, however, is very small, up to 50 V.

SUMMARY arc

- The electric arc is generated assuming that the voltage between the electrode and the material is greater than the ionization voltage gas at a sufficient current density and continuous electric discharge occurs when the heat generated ensures heating gas to the temperature required for thermal ionization of the surrounding atmosphere.

KUBÍČEK, J. DANĚK, L. KANDUS, B. *Technologie svařování a zařízení.* Učební texty pro kurzy svařovacích inženýrů a technologů. Plzeň: ŠKODA WELDING, s. r. o., 2011. s. 32.

Summary arc

- Depending on the chosen technology, it is possible to vary the power of the arc, its shape or its temperature.
- Welding options:
  a) Welding melting metal electrode (MMA coated electrodes, welding MOG, submerged arc welding, shielded welding, MIG / MAG)
  b) Welding with non-consumable tungsten electrode (welding shielding gas TIG).

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Summary arc

- Physical and metallurgical processes are carried out in an arc very quickly at high temperatures and are affected by:
  a) geometric arrangement, and the polarity of the electrodes,
  b) chemical composition of electrodes of the plasma and the surrounding atmosphere,
  c) thermal conductivity of the plasma electrode and the base material.

KUBICEK, J. DANEK, L. KANDUS B. *Welding technology and equipment*. Textbooks courses for welding engineers and technologists. Plzeň: ŠKODA WELDING sro, 2011. p. 32.

Characteristics of the arc

- Arc
- When the source voltage short circuit is higher than the voltage at a constant arcing.
- Primordial arc ignition can take place:
  - The short-term connection (touching) the electrode base material and the consequent disengagement.
  - Contact between the electrode material by passing the short circuit current, high contact resistance at the interface of the electrode - the material of the electrode red-hot and after separation from the material due to thermal emission of electrons will ionize the surrounding gas medium and produce (ignition) of the arc. For the arc just relatively low amperage.
- Among the materials to be welded and the electrode is formed of ionized environment spark ionizes their surroundings.
- This It is usual for alternating current and direct current switching spark discharge to arc discharge.

Basic area arc

- Column arch
  - It is the largest part of the electric arc, a shape slightly widening truncated cone and is brightly lit area of the ionized gas in the form of high temperature plasma, the maximum value depends on many factors, primarily on the gas composition and the related degree of ionization and dissociation and intensity current and voltage value.

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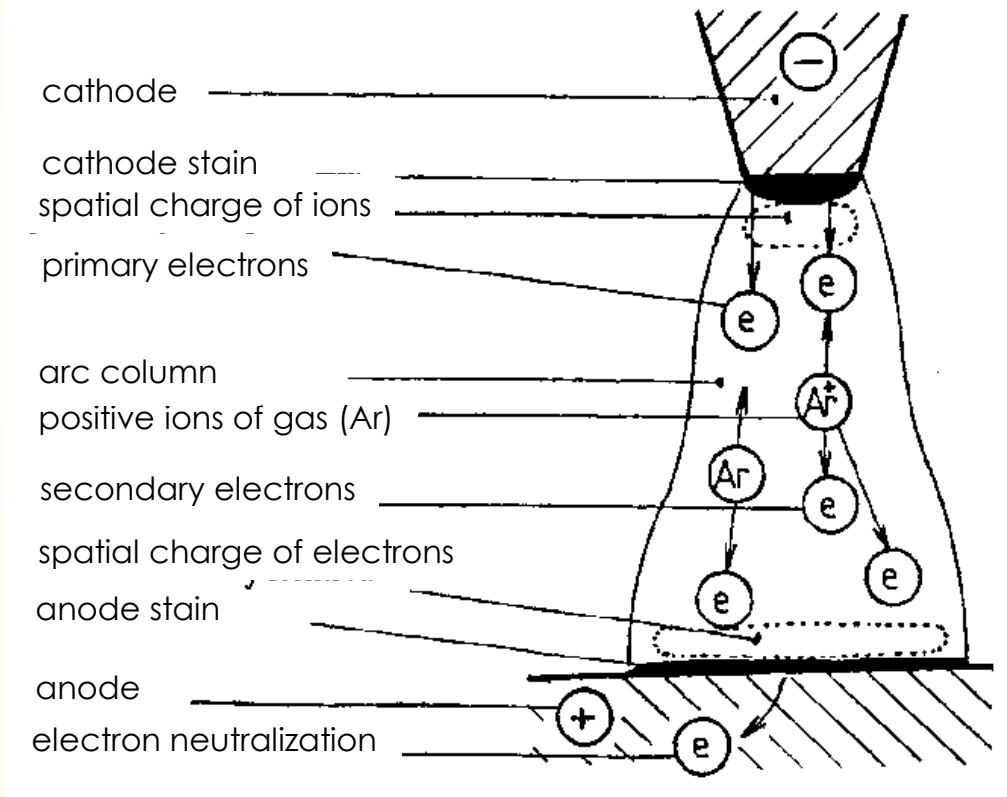
Portions of the arc



