MIET2510

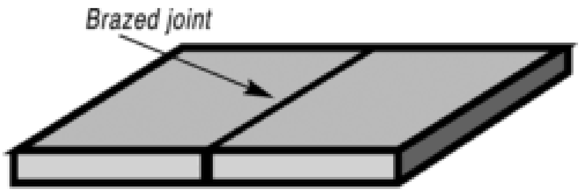
Mechanical Design

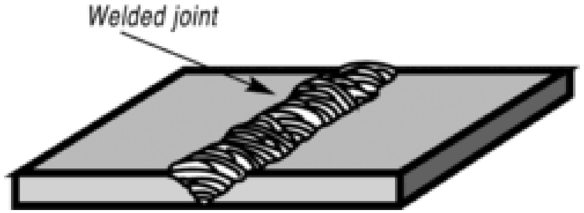
Week 8 – Fasteners and Connections – Part 2

School of Science and Technology, RMIT Vietnam

Welded, Brazed, and Soldered Joints

- A weld is a **permanent joint** that results from diffusion of material across an interface and may include a filler metal. Welding applied to components with similar materials which have same melting temperature.
- Brazing and soldering develop an interface from the adhesion between members and a filler metal. Brazing occurs above 450 C.





Welded Joints compared to Fasteners

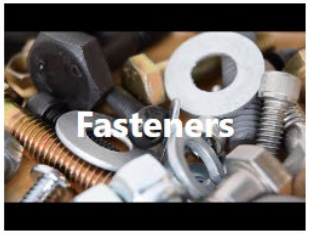
- Advantages;
  - Inexpensive
  - No danger of joint loosening
- Disadvantages;
  - Produce residual stresses
  - Metallurgical changes occur
  - Disassembly is a problem
  - Weld quality depends on operator skill

Welding methods

- **Fusion Welding** involves melting and coalescing materials by means of heat, usually supplied by chemical, electrical, or high energy means. Ex: Oxygen gas welding.
- **Solid-state welding** is a group of welding processes that produces coalescence at temperatures essentially below the melting point of the base materials being joined, without the addition of brazing filler metal

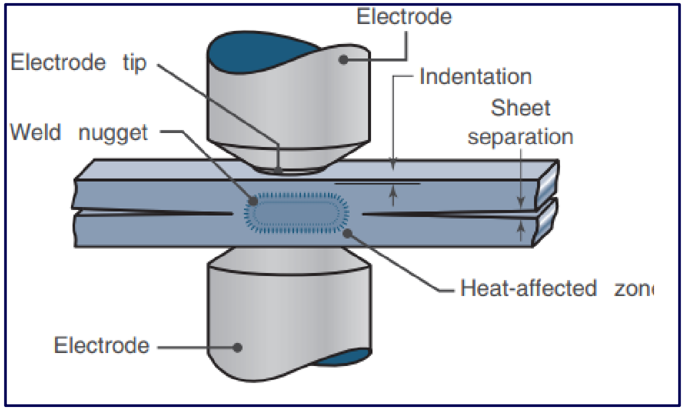
https://bamason2.github.io/miet2510-module/notes/fasteners_and_connectors.html

