MIT 2.008 Design and Manufacturing II

Spring 2025

Homework 3 – Assembly/Disassembly and Joining Processes.

Released: February 26th, 2025 2:00PM

Learning Objectives

- *Visualizing and designing the assembly process.*
- *Learning to implement Design for Manufacturing and Assembly (DFMA) principles by assessing and improving assembly designs.*
- *Learning general knowledge regarding the various joining processes.*

General Notes

- *For qualitative answers, we're not looking for long essays. Please answer using short (1-2 sentences per answer) bullet points.*
- *For quantitative answers, show your work as clearly as possible. When possible, keep answers in algebraic form until plugging in numbers at the very end; this way, it is much easier for graders to understand where you make mistakes and provide meaningful feedback.*

HOMEWORK TOTAL POINTS: 100 pts

Problem 1 - Design for Assembly of a Motor Drive Assembly (80 pts)

The exploded view below (or the next page) shows the design of various parts of a motor drive assembly that is required to sense and control its position on two steel guide rails (as seen in **Appendix 1**. You are a manufacturing engineer and you have been assigned the task to improve this design keeping the principles of Design for Assembly (DFA) in mind. *Note: The dashed lines in the exploded view are colored to show how the various parts fit together.*

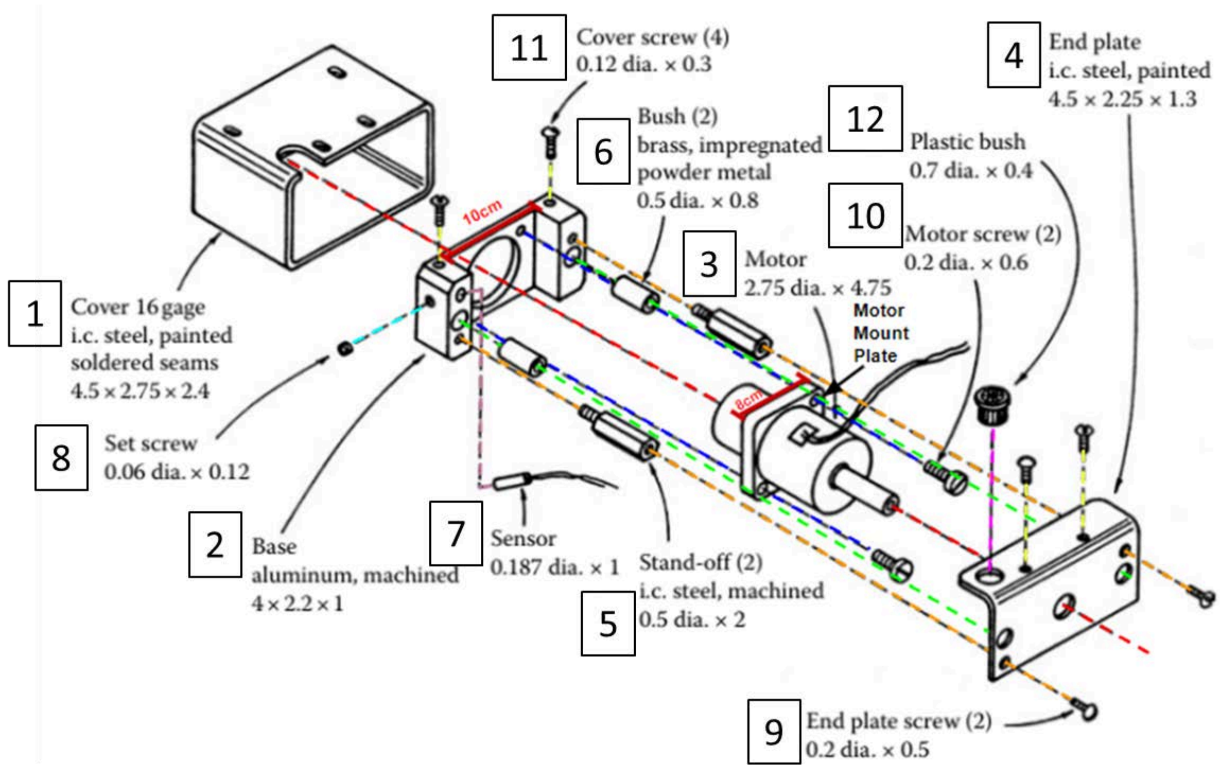


Figure 1. Design Proposal for a Motor Drive Assembly Unit (Exploded View).