AMBROŽ, O. A KOL. *Technologie svařování a zařízení: učební texty pro kurzy svářečských inženýrů a technologů*. Ostrava: ZEROSS, 2001. s. 75.

Electric Arc

- Column arch is conductive, causing electrons.
- You They are due to thermal ionization.
- Polyatomic molecules of gases at high temperatures to cleave atoms.
- Created positive ions are attracted to the cathode.
- The electrons provide a conduction current in the arc column, because their mass is smaller than the mass of ions, therefore, their movement in the voltage drop faster.

cathode region

- It consists of a hot cathode spots, i.e. localized region emitting primary electrons, which is dependent on the geometry and the temperature of the cathode either relatively stable or tends to move along the cathode surface.
- Density current in the cathode spot is a result of narrowing of the arc 104 A.cm^2 to 105 A.cm^2.
- Positive ions that strike the surface of the cathode spots are neutralized and their ionization energy to the cathode.
- This energy and contributes to thermal emission of electrons.
- immediately the cathode spot region adjacent the cathode voltage drop thick lk 10 =$^{-6}$ to 10 m^{-7} m.
- On that is the voltage drop uk = 10 V to 16 V.
- Decrease Space charge voltage causes ions which hinders the electrons released from the cathode.

The anode region

- It is composed of the anode spots, which are discharged (absorbed) and neutralized by the incident electrons, the kinetic energy is converted into thermal energy.
- In area of the anode spot is the space charge of electrons which causes the anode voltage drop UA = 4 V to 8 V at a thickness IA = 10^{-5} to 10 m $^{-6}$ m.
- Decrease stress in the anode region has remained almost constant with increasing current.
- Critic is the current at which the surface temperature reaches the boiling point of the anode of the anode material.
- At supercritical stream come into the anode due to the boiling point region of the metal vapor from which the anode, and this leads to a reduction in ionization potential of the gas mixture and to reduce the voltage drop at the anode region.