Welding Methods



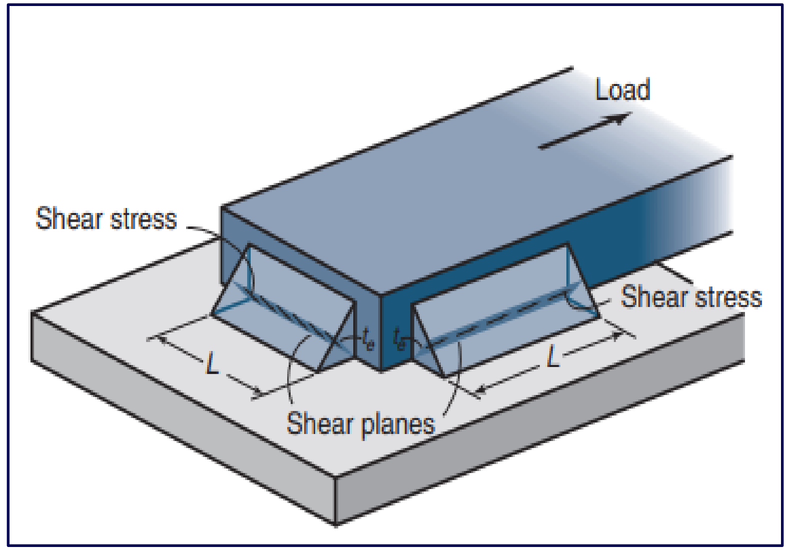
Configurations of welds – Spot Welds

- **<u>Spot welding</u>** is one of the most commonly used processes in sheet metal fabrication and automotive body panel assembly.
- In spot welding, the tips of two opposing solid, cylindrical electrodes touch a lap joint of two sheet metals, and resistance heating produces a spot weld. To obtain a strong bond in the weld, pressure is applied until the current is turned off and the weld has solidified.



Configurations of welds – Line Welds

- The line welding processes result in weld beads or lines that have a small width compared to their length.
- Several different line joints can be achieved, and **fillet weld** is of the most common ones.



Type of weld							
Bead	Fillet	Plug or slot	Groove				
			Square	V	Bevel	U	J

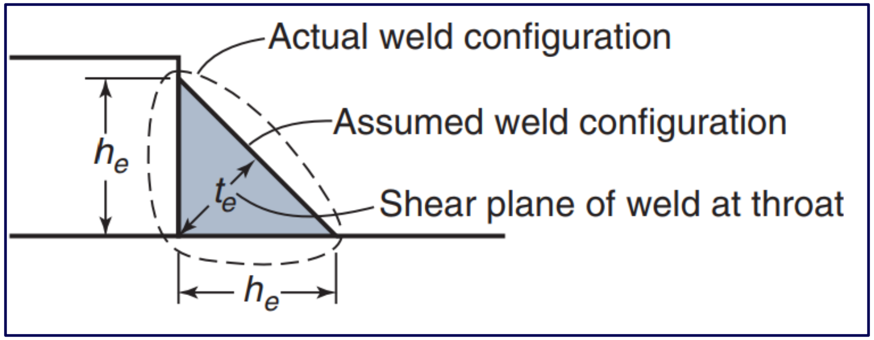
Configurations of welds – Line Welds

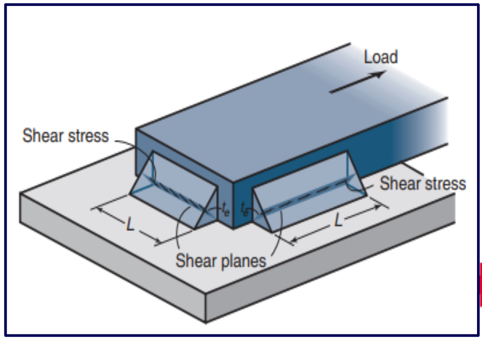
- In Parallel and Transverse Loading, shear stress is:

$$\tau = \frac{P}{t_e L_w} = \frac{P}{0.707 h_e L_w} = \frac{1.414P}{h_e L_w},$$

where t_e is the weld throat length, h_e is the weld leg length, and L_w is the weld length. Thus, to avoid failure, the following should be valid:

$$\frac{S_{sy}}{n_s} = \frac{P}{t_e L_w}.$$





Configurations of welds – Line Welds

- In Torsional Loading, the shear stress is;

$$\tau_t = \frac{Tr}{J},$$

where r is the distance from the centroid of the weld group to farthest point in the weld, T is the applied torque, and J is the polar area moment of inertia. The critical section for torsional loading is the throat section, as it is for parallel and transverse loading.

$$\boxed{J = t_e J_u = 0.707 h_e J_u.}$$

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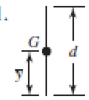
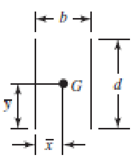
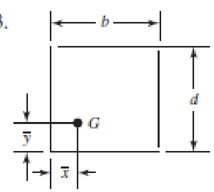
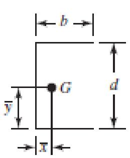
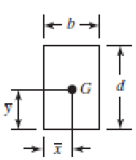
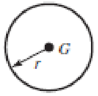
Tensile Properties of Fillet Welds