The table below lists the various parts that go into this motor drive unit and their associated uses.

Part No.	**Part Name**	**Quantity Used**	**Function**
1	Cover	1	Used to cover the drive unit subassembly (all the parts except for the cover and endplate) on all sides, except for the front (which is covered by the end plate)
2	Base	1	Used as a base to mount the motor subassembly, sensor, cover, and end plate. Interface with the steel guide rails via the bushings (as seen in Appendix 1)
3	Motor Subassembly	1	The Motor subassembly is an off-the-shelf part and consists of a motor and a motor mount plate.

4	End Plate	1	This part covers the front side of the drive unit subassembly.
5	Standoff	2	On one side, the standoffs screw into the base (has external threads). On the other side, the end plate screws go through the end plate and screw into the standoffs (internal threads) ensuring the end plate is mounted to the base.
6	Brass Bushing (Bush)	2	The bushings are positioned in holes on the base to interface the base with the two steel guide rails, as seen in Appendix 1.
7	Sensor	1	The sensor serves as an encoder that measures the motor speed for feedback control.
8	Sensor Fixture Screw	1	The screw constrains the sensor in its hole in the base.
9	End Plate Screw	2	The end plate screw attaches the end plate to the standoffs which in turn connects to the base
10	Motor Screw	2	The motor screw connects the motor subassembly to the (thinner part of the) base.
11	Cover Screw	4	There are a total of 4 cover screws: 2 of the cover screws attach the end plate to the cover, while the other 2 screws attach the base to the cover.
12	Plastic Bushing (Bush)	1	This part provides access to the wires that are coming out of the sensors/motor.

a. The first step in assessing the current design is understanding it. Describe how the individual parts shown in Figure 1 and listed above are assembled into the complete drive assembly unit. *Tip: many parts assemble onto the base, so that's a good place to start.*

Steps	Description
1.	

b. Using the DFMA principle of reducing part count/reducing assembly steps, how would you change the design to make the assembly cheaper? (assume cost of assembly is proportional to part count/assembly steps). Please answer by thinking through which parts are essential and must be kept, vs parts that are redundant and can be removed or combined. Afterwards, draw a simple sketch of the new design.

Notes:

- *You cannot change the motor sub-assembly location/design, sensor location/design, or deviate from the requirement that the drive unit needs to have a cover.*
- *Your new design* ***must reduce part count by at least half*** *and* ***reduce assembly steps relative to the existing design****.*
- *There may be multiple possible answers to this. As long as you can provide a brief rationale that is in alignment with DFMA principles, you will get credit.*

Part No.	Part Name	Quantity Used	Keep/Remove/ Combine?	Rationale
1	Cover	1		
2	Base	1		
3	Motor Subassembly	1		
4	End Plate	1		

5	Standoff	2		
6	Brass Bushing (Bush)	2		
7	Sensor	1		
8	Sensor Set Screw	1		
9	End Plate Screw	2		
10	Motor Screw	2		
11	Cover Screw	4		
12	Plastic Bushing (Bush)	1		

Sketch new design below:

c. Similar to part (a), can you describe how the parts of the newly designed assembly in part (b) assemble together? *Hint: You should have a fewer number of assembly steps in the new design.*

Step	**Description**
1	

d. If you use a simple assumption that the cost associated with assembling the drive unit is directly proportional to the total quantity of parts, how much % reduction in assembly cost was achieved by the redesign?