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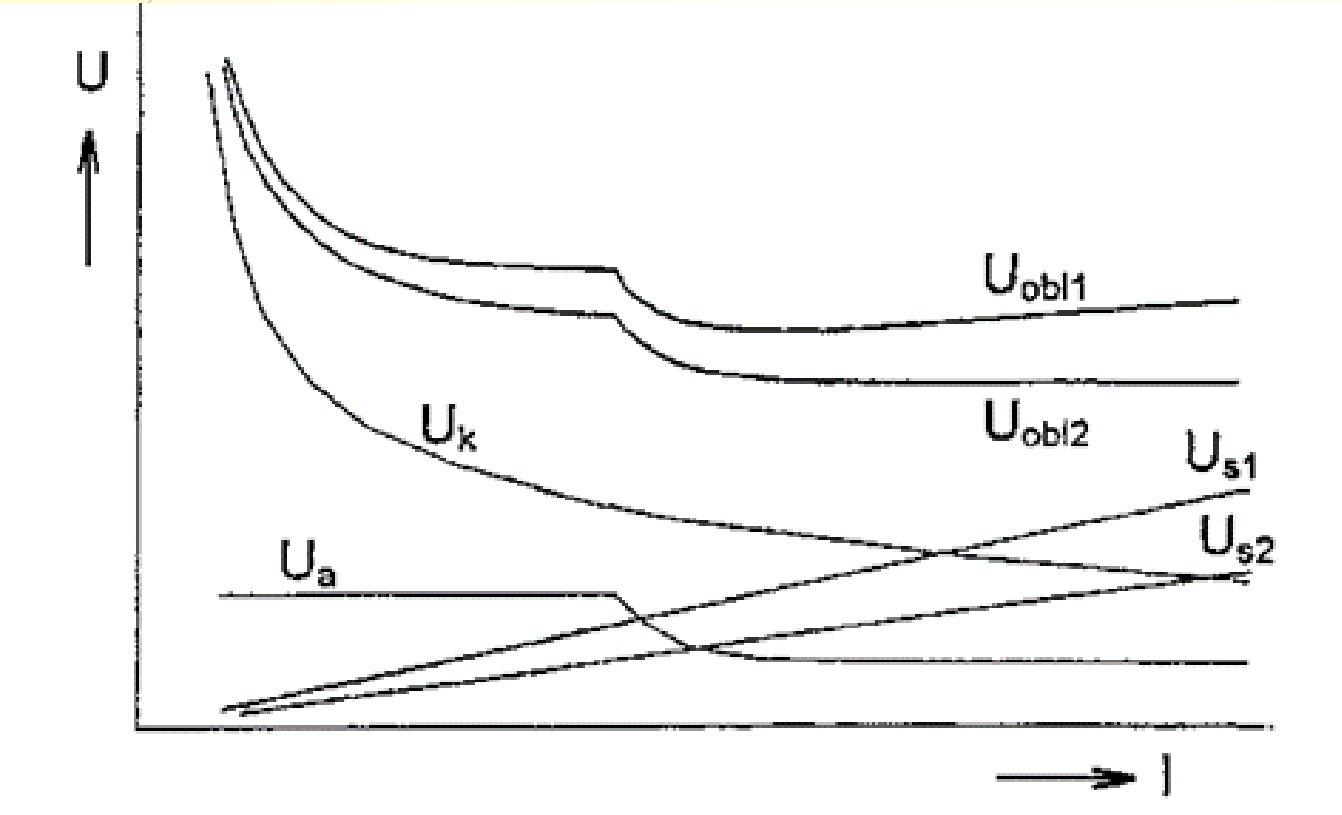
Voltage characteristic curve

- Voltage characteristic curve showing the dependence of the arc voltage on the welding current at a constant arc length.
- If altering the length of arc voltage also varies, since the longer the arc column, the larger the voltage drop at an approximately linear dependence.
- On its own shape, position and slope so. Static characteristic curve affects the chemical composition of the electrode, the plasma gas composition, the geometry of the electrode tip and the diameter.
- Current-voltage characteristic curve will be for the individual welding techniques vary depending on the parameters of the environment and conditions in which the arc will take place.

Voltage characteristic curve



AT_{and} - current-voltage characteristics of the anode region
AT_{to} - current-voltage characteristics of the cathode region
AT_{s1},AT_{s2} - current-voltage characteristics for the arc column length L_1l_2
AT_{obl1}, U_{obl2} - current-voltage characteristics for the entire arc length L_1l_2 (Arc length l_1 > Arc length L_2)

