

Northeastern University College of Engineering

Department of Mechanical and Industrial Engineering

Boston, MA 02115

ME 4550 Mechanical Engineering Design

Instructor: Professor Yustianto Tjiptowidjojo

Course Description: Explores development of the mechanical design process and its open-ended nature. Reviews fundamentals of stress and theories of failure including fatigue considerations in the analysis of various machine components. Treatment is given to shafts, springs, screws, connections, lubrications, bearings, gears, and tolerances. Includes team-based design projects that involve modeling and the design process.

Concentrated Solar Thermal Course Material:

Implementation of Heliostat Project in Mechanical Engineering Design (ME 4550)

The Mechanical Engineering Design (ME 4550) is a four-credit course at Northeastern University which explores the development of the mechanical design process and its open-ended nature. The course reviews the fundamentals of stress and theories of failure including fatigue considerations in the analysis of various machine components. The course examines many essential topics in the design of machine components, such as shafts, springs, screws, connections, lubrications, bearings, gears, and tolerances. Finally, the course includes team-based design projects that involve modeling and the design process as an integral part of the curriculum.

The heliostat design has presented an interesting challenge to mechanical engineers over the years as several of them have been developed over the years. For the driving mechanisms, gear transmissions have been the most used drive over the years, especially worm-gear. An important consideration of a gear mechanism is the backlash, sometimes called lash or play, which is the clearance between mating components, sometimes described as the amount of lost motion due to clearance or slackness when movement is reversed, and contact is reestablished. The presence of backlash affects the tracking precision of the heliostat. To minimize backlash, very accurate dimensioning of the gear components is necessary and thus increases the cost of the driving mechanism. Alternative driving mechanisms include chains, belts, or cables although these options require larger space. We plan to introduce heliostat as one of the design projects in the course for two of the course learning objectives are (1) exploring commercial designs and products and (2) designing a product and developing a portfolio. The project is closely aligned with the course outline where it examines shafts, springs, screws, connections, bearings, gears, and tolerances.

First Heliostat Design (Group 6)

The first heliostat design has the following design specifications:

- 9 m² of 3M SMF 1100 or equivalent film in a square shape
- Aluminum 6061 backing plate
- Drive train:
 - Capable of 360° of azimuthal motion
 - Capable of 90° of elevation control
 - Gears:
 - A spur gear assembly, with less than 3 mrad of backlash
 - Custom anti-backlash system
 - One assembly for elevation control
 - One assembly for azimuthal motion
 - Electromagnetic brake to lock gears if necessary

- Frame:
 - Pedestal
 - Made of A500 structural steel
 - Includes stake to anchor the unit to the ground
 - Capable of surviving wind speeds up to 60 mph for 3 sec
 - Robust
- Capable of functioning in sandy environments indefinitely with maintenance
- Mechanical factor of safety: 1.5 for all critical components

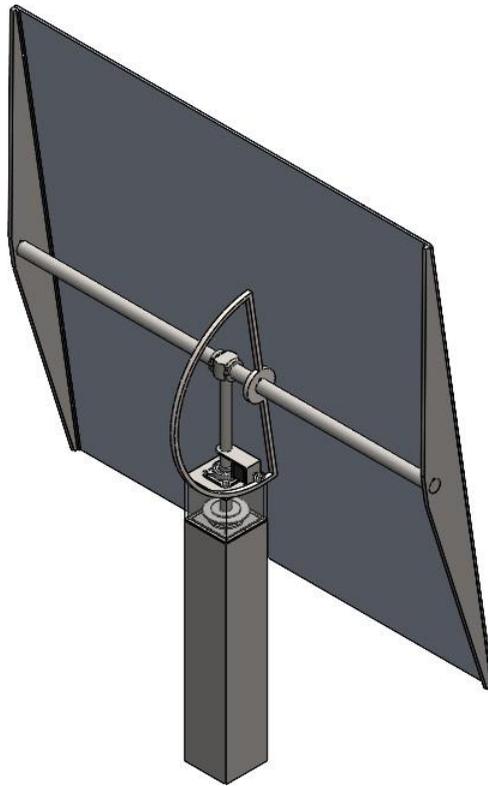


Figure 1. First Heliostat Assembly

The heliostat assembly is pictured above in Figure 1. The heliostat structure consists of three critical components worthy of analysis: the azimuth shaft, the mirror frame, and the mirror backing. The azimuth shaft is the shaft protruding from the pedestal, on which the mirror assembly rests. The azimuth shaft is 0.6 m tall. The body of the shaft is 60 mm in diameter. The mirror frame is the structure behind the mirror connecting it to the azimuth shaft. The mirror frame consists of a shaft and two flanges for connection. The analysis of the frame will be limited to the shaft, the backbone of the frame. The shaft is 3 m long and 80 mm in diameter. The mirror is a thin, reflective film coated on an aluminum panel. The panel is 3 m by 3 m, and 12 mm thick. This structure is rated to withstand wind speeds up to 60 mph. The factors of safety for these critical components are derived in the following analyses, in which these wind speeds are considered. The

summary of analysis for this first design is presented in the PowerPoint slides attached to this report.

Second Heliostat Design (Group 12)

The second heliostat design removes gears entirely from the current system. As one can see in Figure 2, the design hinges on its use of three lead screws that will allow the system the flexibility to redirect in any direction necessary, while distributing any loading evenly, and all with a high degree of precision.



Figure 2. Second Heliostat Assembly

The first component in the design is the mirror at the top. It will be 1 m^2 and weigh about 550N . Connected to the back of the mirror is a metal frame/rail which is welded to the mirror to prevent bending and allows the lead screws to slide across the back while supporting the weight. A ball joint is attached to the end of each lead screw which allows the lead screw to rotate in proportion to the rails. The lead screw is powered by a female threaded motor that is mounted into the motor mount. This motor will only need one horsepower, as the sun moves slowly through the sky, meaning only a small total speed output is needed. This motor mount is then bolted into the tripod base, which supports the total weight of the design. The tripod base is then bolted into the ground, which is assumed to be a cement platform, using multiple cap screws. This will hold the design in place, to ensure that even in high wind loading, the design will remain sturdy.