Lecture 25 – Methods of joining materials
# Methods of joining materials

<table>
<thead>
<tr>
<th>Reference Text</th>
<th>Section</th>
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</table>
Methods of joining materials (Higgins 25)

Joining processes can be grouped into three main groups, according to how the joint is achieved:
• Adhesives
• Soldering, brazing and welding
• Mechanical joining by means of fasteners
Almost any material, including dissimilar materials, can be joined by adhesives.

**Curing methods:**
- Cooling – thermoplastic
- Chemical reaction – 2 part epoxy, polyester
- Evaporation: Water / solvent
- 2 part curing. A
- Surface curing. Cyanoacrylate. (Super glue)
- Anaerobic: Hardens when air excluded. (Loctite 600 series)
- Chemical reaction with water / UV Light (epoxy) / heat (Bakelite)
Almost any material, including dissimilar materials, can be joined by adhesives.

<table>
<thead>
<tr>
<th>Group</th>
<th>Adhesive substance (or raw material)</th>
<th>Materials joined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal glues</td>
<td>Animal hides or bones, fish, casein (from milk), blood albumen</td>
<td>Wood, paper, fabrics and leather.</td>
</tr>
<tr>
<td>Vegetable glues</td>
<td>Starch, dextrine</td>
<td>Paper and fabrics.</td>
</tr>
<tr>
<td></td>
<td>Soya beans</td>
<td>Paper-sizing.</td>
</tr>
<tr>
<td>Natural resins</td>
<td>Bitumens (incl. asphalt)</td>
<td>Laying floor blocks, felt.</td>
</tr>
<tr>
<td></td>
<td>Gum arabic</td>
<td>Paper and fabrics.</td>
</tr>
<tr>
<td>Inorganic cements</td>
<td>Sodium silicate</td>
<td>Foundry moulds.</td>
</tr>
<tr>
<td></td>
<td>Portland cement, plaster of Paris</td>
<td>Building industries.</td>
</tr>
<tr>
<td>Elastomer materials</td>
<td>Natural rubber (latex/solvent)</td>
<td>Rubber, sealing strips.</td>
</tr>
<tr>
<td></td>
<td>Synthetic rubbers (neoprene, nitrile)</td>
<td>Footwear industries, polythene, PVC.</td>
</tr>
<tr>
<td>Synthetic polymer</td>
<td>Polyvinyl acetate and vinyl copolymers</td>
<td>Wood, paper, fabrics, bookbinding.</td>
</tr>
<tr>
<td>materials</td>
<td>Cellulose derivatives (solvent release)</td>
<td>Glass, paper, balsa wood.</td>
</tr>
<tr>
<td></td>
<td>Acrylcs</td>
<td>Acrylics, polycarbonates.</td>
</tr>
<tr>
<td></td>
<td>Anaerobic acrylcs</td>
<td>Metals.</td>
</tr>
<tr>
<td></td>
<td>Cyanoacrylates – cure in presence of moisture (‘super glue’)</td>
<td>Metals, rubbers, PVC, polycarbonates, polystyrene, polyimide</td>
</tr>
<tr>
<td></td>
<td>Epoxy/amine and epoxy/polyamide</td>
<td>Metals, glass, ceramics, wood, reinforced plastics, very wide range of uses.</td>
</tr>
<tr>
<td></td>
<td>Phenol, urea, melamine and resorcinol formaldehydes</td>
<td>Weatherproof plywoods, fabrics and paper.</td>
</tr>
<tr>
<td></td>
<td>Polyurethane – hot or cold-curing liquid</td>
<td>Polyurethane, PVC, polycarbonates, paper and fabrics.</td>
</tr>
<tr>
<td></td>
<td>Polyimide – hot-curing film</td>
<td>Metals, glass, ceramics, polyimide.</td>
</tr>
<tr>
<td></td>
<td>Silicones</td>
<td>Silicone rubbers, sealing seams and joints in other materials.</td>
</tr>
</tbody>
</table>
25.2 Adhesives \textit{(Higgins 25.2)}

25.2.1 Service requirements
strength required,
temperature range in service
resistance to water or moisture.

The working properties of the adhesive are also important,
method of preparation and use,
storage-life,
drying-time,
odour,
toxicity,
Cost
surface preparation
large surface area
25.3 Soldering and brazing  (*Higgins 25.3*)

25.3.1 Soldering
A solder must 'wet' - that is, alloy with - the metals to be joined, and, at the same time, have a freezing range which is much lower, so that the work itself is in no danger of being melted. The solder must also provide a mechanically strong joint.
25.3 Soldering and brazing (Higgins 25.3)

25.3.2 Brazing
Above 450°C.
Borax flux

Table 25.3 Brazing alloys and ‘silver solders’

<table>
<thead>
<tr>
<th>BS spec. 1845</th>
<th>Composition %</th>
<th>Freezing range °C</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cu</td>
<td>Zn</td>
<td>Others</td>
</tr>
<tr>
<td>CZ6</td>
<td>60</td>
<td>Bal.</td>
<td>Si 0.3</td>
</tr>
<tr>
<td>Ag7</td>
<td>28</td>
<td>–</td>
<td>Ag 72</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(eutectic)</td>
</tr>
<tr>
<td>Ag1</td>
<td>15</td>
<td>Bal.</td>
<td>Ag 50, Cd 19</td>
</tr>
</tbody>
</table>
25.4 Welding \textit{(Higgins 25.4)}

- Arc-welding
- Electrical resistance welding
- Thermo-chemical welding
- Radiation welding
25.5 Arc-welding processes \textit{(Higgins 25.5)}