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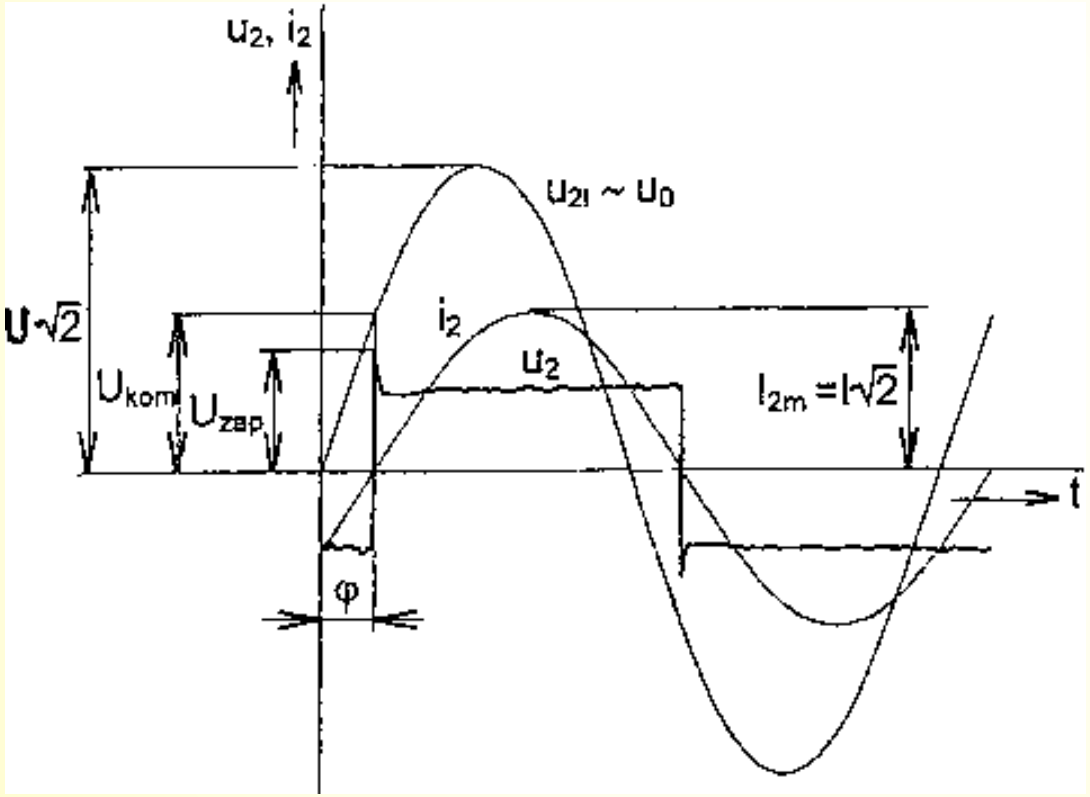
arc stability

- The stability of the welding process is considered as the dynamic behavior of the entire welding system and is subject to the stability of the arc, which is dependent on the welding technology as well as the characteristics of power sources.
- Stability is manifested by better worse caterpillar optionally further ensures uniformity arcing.
- Depends particular characteristics of the power source to the selected welding parameters, the type of electrodes, or the type of shielding gas chosen.

The electric arc in an AC circuit

- Generally, it is easier to ensure the stability of arcing when welding with direct current than alternating current.
- Arc AC powered burns less easily than the DC arc because it goes out as long as the arc voltage drops below the ionization voltage and re-ignites at a much higher voltage.
- This The fact is caused by the fact that both voltage and amperage changes its size and direction.
- For re-ignition Arc is necessary to increase the ignition voltage.
- It can be provided by creating a phase shift between current and voltage e.g. circuit of the inductance in an electrical circuit (the interposition of inductors to the circuit power source).

The time course of arc voltage AC welding



AT_2 - the voltage on the arc;
AND_2 - AC arc going;
$AT_{2\,t}$ - the voltage source;
AT_{Zap} - ignition voltage;
AT_{com} - commutation voltage;
p - phase shift between current and voltage source; $AT_{com} > AT_{zap}$

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Material transfer arc

- Factors affecting material transfer arc:
  - The chemical composition of the metal electrode,
  - The composition of the package, fluxes, shielding gas,
  - The length of the free electrode ends,
  - Feed speed.
- For the arc stability it is necessary to maintain a balance between the feed speed of the electrode, and the melting speed of metal transfer.

Transmission options metal arc

- Electric arc welding with melting metal electrode gas shield provides a large range of options for transferring a material from the consumable electrode to the weld pool depending primarily on the current, arc voltage, electrode diameter, and shielding gas composition.

Transmission method weld metal

- Depending on the above mentioned aspects can be distinguished weld metal transfer modes, these:
  - Shower transfer
  - Drop transmission
  - Short circuit transmission

Shower transfer

- Which is characterized by a relatively long arc, high current density and high voltage arc (Us = 28 V to 40 V; Is = 200 V and 500 A).
- The liquid metal passes through the arc as a stream of discrete tiny drops.
- This method of transmission occurs mainly during welding in protective gases rich in argon.
- FROM electrode releases one drop metal when using the pulse current.