Weld	Throat Area	Location of G	Unit Second Polar Moment of Area
1. 	$A = 0.707hd$	$\bar{x} = 0$ $\bar{y} = d/2$	$J_u = d^3/12$
2. 	$A = 1.414hd$	$\bar{x} = b/2$ $\bar{y} = d/2$	$J_u = \dfrac{d(3b^2 + d^2)}{6}$
3. 	$A = 0.707h(b + d)$	$\bar{x} = \dfrac{b^2}{2(b + d)}$ $\bar{y} = \dfrac{d^2}{2(b + d)}$	$J_u = \dfrac{(b + d)^4 - 6b^2d^2}{12(b + d)}$
4. 	$A = 0.707h(2b + d)$	$\bar{x} = \dfrac{b^2}{2b + d}$ $\bar{y} = d/2$	$J_u = \dfrac{8b^3 + 6bd^2 + d^3}{12} - \dfrac{b^4}{2b + d}$
5. 	$A = 1.414h(b + d)$	$\bar{x} = b/2$ $\bar{y} = d/2$	$J_u = \dfrac{(b + d)^3}{6}$
6. 	$A = 1.414\pi hr$		$J_u = 2\pi r^3$

*G is the centroid of weld group; h is weld size; plane of torque couple is in the plane of the paper; all welds are of unit width.

Configurations of welds – Line Welds

In bending, the welded joint experiences a transverse shear stress as well as a normal stress.

In bending, the normal stress is: $\boxed{\sigma = \frac{Mc}{I}}$ $\boxed{I = t_e I_u = 0.707 h_e I_u}$

where c is the distance from the neutral axis to the outer fiber.

In bending, the shear stress is similar to the shear stress in transverse loading.

Configurations of welds – Area Welds

- Many welding operations produce a weld joint over an area, such as cold rolling, diffusion bonding, or friction welding; this is also the situation for brazed and soldered joints.
- From a design analysis standpoint, these joints can be treated like adhesively bonded joints as discussed in next section, but the allowable stresses over the interfaces are accordingly larger.

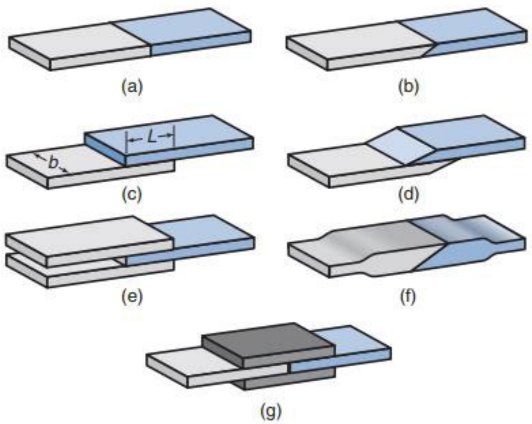


Figure 16.29: Examples of adhesively bonded joints. (a) Butt; (b) scarf; (c) lap; (d) bevel; (e) double lap; (f) increased thickness; (g) strap.

Adhesive Bonding

Adhesive bonding is the process of joining materials chemically through the formation of interatomic or intermolecular bonds. Adhesive bonding can be used to join a wide variety of materials (metal to metal, metal to ceramic, metal to polymer, etc.) for both structural and non-structural uses.

	Epoxy	Polyurethane	Modified acrylic	Cyanoacrylate	Anaerobic
Impact resistance	Poor	Excellent	Good	Poor	Fair
Tension-shear strength, MPa	15–22	12–20	20–30	18.9	17.5
Peel strength, N/m[a]	< 523	14,000	5250	< 525	1750
Service temperature range, °C	–55–120	–40–90	–70–120	–55–80	–55–150
Solvent resistance	Excellent	Good	Good	Good	Excellent
Moisture resistance	Good–excellent	Fair	Good	Poor	Good
Odor	Mild	Mild	Strong	Moderate	Mild
Toxicity	Moderate	Moderate	Moderate	Low	Low
Flammability	Low	Low	High	Low	Low

[a] Peel strength varies widely depending on surface preparation and quality.

