Materials Joining Technology

Dr. N S Mahesh
Session Objectives

- At the end of the session the delegates should have understood
  - The details of spot, arc and fusion welding technologies traditionally used for steel for the assembly of panels into the body structure
  - Modification procedures required for Al joining
  - Brazing and soldering techniques
  - Adhesives and mechanical fastening often used in lightweight designs
Introduction

• The durability and performance of any structure is largely dependent on the quality and the design of the component joints

• Whole structure can not be made in one piece

• Two fundamental options for joining materials and components –
  • Mechanical joining and
  • Metallurgical joining

Autobody structure being welded
Classification of joining processes

Mechanical Bonding
- Temporary (threaded fastener)
- Permanent and semi permanent
  Ex: Rivets, Stitches, Staples, Shrink fits

Atomic Bonding

Solid state
- Cold welding
- Friction welding
- Diffusion welding
- Hot forge welding
  - Pressure welding
  - Explosive welding
  - Ultrasonic welding

Liquid state
- Electric
  - Arc welding
  - Induction welding
  - Resistance welding
- Chemical
  - Gas welding
  - Thermit welding

Solid/liquid state
- Brazing
- Soldering
- Adhesive bonding
Resistance Welding

• Resistance welding is the science of joining two or more metal parts together in a localized area by the application of heat and pressure.

• The heat is produced by the resistance of the material to carry a high amperage current. The greater the path of resistance is, the higher the heat intensity. This heat is controlled via time application and level of current applied.

• The pressure is applied to forge the joint and consolidate the nugget to provide the weld strength.

• No extraneous materials such as rods, fluxes, inert gases, oxygen, or acetylene are required.

\[ H = I^2RT \text{ Joules} \]

Type of resistance welding
- Resistance spot welding
- Resistance seam welding
- Resistance projection welding
Resistance Spot Welding

- The process is used for joining sheet materials and uses shaped copper-chromium or zirconium alloy electrodes to apply pressure and convey the electrical current through the workpieces.
- Heat is developed mainly at the interface between two sheets, eventually causing the material being welded to melt, forming a molten pool, the weld nugget.
- The molten pool is contained by the pressure applied by the electrode tip and the surrounding solid metal.

Resistance spot weld section
Resistance Spot Welding

- Short weld time and hence high weld speed
- Highly adaptable to automation and robotic techniques.
- Typical BIW contains 5000 welds
- Strength and durability of automobile largely depends on quality of RSW.
Resistance Welding

• **Projection welding:** The force and current to make the weld is localized by the use of projection raised on one or more of the sheet surfaces.

• Used for mechanical fixing of autobody structures Eg. Weld nuts

• **Seam welding:** Continuous weld made by weld bead or a series of overlapping weld laps.

• Used for the attachment of body structure bodyside to the roof.
Seam Welding

Seam Welding (RSEW)

- Sliding contact
- Upper electrode wheel
- AC Power Supply
- Welded metal sheets
- Lower electrode wheel
- Weld
Seam welding in progress

Bellows

Batteries
Projection Welding
## Typical Spot Welding Conditions for Coated and Uncoated Steels

<table>
<thead>
<tr>
<th>Welding parameter</th>
<th>Coating type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uncoated mild steel</td>
</tr>
<tr>
<td>Welding force (kN)</td>
<td>2.5</td>
</tr>
<tr>
<td>Welding current (kA)</td>
<td>8</td>
</tr>
<tr>
<td>Welding time (cycles)</td>
<td>8</td>
</tr>
</tbody>
</table>
Fusion welding

- Oxy fuel gas welding
- Arc welding
  - Arc welding is used in autobody construction, especially where stress levels are considered to be high
  - Mostly used in automotive industry is MIG
  - TIG
- Thermal welding
- Electron beam welding
- Cutting
Arc Welding