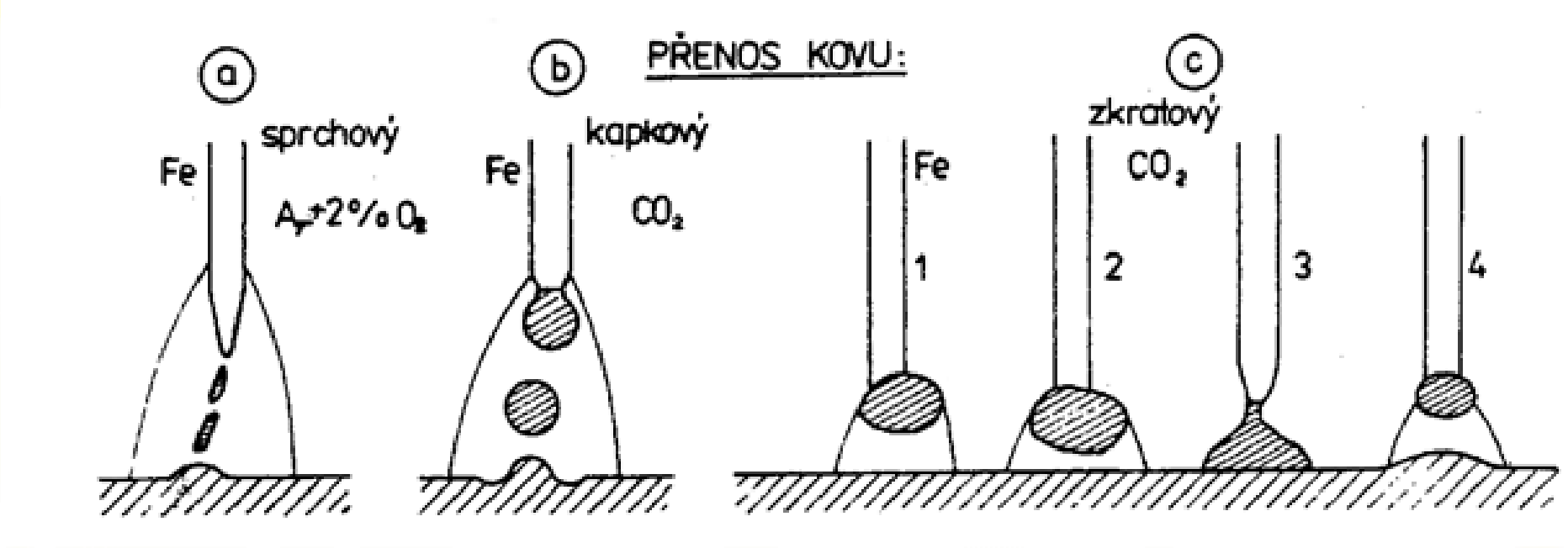
Droplet transmission

- Yippee characteristic for welding in protection gas CO2 during the welding parameters (Us = 24 V to 28 V; Is = 200 A to 300 A) and a short arc metal droplets larger melt off frequency of 5 to 10 drops per second.
- With increasing current size droplet size decreases and increases the frequency of delamination thereof.

Short-circuit transmission

- At a short arc, which is characterized by a regular alternation of the arcing phase and a short circuit, in which a gob of molten metal at the end of the electrode contacts the molten bath and creates a short circuit after interruption of the arc is ignited once again.
- Current density is moderate to low, also the arc voltage (Us = 14 V to 22 V; Is = 50 A to 200 A).

Method of transmitting metal electrode arc



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Transmission metal electrodes in the arc

- When transferring the molten material of the electrode to the weld pool applies complex system of action of force.
- Size direction and resultant force affecting the shape, size and frequency of the droplets of metal electrodes are determined by the following factors:
  - Technological welding parameters,
  - Current, voltage, current density, electrode diameter, polarity,
  - Physical properties of the molten metal,
  - Surface tension, viscosity, melting point, boiling point,
  - Properties of a protective gas,
  - Temperature, thermal conductivity, chemical interactions.

Effects of the arc

- Thermal effects arc
- Mechanical effects arc

Thermal effects of the arc

- The electric arc is intense source of heat, in terms of fusion welding has very favorable properties.
- Thermal effect of the arc is concentrated on a relatively small area and the efficiency of energy transfer into the welding material is good.
- Through the welding parameters can be used in connection with the thermal and mechanical effects and influence the arc welded joint in terms of its geometry (width and depth of penetration, heat affected zone width) and the size and deformation stress in the welded material.

