3.37 (Class 15)

Review

More materials can be brazed than soldered

- Higher temps
- Greater strengths

Thinner braze joints are stronger (in tension) due to contact strengthening

Today

Fusion Welding Processes

Interested in heating the material to melt it

Diagram on the board (W/cm^2)

- Sun's rays approx 1/10 W/cm^2
- Two limits for heating surface of metals
    - Below approx 300 W/cm^2 can't melt most metals, thermal conductivity of metal will conduct heat away faster than can store it on the surface
    - Above approx 3x10^6 W/cm^2 start vaporizing the metal (laser and electron beam hole welding approx 10^7, laser weapon at approx 10^8 shatters the material)
    - 10^3 oxy-fuel (typically acetylene) approx 10^3
    - Air-fuel flame (propane torch) below 10^2, also semiconductor chip
    - Open flame, just above 10
    - Arcs approx 10^4
    - Resistance welding approx 10^5
    - Aside on electron beam weapons, propagate beam for 30 miles, but have hose instability, generate very high densities, too high to be useful for welding
- Increasing heat efficiency as power density goes up
    - 10^3, may be about 0.1 efficiency, have to preheat more material
    - 10^6, at about 0.99 efficiency
    - Middle, from about 0.3-0.7
- Decreasing Heat Affected Zone (HAZ) size as power density goes up
    - Approx 1 – 10 cm at 10^3, controlled by heating time
    - Approx 0.1 – 0.5 cm at 10^4
    - Approx 0.1 – 0.5 cm, at 10^6 no smaller after above 10^4, not putting lots of extra heat in during the heating cycle, controlled by how long it takes to cool
    - Common fallacy is to try to eliminated the heat affected zone by using electron beam welding

  - Only time saw weld with virtually no heat affected zone, was plutonium at LLNL, like a ceramic, has very low thermal conductivity
- Increasing travel speed as power density goes up
  - Approx 0.01 – 0.1 cm/s at 10^3
  - 0.1 – 1.1 cm/s at 10^4
  - 100 cm/s at 10^6
  - Controlling size of the weld pool
  - Human reaction time on the order of 150-200ms, bill drop game on the order of 1/10th of sec
  - Time to control weld pools 10's of ms at high energy densities, can't control manually
  - Manual welding training often starts with oxyacetylene, slower so that can watch the weld pool and carefully control it
- Increasing need to automate as power density goes up
  - Lasers and electron beam need to be automated to use them
- Increasing equipment cost as power density goes up
  - Can approximately change W/cm^2 to $/capital equipment
  - Oxyacetylene kit can be had for about $1000
  - Arc welding setup for production welding approx. $10,000
  - Laser electron beam with automation, safety equipment, approx $0.5 - $1million, bigger systems can be $10million
  - Resistance welding is the only process that doesn't fit this, $10,000 for equipment that gives the equivalent power density, HAZ, need to automate, travel speeds, etc., no surprise that this is heavily used in the automotive industry
- Increasing production volume requirements as power density goes up
  - Oxyacetylene approx 10 joints/day (say for plumber who needs to do just a few welds)
  - Arc welding approx 100 joints/day
  - Laborer's time, efficiency is very low
  - Automotive (only know how to make 50,000+ per day)
    - Run almost all the time
  - Aerospace (precision and high value added), few expensive parts
    - On-time is about 1-2%
    - Care more about making the perfect weld
- Increasing depth/width ratio
  - Diagrams on board
  - 0.1
  - 0.5
  - 10/1
  - 200/2 (too thin, traps porosities during non-homogenous cooling)

Flames

- Enthalpy of the reaction
  - Acetylene (C2H2, triple bonded carbon with hydrogen on either side, lots of energy released when break this bond)

    - Propylene and other complex hydrocarbons start to average out to about the same
    - Gasoline not much different than polyethylene, or say tar
    - Some things have higher enthalpies than acetylene
        - C2N2, Cyanagen, used a rocket propellant, poison gas, and welding gas (never seen it used)
        - H2N2, Hydrazine, used in nuclear reactors
- Stoichiometry of the oxygen to fuel ration
    - From the Welding Handbook
    - Stochiometric mixture is near the peak
    - Rich or lean will drop the temperature considerably, have lots of unburned fuel, create extra baggage since not all atoms participate in the reaction (like society and welfare)
- Presence of inerts (for example Nitrogen in Air)