25.5.1 Metallic-arc welding
25.5 Arc-welding processes *(Higgins 25.5)*

25.5.2 Submerged-arc welding
25.5 Arc-welding processes (Higgins 25.5)

25.5.3 Gas-shielded arc-welding

*The TIG process*
25.5 Arc-welding processes (*Higgins 25.5*)

The *MIG* process

Gas metal arc welding (MIG welding)
25.5 Arc-welding processes \textit{(Higgins 25.5)}

The CO2 process
25.5 Arc-welding processes \textit{(Higgins 25.5)}

25.5.4 Plasma-arc welding
25.5 Arc-welding processes *(Higgins 25.5)*

25.5.5 Summary of arc-welding processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Shielding</th>
<th>Current A</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallic arc</td>
<td>Flux</td>
<td>25–350</td>
<td>Pressure vessels, pipes, ships.</td>
</tr>
<tr>
<td>Submerged arc</td>
<td>Flux</td>
<td>350–2000</td>
<td>Thick plate, pressure vessels, boilers, pipes, ships, low-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and medium-carbon steels.</td>
</tr>
<tr>
<td>MIG</td>
<td>Inert gas</td>
<td>60–500</td>
<td>Medium gauge items, car body repair.</td>
</tr>
<tr>
<td>TIG</td>
<td>Inert gas</td>
<td>10–300</td>
<td>Aircraft and instrument industries, Al, Cu, Ni and stainless steel</td>
</tr>
<tr>
<td>Plasma arc</td>
<td>Inert gas</td>
<td>115–240</td>
<td>Thick plate, stainless steel.</td>
</tr>
</tbody>
</table>
25.6 Electric resistance welding  

(Higgins 25.6)

25.6.1 Spot-welding
25.6 Electric resistance welding  \((Higgins\ 25.6)\)

25.6.2 Projection-welding
25.6 Electric resistance welding  \textit{(Higgins 25.6)}

25.6.3 Seam-welding
25.6 Electric resistance welding  (Higgins 25.6)

25.6.4 Butt-welding

Higgins
25.6 Electric resistance welding  *(Higgins 25.6)*

25.6.5 Flash-welding
25.6 Electric resistance welding  *(Higgins 25.6)*

25.6.6 Electro-slag welding
25.6 Electric resistance welding  \textit{(Higgins 25.6)}

25.6.7 Induction welding
25.7 Thermo-chemical welding  \textit{\cite{Higgins:2017:Engineering}}

25.7.1 Oxyacetylene welding
25.7 Thermo-chemical welding  \( (Higgins\ 25.7) \)

25.7.2 Thermit welding
25.8 Radiation welding  \((Higgins 25.8)\)

Electron beam

25.8.1 Laser welding
25.9 Solid-state welding (Higgins 25.9)

25.9.1 Cold-pressure welding
25.9 Solid-state welding \((Higgins \ 25.9)\)

25.9.2 Friction-welding
25.9 Solid-state welding *(Higgins 25.9)*

25.9.3 Explosive welding
25.10 Structure of welds *(Higgins 25.10)*

*Figure 25.12 The crystal structure of a fusion-weld.*

Coarse structure in over-heated zone of plate

Coarse ‘as-cast’ weld metal

As-rolled structure of original plate
25.11 Welding of plastics (Higgins 25.11)

25.11.1 Hot-gas welding
25.11.2 Seam- and spot-welding
25.11.3 Electrofusion-welding
25.11.4 Stitch-welding
25.11.5 Jig-welding
25.11.6 Friction-welding
Joining Metals
Sheppard, Phil. Bendigo, Vic. : Classroom Video, c2006. DVD (29 min.).
An introduction to the methods of joining metals, including riveting and fusion and non-fusion methods of welding.

Mt Druitt College Library: DVD 671.5/JOIN
Joining Metals Notes (pdf)
Recommended Viewing: All sections.
Resources.

Wikipedia: Welding

Ashby diagrams
Glossary

Alternating Current
Arc
Bead
Butt Joint
Depth of Fusion / penetration
Edge Preparation
Fillet Weld
Weld: throat, root
Flux
Heat Affected Zone
Intermittent Weld
MIG (GMAW)
Porosity
Pre Heating
Seam Weld

MMAW
Shielding Gas
Slag
Spot Weld
Submerged Arc
TIG Welding (GTAW)
Thermit
Fusion
Anaerobic
Cyanoacrylate
Friction welding
Adhesive shear, peel and tear
QUESTIONS: Joining of Materials
Higgins Ch25, Newell, Timmings, Sheedy, Callister, Ashby

1. Define all glossary terms
2. What type of soft solder is used for electronic work? Why?
3. Describe two different types of brazing alloy.
4. Describe two different arc welding processes, and name an application for each.
5. Describe the electroslag welding process.
6. Discuss the design of a joint for adhesive bonding.
7. Describe the heat-affected zone of a welded joint and explain how it affects the properties of the metals being joined and the strength of the joint.
8. Describe the chemical reactions that take place during oxy-acetylene welding and how these reactions can affect the joint.
9. Describe the composition, need for, and function of the flux coating of an arc welding electrode.
10. List the advantages and limitations of brazing compared to welding.
11. An adhesive works best in shear stress. Explain why and show a sketch of a typical adhesive joint that demonstrates this.
12. Explain why there are problems in welding of high carbon steels. Explain the need for preheating and post-welding heat treatments.

13. Give reasons for adhesives finding greater use in engineering and structural applications. Name five types of adhesives and list some of their inherent features and limitations.