Thermal effects of the arc

- The amount of heat generated in each area of the arc is generally proportional to the voltage drop and current action time (e.g. at the anode Qa = Ua . Is. t).
- Most of the heat is therefore develops in the anode region (which is converted into kinetic energy of the impacting of charge carriers - electrons to heat), less on the cathode (the cathode is cooled by the thermal emission of electrons) and at least the arc column.
- Temperature the anode is about 200 ° C to 500 ° C higher than the temperature of the cathode.

Thermal effects of the arc

- The temperature of the arc and the molten metal of the electrode and the base material are the most important factors which determine the physical, chemical and metallurgical properties of the welding process.
- Temperature depends on the degree of dissociation and ionization of the gas in the arc, the solubility of gases in a metal melt and transferring the metal electrode arc.
- On the heat balance of the arch has a decisive influence the direction of flow of plasma and transfer of heat conducted between the plasma and the molten weld pool.
- Temperature column in addition to the arc is dependent on the heat input and thermal conductivity of the gas in which the arc exists, and is higher, the heat dissipation is worse, i. thereby thermal conductivity of the surroundings less.

Thermal effects of the arc

- For gases commonly encountered in welding the thermally conductive least argon, best conductive carbon dioxide.
- Therefore when the same thermal input of the same length and has the largest diameter column and the highest temperature of the arc in argon, the smallest diameter of the column and lowest temperature of the arc in the carbon dioxide.
- The maximum temperature of the arc at the core and edge of decline.

Thermal effects of the arc

- When welding with covered electrode, the temperature curve between 4200 ° C to 6400 ° C at the submerged arc welding of 6200 ° C to 7800 ° C in a protective atmosphere TIG 6500 ° C to 9000 ° C and MIG / MAG welding with temperatures in the range 8000 ° C to 15000 ° C.

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Thermal effects of the arc

- When welding with consumable electrode, the thermal efficiency of the process is always greater than the TIG method, since heat generated at the electrode is not lost utilized to melt the filler material which passes in the form of drops into the weld metal.

Mechanisms that contribute to the energy transfer of the arc into the weld metal

- Equipment direct heat on the base material,
- Stream of hot heat transfer and absorption of part of the plasma radiation energy curve,
- Heat transfer from the electrode to the weld pool metal droplets,
- Heat obtained by conversion of kinetic energy of the falling drops of metal.

Mechanical effects arc

- Mechanical effects arc manifested considerable force action on the weld pool and thus a prerequisite for achieving a deep penetration.
- Most significant influences are:
  - Intensity of the plasma arc column, creating pressure, which is directed perpendicular to the surface of the weld pool, compresses its center and contributes to increasing the ratio of the depth and width of the weld bead (the highest pressure is achieved by welding in CO_2, The lowest in He)
  - Kinetic energy of the droplets of molten additive material and transmitted by the accelerated plasma flow,
  - Reactive vapor pressure leaking from the active region of the molten bath and the pressure of the superheated vapor from the metal electrode surface.
- For the flow of liquid metal in the weld pool are involved in addition of the electromagnetic force caused by electric current passing through the weld pool, the surface tension forces and lift forces associated with the different density of the liquid metal.

