MINI-PROJECT 7

JOINING AND ASSEMBLY

ME 270: *Design for Manufacturability*

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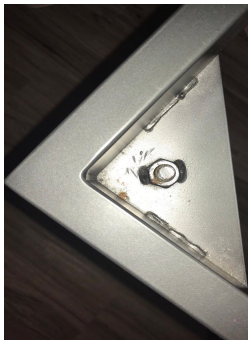
AB5_3

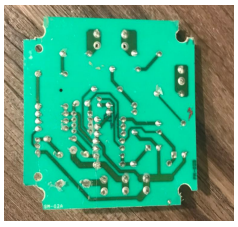
PRODUCTS

WELDING



Welding is always used to provide strong connection, which makes most of the products made by welding large and heavy. What we found is to connect a mattress frame. The welding part is used for connecting outer frame and a triangular board. And the board is connected to the leg of the frame.

BRAZING AND SOLDERING



This product is a circuit board which is made by wave soldering. Wires would be soldered to its respective connectors on the circuit board.

ADHESIVE BONDING

This product is a magnetic ring adhered to a steel casing. It is disassembled from a mini-fan in a DC power supply.

MECHANICAL FASTENING

This product is an outlet. The metal part that contains electric elements is connected together by threader fasteners like screws. And outlet panel is also connected to the metallic box of electric element by screws.

FORM CLOSURE JOINING

This product is a still in-use vacuum. The stick and vacuum head are connected by snapping fit. There is a raised area inside figure 2 which can interlock with the groose shown in figure 1 along the direction of the stick. A pressing of the grey button causes the deformation and these two parts will be unlocked.

JOINT GEOMETRIES

T-joint is involved in welding. Sleeve-joint is involved in adhesive bonding and form closure joining. Lap-joint is involved in mechanical fastening. It is ambiguous to tell the joint geometry in wave soldering because it is involved to T-joint and sleeve-joint but also can not be clearly classified.

Materials are similar for the 2 components joint of T-joint and Lap-joint, and all of them are metallic in this case. And for the form closure joining, it is a connection of plastic, but for the adhesive bonding, it is a magnet connected with metal.
It is hard to get rid of the bonding made by welding and adhesive bonding. Disconnect the joint of soldering is easy but it can hardly be done without damage the components. For a normal joint made by form closure joining, which does not have a button to reduce the force need for unlock, it needs a force to make it but achievable. Undoing mechanical fastening is the easiest as long as tools are provided.

WELDABILITY OF AISI

The main difference between AISI 304 and AISI 316L is that there is a concentration of molybdenum in AISI 316L. AISI 304 is a base meta while AISI 316L is a filler metal. The “L” in the metal name indicates that that that metal is limited to lower temperatures. It also signifies that there is an extremely low carbon content in the product. This means that the weld will only hold well if there is another base metal with a low carbon content as well when it is put into use. AISI 304 however will work under many more circumstances and on a larger variety of metals.

THERMAL CONDUCTIVITY[1]

Higher thermal conductivity means that heat will spread quickly among the material. It makes the welding process less efficient because more heat is spread to the area that we do not want to weld. Residual thermal stresses are caused by non uniform temperature, and higher thermal conductivity leads to relatively uniform temperature, hence fewer residual thermal stresses. Therefore, the efficiency of the welding process of low-carbon steel is higher and the resulting residual thermal stresses of aluminum is fewer.

[1] https://www.slideshare.net/jeetendramalav/residual-stress-in-welding

WELDING METHODS

OXY-ACETYLENE GAS WELDING[2]

Oxy-acetylene gas welding is a very common welding process, coming short of Tungsten and Metal-inert gas welding. The process uses oxygen and acetylene gases in pressure cylinders. As the gases are allowed to pass from their respective steel tanks, they are fed into a torch which is used to melt materials together at a flame temperature of over 6000℉. The temperature is adjusted by regulating how much gas is allowed to flow to the flame. This welding process is is better for low carbon steels and is better for use with aluminum alloys.

TUNGSTEN-INERT-GAS WELDING[3]

Tungsten-inert gas welding, also known as TIG welding, is a welding process used for precise welds where the flame temperature is low, metal thickness is low, and can even be used on expensive and “exotic” metals. This process is slower than MIG welding, but it is significantly more precise. TIG welding uses a non-consumable tungsten electrode which provides a lot of control to the user when it comes to typical welding factors such as heat. This welding process also does not require the use of a filler metal unlike other welding processes. TIG welding is more commonly used to weld steel, titanium, and is best used with aluminum alloys.

METAL-INERT-GAS WELDING[4]

Metal-inert gas welding, also known as MIG welding, is a welding process used extremely often. The process includes a consumable wire electrode that melts filler metal from a feeder wire. This process is much less precise welding operation than TIG welding, but it still creates a very strong and uniform weld on two metals. This weld can also be held in almost all joint positions which makes it a very versatile welding process. Unlike TIG and oxy-acetylene gas welding, MIG welding is better for low alloy metals and is better for carbon steels.