Adhesive Bonding – Common Joints

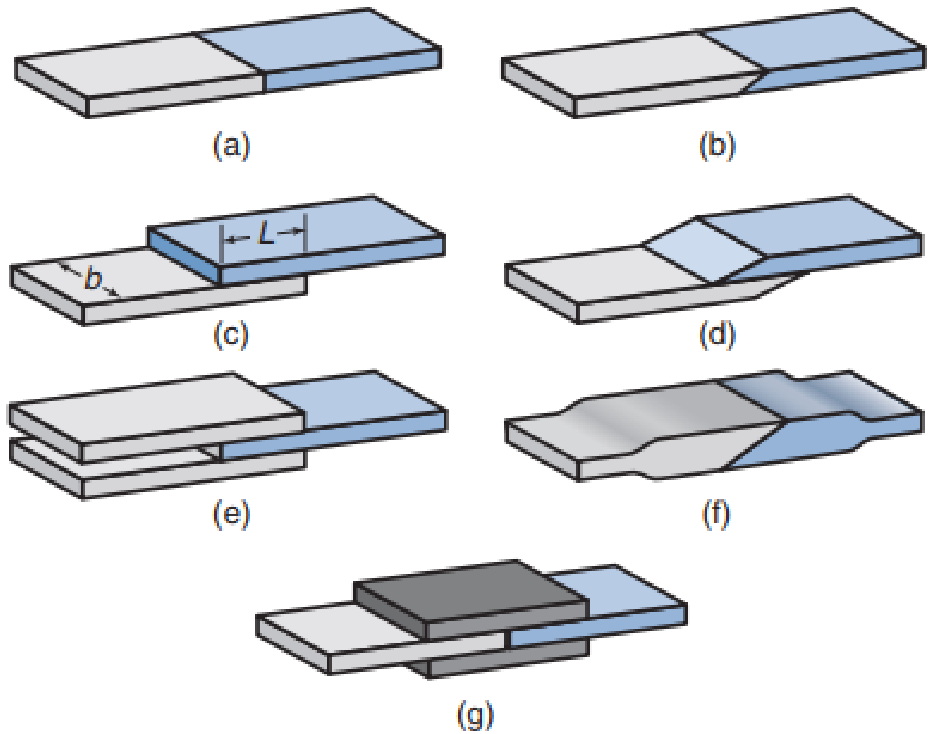


Figure 16.29: Examples of adhesively bonded joints. (a) Butt; (b) scarf; (c) lap; (d) bevel; (e) double lap; (f) increased thickness; (g) strap.

Adhesive Bonding - Advantages

- Uniform stress distribution with resultant increased life
- Reduced weight
- Improved fatigue resistance
- Ability to join thick or thin materials
- Ability to join dissimilar materials
- The adhesive results in leakproof joints
- Vibration-damping and insulation properties
- Economic advantages associated with cost of adhesive and ease of assembly

Adhesive Bonding - Disadvantages

- Possible need for extensive surface preparation
- Service temperatures are more limited compared to welds, brazes, or solders
- Tendency to creep under sustained load
- Questionable long-term durability

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Adhesive Bonding – Stress Analysis

- For typical lap joint configuration: $$\tau_{\max} = 2\tau_{\text{avg}} = \frac{2P}{bL}.$$

- For scarf joint under axial load, normal stress and shear stress is

$$\sigma_n = \sigma_x \sin\theta = \frac{P}{bt_m}\sin^2\theta,$$

$$\tau = \sigma_x \cos\theta = \frac{P}{bt_m}\sin\theta\cos\theta = \frac{P}{2bt_m}\sin 2\theta.$$

- For scarf joint under bending, the shear stress is

$$\tau = \frac{\sigma_n}{\tan\theta} = \frac{6M}{bt_m^2}\sin^2\theta\frac{\cos\theta}{\sin\theta} = \frac{6M}{bt_m^2}\sin\theta\cos\theta = \frac{3M}{bt_m^2}\sin 2\theta.$$

- For scarf joint under torsional loading, the shear stress is $$\tau = \frac{2Tr\sin\theta}{\pi\left(r_o^4 - r_i^4\right)}.$$ $$\sigma_n = 0.$$

Thank you for your attendance :D

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Reference

- *Mechanical Design of Machine Components (2nd) by Ansel C.Ugural.*
- *Mechanical Engineering Design (10th) by Richard G.Budynas and J. Keith Nisbett.*
- *Theory of Machines and Mechanisms (5th) by John J.Uicker, Gordon R.Pennock, Joseph E. Singley.*