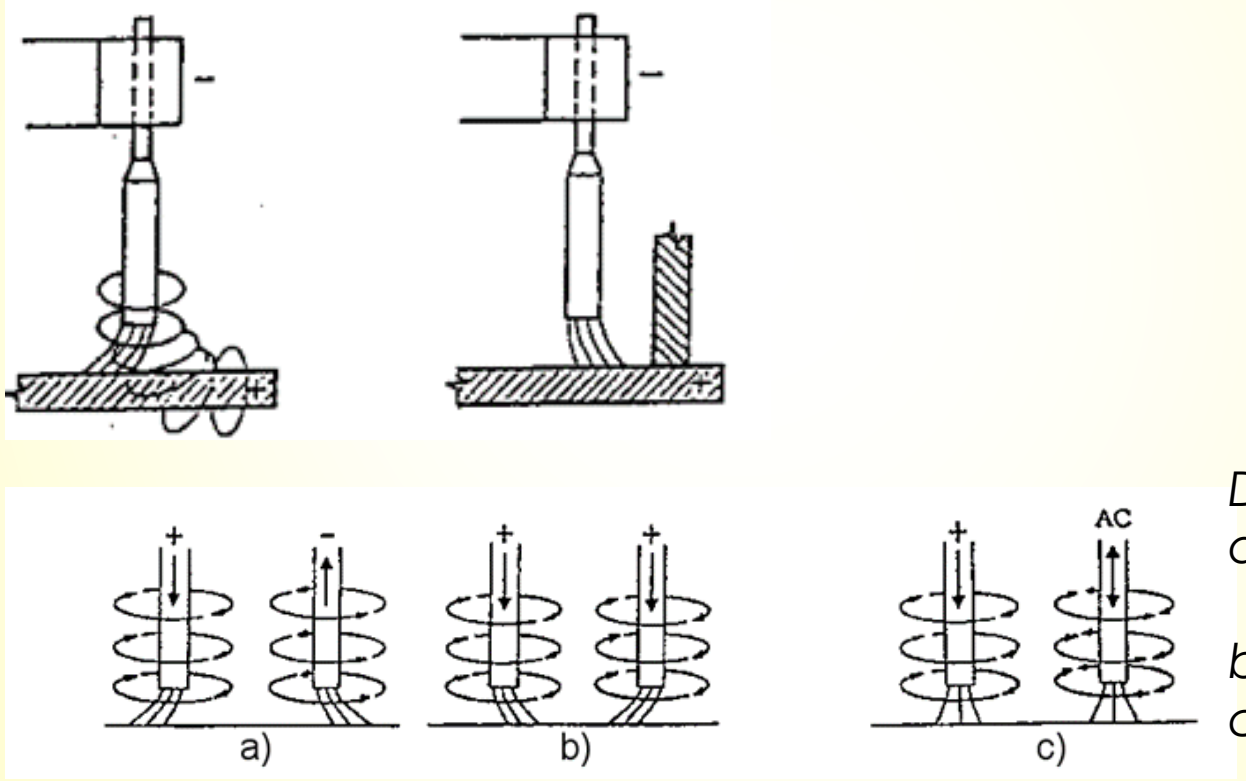
The influence of magnetic fields on the arc

- Around each of the conductor and thus the arc through which flows an electric current, a magnetic field, which manifests itself primarily by their force effects of arcing.

Blowing arc

- Due to the low stiffness of the arc as a gaseous and a flexible conductor of electric current may have a small magnetic field strength, resulting in deflection of the arc from the electrode axis direction in a range having an adverse effect on the formation of the weld bead.
- The consequence then it is unsightly and poor weld.
- This phenomenon is called arc blowing it is both cause a magnetic field generated around each of the current conductor but also uneven flow distribution in the welded article and articulation of welded structures. Mitigate the adverse effects of this phenomenon can be achieved by placing the inlet clamp as close to the welding electrodes against the tilting direction of the blowing of the arc and the like.
- At AC welding are difficulties with blowing an arc substantially less than with direct current.

Magnetic blowing arc



Description:

a) at inappropriate, connecting the grounding cable,
b) at welding close to the ribs.
c) at two arcs next to each other

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Questions to ponder

1. Explains the arc and the conditions of its occurrence.
2. What are the ways ignition arc?
3. Description of essential parts of the electric arc.
4. How and thereby evaluate the stability of the arc?
5. Describe the types of metal transfer the arc.
6. Which forces and how they affect drops of molten metal arc transmitted?
7. What factors influence the direction of electromagnetic forces in the arc?
8. How to exhibit thermal effects of the arc?
9. Description of the mechanical effects of arcing.
10. What is "blowing Arc "and what is due?

Recommended literature and information sources

- AMBROŽ, O. A KOL. Technologie svařování a zařízení: učební texty pro kurzy svářečských inženýrů a technologů. Ostrava: ZEROSS, 2001, 395 s. Svařování. ISBN 80-85771-81-0.
- KUBÍČEK, J. DANĚK, L. KANDUS, B. Technologie svařování a zařízení. Učební texty pro kurzy svařovacích inženýrů a technologů. Plzeň: ŠKODA WELDING, s. r. o., 2011, 242 s.