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[2] http://www.advantagefabricatedmetals.com/oxyacetylene-welding.html
[3] http://www.advantagefabricatedmetals.com/tig-welding.html
[4] http://www.advantagefabricatedmetals.com/mig-welding.html

RESISTANCE SPOT WELDING[5]

Resistance spot welding is a welding process where metal surfaces are joined together from the heat created from the resistance generated from a running electric current. Typically in this welding process, sheet metal thickness is extremely thin. The process uses two copper electrodes that force the current into a specific point that will in turn melt the joint in which the two surfaces should join. The current cannot be held to the metal for too long or else it will form a hole, so this process has to be very precise for it to work properly. Spot welding is not used with carbon metals and is better used with aluminum alloys.

LASER WELDING[6]

Laser welding is a welding process that joins metals together using a laser. The laser has an extremely small diameter and thus allows for deep welds with a high welding rates. This process is often automated and is used in high volume production lines. This welding process is very different than the other welding processes outlined above as it is compatible with both carbon steels and aluminum alloys. This process is preferred to use with aluminum alloys as there concerns with the material fracturing if it has too high of a carbon concentration.

WELDING PLASTICS[7]

Plastics can be welded together if they each meet specific criteria regarding their structure and tolerances. Plastics can only be welded to each other if they are both amorphous. On top of this requirement they must also have similar glass transition temperatures. If the glass transition temperatures are significantly different, then one of the plastics could undergo deformation or melt which would affect the integrity and functionality of the plastic. Two plastics that could be welded together would be ABS and PS as they both are amorphous and have similar glass transition temperatures.

[5] https://en.wikipedia.org/wiki/Spot_welding
[6] https://en.wikipedia.org/wiki/Laser_beam_welding
[7] https://www.twi-global.com/technical-knowledge/faqs/faq-is-it-possible-to-weld-dissimilar-plastics

EUTECTICS: BRAZING AND SOLDERING[8]

Apart from a low melting point and a high bond strength, eutectics has a very beneficial trait that is extremely conductive when using eutectic wafer bond. This trait is specific to eutectic alloys formed by wafer bonding and is extremely beneficial when soldering on semiconductors. It has incredible electrical interconnection abilities because it of the process. Eutectic alloys are formed from combining two or more metals that will react and form a precipitate which gains traits that can be controlled based on the metals used that were reacted together. Another useful quality of eutectics is that you can easily alter the traits of the alloy formed based on the base metals used in the reaction.

OVERLAP LENGTH

The overlap length can be calculated using tensile strength.

$$thickness \times A_{tube} = \tau \times A_{shear}$$
$$690 \times \pi \times D \times t = \tau \times \pi \times D \times L$$
$$690 \times t = 20 \times L$$
$$L_{overlap} = 34.5t$$

OVERLAP STRENGTH

The adhesive joint will become stronger than the sheets when the sheet thickness is less than the overlap length. This is shown through the following equation where overlap length is L and sheet thickness is t.

$$10 \times L \times 1 = 10 \times t \times 1$$
$$L = t$$

Based on the overlap strength defined above we can conclude that strength and sheet thickness are directly related.

ADHESIVES

DRYING ADHESIVES

Drying adhesives can be identified by two types called solvent-based adhesives and polymer dispersion adhesives. Examples of drying adhesives include rubber cements, super glue, and the common household white glue. These are made from polymers

[8] https://www.sciencedirect.com/topics/engineering/eutectics

dissolved in solvents and as the solvents evaporates the adhesive components. Drying adhesives create semi-permanent joints.

MULTI-COMPONENT REACTIVE ADHESIVES

Multi-part adhesives harden by mixing compounds which chemically react. When the two polymers react with each other they form a wide variety of industrial resins and epoxies. Often, these epoxies have a unique trait of being waterproof. Unlike drying adhesives, multi-component reactive adhesives create permanent joints.

SINGLE-COMPONENT REACTIVE ADHESIVES

Single-component reactive adhesives are similar to multi-component reactive adhesives as they both involve a chemical reaction in order to bond materials. However, instead of multiple polymers reacting with each other, single component adhesives are formed when one polymer reacts with an external energy source such as ultraviolet light or heat. These reactive adhesives create permanent joints just like multi-component reactive adhesives.

HOT MELTS

Hot-melt adhesives are thermoplastics that are melted down and solidify when cooling to bind two different surfaces together. This form of adhesive can be used on multiple different types of surfaces. An example of hot-melt adhesives commonly appear as hot glue guns. Like drying adhesives, hot-melt adhesives create semi-permanent joints.