• The processes involves either consumable or a non consumable electrode (rod or wire).
• An arc produced between tip of the electrode and work piece to be welded, by use of an AC or a DC power supply.
• Type of arc welding:
  – Manual metal arc welding
  – Gas-shielded metal arc welding (Metal inert gas (MIG) welding)
  – Gas-shielded tungsten arc welding (Tungsten inert gas (TIG) welding)
  – Submerged arc welding
  – Plasma arc welding
Gas-shielded Metal Arc Welding (Metal Inert Gas (MIG) Welding)

- **Heat source** - arc between parent metal and consumable electrode wire (0.6 to 1.6mm diameter)
  - 60-500A, DC only
  - 16-40V
  - 1 to 20kW
Metal Inert Gas (MIG) Welding

• The arc melts the parent metal and electrode wire to form a weld pool which is protected from the atmosphere by shielding gas
  – For non ferrous materials
    • Argon and helium
  – For steels
    • Carbon dioxide, argon +5-20% carbon dioxide, or argon +1-5% oxygen
Metal Inert Gas (MIG) Welding

- The wire is fed at a constant speed to give the desired weld current
  - High welding current can only be used in the horizontal orientation since metal transfer is by arc spray
  - Lower welding current which allow dip transfer used in other orientations
- The voltage control arc length
- The process may be readily mechanized

GMAW torch nozzle cutaway image. (1) Torch handle, (2) Molded phenolic dielectric (shown in white) and threaded metal nut insert (yellow), (3) Shielding gas nozzle, (4) Contact tip, (5) Nozzle output face
Gas-shielded Tungsten Arc Welding (Tungsten Inert Gas (TIG) Welding)

- Heat source - arc between a tungsten tip and the parent metal
  - 30-400A, AC or DC
  - 10-20V
  - 0.3-8kW
- Inert gas shielding
- Consumable filler rod can be used (1 to 4mm diameter)
Gas-shielded Tungsten Arc Welding

GTAW torch with various electrodes, cups, collets and gas diffusers

GTAW weld area
Tungsten Inert Gas (TIG) Welding

• The arc melts the parent metal to form a weld pool which is protected from the atmosphere by a shielding gas
  – Argon or helium
• A filler rod can be use if required
• To start the arc without workpiece contact a high frequency pulse from the power supply can be used
  – AC used for welding Al and other metals with refractory oxides
  – DC used with the electrode negative in other cases
Laser Welding

- CO$_2$ or Nd-YAG
- High static and dynamic stiffness of the resultant joints
- Design flexibility
- Low thermal distortion of the joint
- Visual quality of the joint
- Reduced weight through the reduction of flange sizes
- Improved structural stiffness as a continuous joining technique
- High investment and running costs-main and premium priced vehicles
  - Eg: BMW 5 series, Audi A2
Weldability

The capability of a material to be welded under the imposed fabrication conditions into a specific, suitably designed structure and to perform satisfactorily in the intended service.

- Weldability depends on various factors such as, nature of metals, weld designs, welding techniques, skills, etc.
- It has been stated that all metals are weldable but some are more difficult than another.
- Steel is readily weldable (in many ways) than aluminum and copper.
- Copper is not easily welded due to its high thermal conductivity which makes it difficult to raise the parent metal to its melting point. require preheating ~300-400°C.
- Some aluminum based die casting alloys give weld pool too large to control, and aluminum welds normally have oxide inclusions and porosity.
Weldability—steels

- Steels -- Weldability of steels is inversely proportional to its Hardenability, due to martensite formation during heat treatment.

\[
\begin{align*}
\text{Carbon content} & \uparrow & \text{Hardenability} & \uparrow & \text{Weldability} & \downarrow
\end{align*}
\]

- There is a trade-off between materials strength and weldability.
- Austenitic stainless steels tend to be the most weldable but suffer from distortion due to high thermal expansion. Cracking and reduced corrosion resistance.
- Ferritic and martensitic stainless steels are not easily welded, often to be preheated and use special electrodes.
- Ferritic steels is susceptible to hot cracking if the ferrite amount is not controlled.
Defects in weldments

- It is **unusual** for the weldments to be completely sound.
- They normally contain small defects such as porosity, slag, oxide inclusions, lack of fusion, undercut, crack, distortion, etc.

