

### 3.37 (Class 20)

#### Review

- 70% of heat dissipated at the anode, 30% at the cathode
  - Affects the strategy in choosing anode/cathode for different welding processes
- The current in the arc carries 80-90% of the heat to the anode
  - Not inhibited by the boundary layer
- The thermal conductivity of helium increases heat transfer to the workpiece
  - Substantial increase in melting efficiency over argon

#### Today

##### Continuing with shielding gasses

- In Europe and other parts of the world, don't have inexpensive helium, sometimes use hydrogen, but can't use with most steels or aluminum, can use with certain steels and copper alloys, often use Ar-H<sub>2</sub>(5%)
- Reactive Thermal Conductivity, chemical reaction that dissociates the hydrogen H<sub>2</sub> → 2H due to high temperatures, heat required to break this bond, then down in the boundary layer, these combine to form H<sub>2</sub> and give up this energy, appears like a higher thermal conductivity
- ArH<sub>2</sub>(5%) gets about the same performance (reactive thermal conductivity) as helium (inherently higher thermal conductivity)
- This is one area where the welding handbook is out of date, doesn't explain this correctly, plasma physicist would laugh
- This works for CO<sub>2</sub> as well → CO + O, this is used to weld steel, CO<sub>2</sub> arc has hot central core, due to the large spike in thermal conductivity, these behave differently than argon arcs, can get dramatic differences

##### Shielding gasses—which used with which metals

- Al
  - Ar
  - He
  - ArHe
- Carbon and low alloy steels (most)
  - Ar-1-2%O<sub>2</sub> (smoother sounding arc)
  - Ar-5-20%CO<sub>2</sub> (same thing, haven't really figured out how this stabilizes arc behavior)
  - 100% CO<sub>2</sub> (very cheap gas, love to use this in the auto industry, start getting spatter all over, good for non-cosmetic situation like structural steel beams, also have oxidation, welding electrode consumption, for best properties and appearance will want to use more expensive gas)
  - He, He-O<sub>2</sub>

- Ar-He-CO<sub>2</sub>
- Ar-He-CO<sub>2</sub>-O<sub>2</sub> (TIME, can prove that this is a bogus patent, same as without O<sub>2</sub>, has been making a fortune from the military)
- Can add Li, Ba Sr
- Nickel-based alloys
  - Ar (potential for lack of fusion defects)
  - Ar-1%O<sub>2</sub> (potential for oxidation defects, good for single-pass weld, have to grind the surface before putting the next bead on)
- Austenitic Stainless Steels
  - Ar-1%
  - ArH<sub>2</sub>-O<sub>2</sub>
  - ...

#### Costs

- Welder costs \$30-\$40/hour, add supervision, overhead, etc., will cost about \$150K/yr, about \$75/hour for the welder, say \$10/hour worth of argon, ...
- Door product center at Boeing, build about 750 doors per year, employs 250 people, value of a door?, didn't have any idea, can estimate, costs about \$50,000 for a door, calculated at about \$150K/person/year approximately, this is a rough calculation but does get you in the ballpark

#### Arc ignition

- Need to start the arc
- Welding Handbook will tell you that the way an arc starts:
  - Paschen Breakdown
    - 1000V difference, small distance, get breakdown
    - Say 0.1mm, 10,000V, 10<sup>6</sup>V/cm for Paschen breakdown
    - this doesn't have anything to do with it, don't have these kinds of voltages in welding power supplies
  - Field Emission
    - All need is about 10<sup>8</sup> V/cm, lots of voltage
    - Say 0.1mm, 10,000V, 10<sup>6</sup>V/cm for Paschen breakdown + surface asperities concentrates the field strength, not true for liquid metal, still takes 10<sup>8</sup>V/cm
    - Just another version of Paschen breakdown
    - So welding handbook is wrong on this too
  - Touch start
    - Ragner Holm (with wife Elsie), German scientist, worked for Westinghouse, book "Electrical Contacts, Theory and Application"
    - Diagram on board, voltage V<sub>0</sub> across the contact, heating of the interface where two asperities meet, solve Laplace equation for isopotentials and isothermals (same equation, diff const), solve the differential equation (given on board) to get the result that temperature at the interface is proportional to the voltage
    - Melting voltage for aluminum, need 0.3V, copper need 0.43V, tungsten 1.1V
    - Very low voltages create high enough temperatures for melting

- To create an arc, just need enough voltage for the anode and cathode voltage drops
- How to create an arc with robotic welding?
  - Feed in slowly with search voltage, then raise the voltage
  - Touch start,
- High frequency (Tesla coil), resonant some free electrons off the atom
  - Sometimes used to start welding arcs