Simplifying assumptions:

- Total cost is directly proportional to the total quantity of parts
- Regardless whether a part is as simple as a single screw or as complex as an off-the-shelf motor subassembly, each count as one part.
- Two screws count as two parts.

Problem 2 - Joining Methods (General Questions)

a. What is the difference between brazing and soldering? When would you use one over the other?

Brief Rationale

b. You are advised by someone at work to use aluminum rivets to join the hull plates of an ocean-going ship made out of steel. Is this a good idea? Why or why not?

Brief Rationale

Problem 3 - Joining Methods (Shrink Fit Situation)

Shrink fits (analogous to press fits) take advantage of thermal expansion to hold two components together without additional fixturing or adhesives. This is especially useful in heat shrink chucks that use this pressure to hold the cutting tool in a high precision CNC milling machine. Here is more info: https://blog.wirutex.com/thermogrip-chuck-cnc-machines

While the CNC tool holder and tool itself will be different material/geometries and will be a little more involved to analyze, let us instead work with an analogous shape as shown in Figure 2 to get a sense of shrink fit forces.

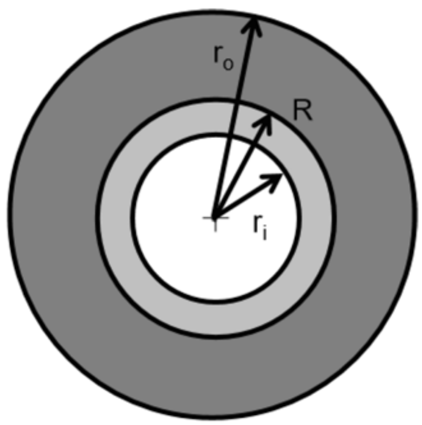


Figure 2. Shrink-fitting of two aluminum rings

Consider:

- a 5 mm thick aluminum ring of inner radius (r_i) = 40 mm and outer radius (R) = 45 mm that was shrunk to fit into
- an aluminum outer ring with outer radius (r_o) = 100 mm.
- The interface between them is thus at R=45 mm from the center.
- Their depths (into the page) are equal to 15 mm.
- The static friction coefficient between them is 0.7.
- Use Tables 2.2 and 3.1 in Kalpakjian (shown in **Appendix 2**) to find the mechanical and physical properties of aluminum.

The process of assembling them together was:

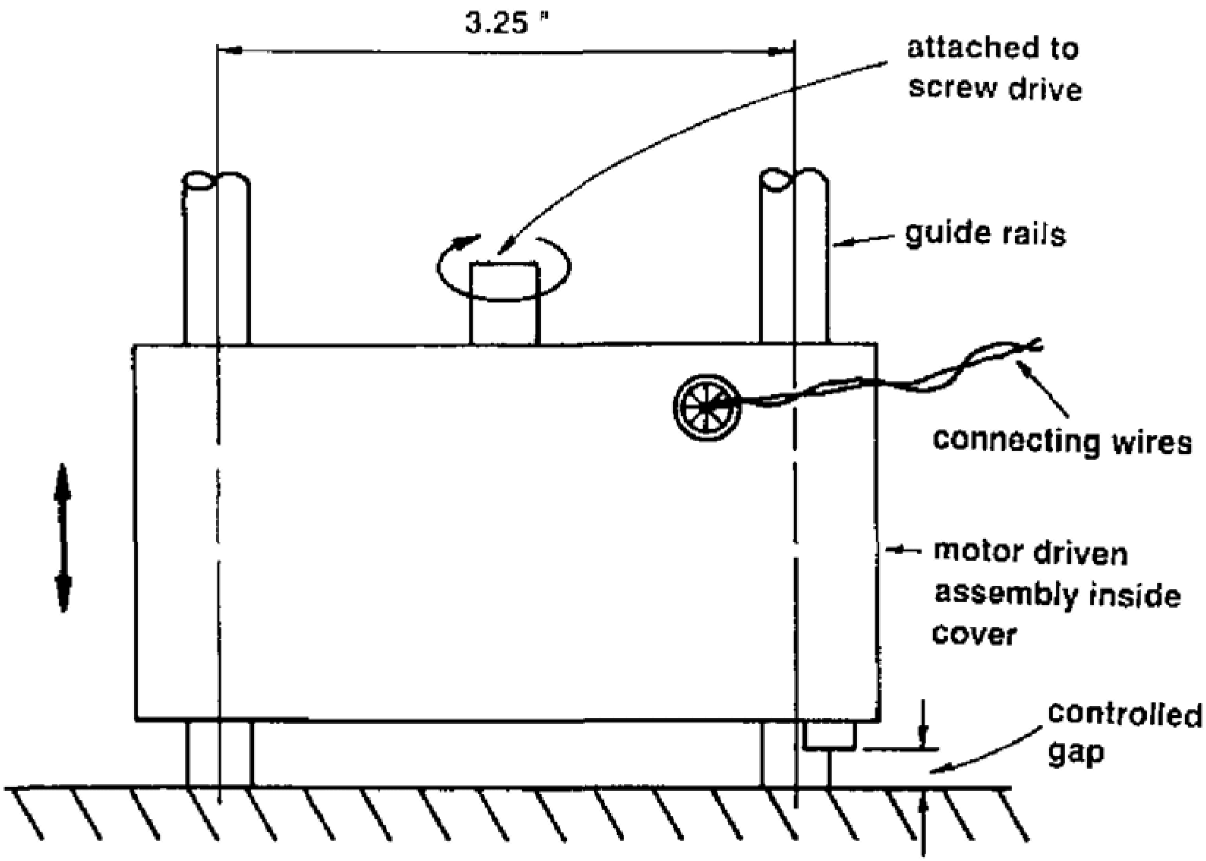
1. Heat the outer ring to 200°C above the ambient to expand the ring until the inner radius of the outer ring could just fit over the inner ring.
2. Slide the two rings together and allow assembly to cool to ambient.

Calculate:

a) The pressure developed at the interface after they have reached thermal equilibrium with the ambient. Refer to **Appendix 3** for the equation.

b) The force required to separate the two rings by sliding them apart after considering the pressure developed as calculated above.

Appendix 1. Configuration of motor drive assembly on two guide rails



Appendix 2. Mechanical and physical properties of aluminum.

Table 2.2: Mechanical Properties of Various Materials at Room Temperature.

Materials	Elastic modulus (GPa)	Yield strength (MPa)	Ultimate tensile strength (MPa)	Elongation in 50 mm (%)	Poisson's ratio, ν
Metals (wrought)					
Aluminum and its alloys	69–79	35–550	90–600	45–4	0.31–0.34

Table 3.1: Physical Properties of Selected Materials at Room Temperature

Material	Density (kg/m^3)	Melting point (°C)	Specific heat (J/kg K)	Thermal conductivity (W/m-K)	Coefficient of thermal expansion (μm/m-°C)	Electrical resistivity (Ω-m)
Metallic						
Aluminum	2700	660	900	222	23.6	$2.8\ 10^{-8}$

Appendix 3. Pressure developed at the interface of a shrink-fit material due to thermal deformation.

$$P = \frac{E}{R} * \delta * \left[\frac{\left(r_o^{\,2} - R^2\right) * \left(R^2 - r_i^{\,2}\right)}{2 * R^2 * \left(r_o^{\,2} - r_i^{\,2}\right)}\right]$$

P = Pressure developed at the interface (Pa)

E = Elastic modulus (Pa)

R = radius at interface (m)

δ = thermal deformation (m)

r_i = inner radius of inner ring (m)

r_o = outer radius of outer ring (m)