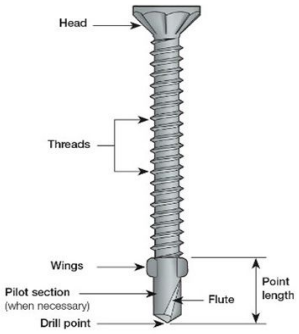
BOLT ELONGATION

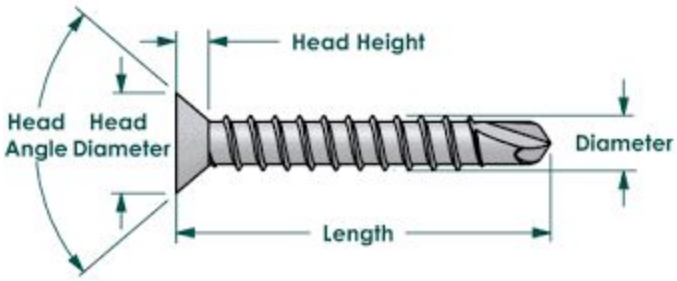
Elastic strain is Yield stress/Young's modulus
Yield stress: 660 MPa
Young's modulus: 200 GPa
Elastic strain = Yield stress/Young's modulus = 0.003
Elongation = Elastic strain * length = 0.09 mm

SELF TAPPING AND CUTTING SCREWS

Self-cutting screws are also known as self-drilling screws and these screws work as both a fastener for thin pieces of sheet metal and as a drill bit. Self-tapping screws use its own threads on the screw body to dig into the material. In addition the wings on the body at the bottom of the threads act as a tap and can form threads in the material being drilled into. The most significant difference between the two are that the self-tapping screw requires a pilot hole with a diameter smaller than the one of the

screw while the self-drilling screw does not. The image on the left is of a self-tapping screw while the one on the right depicts a self-cutting screw.





RIVETING AND JOINT STRENGTH[9]

The rivet and the hole itself affect joint strength because there are three ways in which a rivet can fail. The first way is by tearing the plate is the force is too much, the plate may fail in tension. Using the equation...

$$P = s(p - d)t$$

s = tensile strength of the plate
p = pitch
d = diameter of rivet hole
t = thickness of plate

The greater the diameter of the rivet hole and pitch, the greater force allowed before failing. If difference between the pitch and the diameter are greater, than the force allowed before failing is greater.

The second way a rivet can fail is by shear stress. The equation below calculates the greatest force the rivet can endure before failing for a lap joint. Therefore, the greater the diameter of the rivet hole, the greater the force it can withstand.

$$P = s(pi/4)d^2$$

s= shear stress of the material of the rivet

The third way a rivet can fail is by crushing the rivet. If the bearing stress is too high, the sheet may be damaged. Using the equation below, the greater the diameter of the rivet hole, the greater force it can withstand.

$$P = s \times d \times t$$

[9](http://www.idc-online.com/technical_references/pdfs/mechanical_engineering/Design_of_Riveted_Joints.pdf)

s = bearing stress between rivet and plate

However, rivets expand to fill the hole with an interference fit. This interference fit makes the rivet fail earlier because the joint bears the loading earlier.

MAXIMUM ELASTIC DEFORMATION

ABS[10]:
Young's Modulus 1.825 GPa
Yield strength 39 MPa

ABS with 30% GF[11]:
Young's modulus 7.16 GPa
Yield strength 73.5 MPa

Elastic strain=Yield strength/Young's modulus
Elastic strain:
Standard ABS: 0.02137
ABS with 30% glass fiber: 0.01027
Both of them are very brittle, and they can easily crack during snap fitting, so they are not suitable for snap fits.

PRODUCT JOINING METHODS

PRODUCT 1

Welding and mechanical fastening are involved in the mattress frame. Inside single fillet corner joint is used for welding and it makes a T-joint. Bolts are used in mechanical fastening and makes a lap-joint. The former is permanent and the latter is semi permanent.

PRODUCT 2

The circuit board is made by wave soldering. This is a permanent connection.

PRODUCT 3

The magnet ring and cover are connected by adhesive bonding. It is a permanent connection and they form a sleeve-joint.

PRODUCT 4

[10] http://www.matweb.com/search/DataSheet.aspx?MatGUID=3a8afcddac864d4b8f58d40570d2e5aa
[11] http://www.matweb.com/search/DataSheet.aspx?MatGUID=b4916d0a6777469986e9d8687a8b4a69

The metallic part of outlet box is build by screws which is mechanical fastening. This is a semi permanent connection and they form a lap-joint. The jack and metallic box are connected by knockdown fit which is a permanent connection.

PRODUCT 5

The vacuum is connected by snap fit, mechanical fastening, welding, soldering and adhesive bonding. The whole part is very complex and involves all kinds of joint methods and processes.

DESIGN FOR MANUAL OR ROBOTIZED ASSEMBLY

There are four types of assembly lines: classic, automated, intermittent, and lean. The classic assembly line uses multiple steps and multiple workers to create one product. The advantage of this type is that each product created is almost identical regardless of size or complexity of the product. The automated line is usually made up of multiple machines. The advantage of this line is that it reduces long-term costs and the likelihood of human error as well as the ability to use hazardous material without harming humans. The intermittent line does not produce identical products but allows for easy customization. It allows quick assembly with easy customization. The lean line is similar to the classic line however instead of one person at each step, there are a team of people at each step of the assembly. This is better for the workers and the workers are able to have a longer career on the line. The “easiest” to design for is all dependent on the customization of the product. If the product is customizable, then the best line would be the intermittent line. However, if an identical, complex product needs to be assembled, the automated assembly line would be easiest to design for because it limits human error and are able to use hazardous material.