- Understand the cause
  Solve/prevent the problem
- Furthermore, different metals have different weldability so we need to understand the nature of the metal to be welded

Cross sections of welds containing typical defects
Defects in weldments

Incomplete fusion

Root and joint penetrations

Groove welds and various defects
Mechanical Fastening

• Spot clinching and self-pierce riveting
  – The joining of material combinations which cannot be easily welded such as pre-painted steels or very dissimilar metals
    • Ex: Al application in autobody make use of mechanical fastening techniques to overcome the poor inherent weldability of Al
  – The joining of materials in applications where high fatigue life is critical compared to static strength
  – The joining of materials where a long tool life is of relative importance
  – Screws and bolts
Self-piercing Riveting
Self Piercing Rivet

Back side access
Flush to top sheet (countersunk rivet)
Rivet tail should not pierce button
Can be used for dissimilar materials (no fusion)
Ductility in the material, die side 12% (problem with high strength material)
Total thickness Steel 6mm thick, Aluminium 10 mm
Can join more than two sheets
Pre-painted sheet is possible
No fumes/flames, low noise
Low energy demand
Good fatigue performance
Spot Clinching Process

• Clinching, or press joining, is a high-speed mechanical fastening technique for point joining of sheet metal.
• With clinching, the sheets are clamped between a die and a blankholder (1).
• The punch locally forms the sheets down into a die (2).
• The sheets are squeezed between the punch and die causing sideways movement of the material (3) to form an interlocking button (4).
• Alternative process variants use a solid circular die or a rectangular punch and die which allows partial shearing of the sheets. Clinching is a fast and simple single-step technique requiring no consumables or pre-drilled holes.
Schematic Representation of the Clinching Operation
Hemming Process

Inner panel

Hemming roller

Outer panel

Die

http://nsmwww.eng.ohio-state.edu/Stamping_Glossary/html/r.html

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Adhesive Bonding

• Classified based on transition from liquid to solid takes place either physical (hot melt adhesives) or chemical (curing adhesives)
• Thermosets and thermoplastics are used in automotive applications
• Thermosets are preferred where high shear strength, stiffness and durability is required
• Thermoplastics are preferred where energy absorption due to impact loading is likely
Joins plain, coated, and dissimilar metals.
- No rivets, screws or other fasteners.
- Eliminates spot welding operations.
- Long tool life; 250,000 joints common.
- Joins in a single press stroke.
- Non destructive checking with a simple gage.
- Strong and highly fatigue resistant.
- Leakproof joints.
- No sparks, fumes or soot.
Adhesive Bonding

• Trim assembly applications to attach
  – Carpets, mirrors, stiffeners on the inside of doors, bonnets and hoods etc
• Ability to join dissimilar materials that are not weldable
• Bonnet panel stiffeners, glass to metal, dissimilar materials
• Provides uniform stress distribution, increasing structural stiffness
• Improvements in NVH performance
• Sealing of joints
## Common Adhesives

<table>
<thead>
<tr>
<th>Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>Cheap, easy to apply</td>
<td>Overheating can produce corrosive by-products</td>
</tr>
<tr>
<td>Nitrile phenolic</td>
<td>Cheap, easy to apply</td>
<td>May retain moisture</td>
</tr>
<tr>
<td>Rubber based</td>
<td>Good anti-flutter properties</td>
<td>Cannot meet higher structural strength</td>
</tr>
<tr>
<td>Epoxies</td>
<td>Capable of meeting higher strength requirements</td>
<td>Health and safety requirements which require careful application</td>
</tr>
</tbody>
</table>
Summary

- Resistance welding is the predominant mode of joining used in assembly of steel enclosures
- Significant changes are required for the resistance welding of Al compared with steel
- Soldering has extensive applications in manufacturing of electronic devices and circuits
- For optimum performance and durability of adhesive bonding, use of pretreatment is recommended
- Mechanical fastening systems are finding increasing use as mixed material joints