BILKENT UNIVERSITY

DEPARTMENT OF MECHANICAL ENGINEERING

INDUSTRIAL DESIGN PROJECTS

2023 – 2024

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Content

PREFACE

University-industry collaborations provide future engineers with a broad understanding of industry and business practices. Such collaborations also provide a platform for students to demonstrate creative design solutions to important problems encountered by industry. We provide this learning opportunity with a two-semester sequence of design courses for the senior-level students. This year, 12 groups, each consisting of five to six students, were provided with design projects from leading industrial organizations. Projects were selected such that students could leverage their undergraduate studies to design a product needed in today's world. Projects were also selected to bring out the students' creativity in both the design phase, which is completed in the first semester, and the embodiment phase normally completed in the second semester. At their final presentation sessions, the students are provided with a unique opportunity to present detailed design specifications of their products and the finished prototypes to the industrial sponsors.

We as a department are grateful to the academic and industrial mentors, instructors, and teaching assistants for the continuous guidance and advice they provided.

On behalf of the Mechanical Engineering Department, I would like to thank all those who have generously contributed their time and resources that enabled tomorrow's engineers to gain invaluable experience during this process and demonstrate their capabilities in these trying times.

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Design and Production of a Push-to-Open Mechanism for Dishwashers

TafelVanZes (1)

Sudeys Kara | Tolga Çağdaş Şahin | Bumin Reçber | Kerem Kuzgun | Selin Öncül | Ahmet Çağlar Gökalp

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Industrial Advisor : Alper Başaran
Teaching Assistant : Emirhan İnanç

ABSTRACT

The project aims to create a push-to-open mechanism for Arçelik dishwashers, with a goal of completion within two academic semesters. This innovative mechanism allows users to open the dishwasher door by exerting a specific push force, eliminating the need for external handles. Testing focuses on optimizing the door's opening force and seamlessly integrating the mechanism into the dishwasher's overall design. In the final design, the piezoelectric sensor was replaced with a load cell, and the electromechanical pusher system was upgraded with a linear actuator for improved efficiency and reliability. Signals from the load cell are processed by an Arduino board to activate the linear actuator within a predefined force range, ensuring smooth door opening. The project aims to secure a patent for its advancements, setting a new standard for user-friendly dishwasher technology.

Problem Definition

Dishwashers poses a significant role in today's modern life by being an everyday chore. In order to place dishes into or take dishes from a dishwasher, users need to open the external door of the dishwasher. They do so via a handle that is placed on the door. However, the handle does not convey an aesthetically pleasing appearance in built-in dishwashers therefore desired to be removed with the new productions.

Figure 1: A classical dishwasher with a Handle [1].

With this project, an innovative solution of push-to-open mechanism for Arçelik dishwashers is designed and implemented where the door of a dishwasher can be opened by freeing the locking mechanism when a defined minimum force of 30 Newtons is applied on the specified place on the dishwasher's door and the door locking mechanism handles its duty when the door is closed. The mechanism has to be placed to either front travers or inside the panel.

Figure 2: Built-in Dishwasher without a Handle[2].

The push-to-open mechanism allows dishwasher users to open the door of the dishwasher by applying a required push force on a specific determined area on the surface. Preferably, min 30 N and max 65 N of force applied should be compatible with the mechanism. This removes the necessity for the placement of handles on the outer surface of the door to open the machine. When push force is applied, it is expected that the lock mechanism and door opening mechanism are activated simultaneously.

The dishwasher program stops when the door is freed so that the user is able to fully open the door. The test setup design for the handless door is iterated to maximize the opening force of the door. Since the mechanism is to be used in a fully integrated (fully built-in) Arçelik dishwasher, the user is expected to apply push force to the custom panel of the appliance which is designed to fit in the overall design of the kitchen cabine.

[1] "GSN 9120: GSN 9120," *Blomberg GSN 9120 user manual (English - 28 pages)*. [Online]. Available: https://www.manuals.co.uk/blomberg/gsn-9120/manual?p=11. [Accessed: 19-Apr-2024]
[2] "AB 281 Tam Ankastre Bulaşık Makinesi," *Arçelik* . [Online]. Available: https://www.arcelik.com.tr/tam-ankastre-bulasik-makinesi/ab-281-ankastre-bulasik-makinesi. [Accessed: 21-Apr-2024]

Design

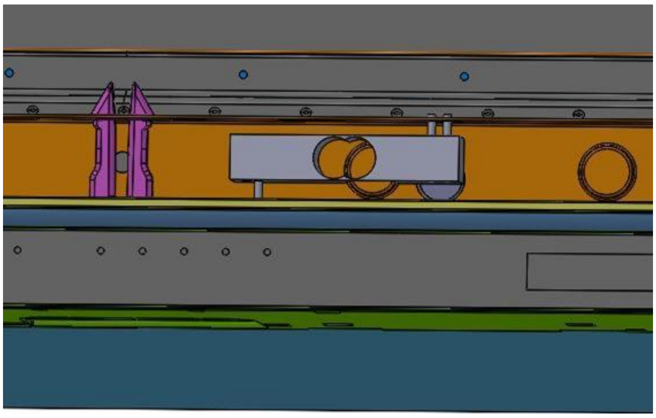


Figure 3 : Location of the Load Cell

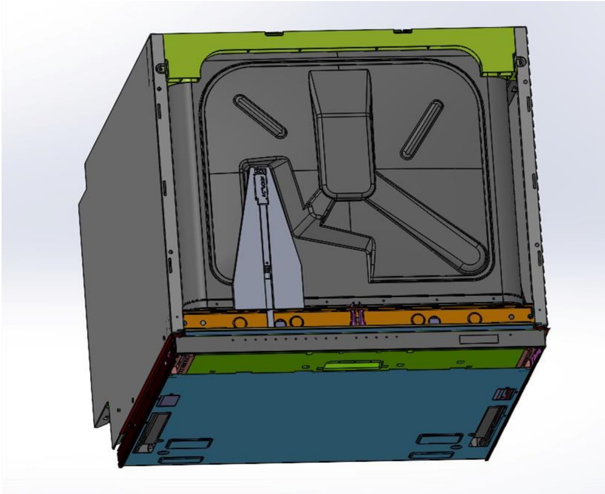


Figure 4 : Linear Actuator System Integrated on Dishwasher

The designed mechanism works by sensing the push force via load cell. The system consists of two main subsystems: a load cell sensor and an electromechanical pusher. The pusher mechanism consists of a linear actuator and bar. Using a linear actuator as the simple mechanism is sufficient for the requirement, since having smaller number of parts have advantages in terms of reliability. The load cell senses the force exerted by the user on the front surface of the decorative panel. Then, the sensor produces signals correlated with the amount of force applied to the decorative panel, and the created signals will be used.

The system is designed to act upon an analogue signal: when the load cell, due to specific triggers like a push or a tap, generates an analogue signal, this signal is fed into one of the Arduino digital pins. Upon detecting this analogue signal (high), the Arduino activated and linear actuator that controls the dishwasher's door. As a result, the linear actuator is energised, and the door opens. In contrast, if the sensor outputs an analogue signal (low), the system switches off the transistor, deactivating the linear actuator and the dishwasher door remaining closed.

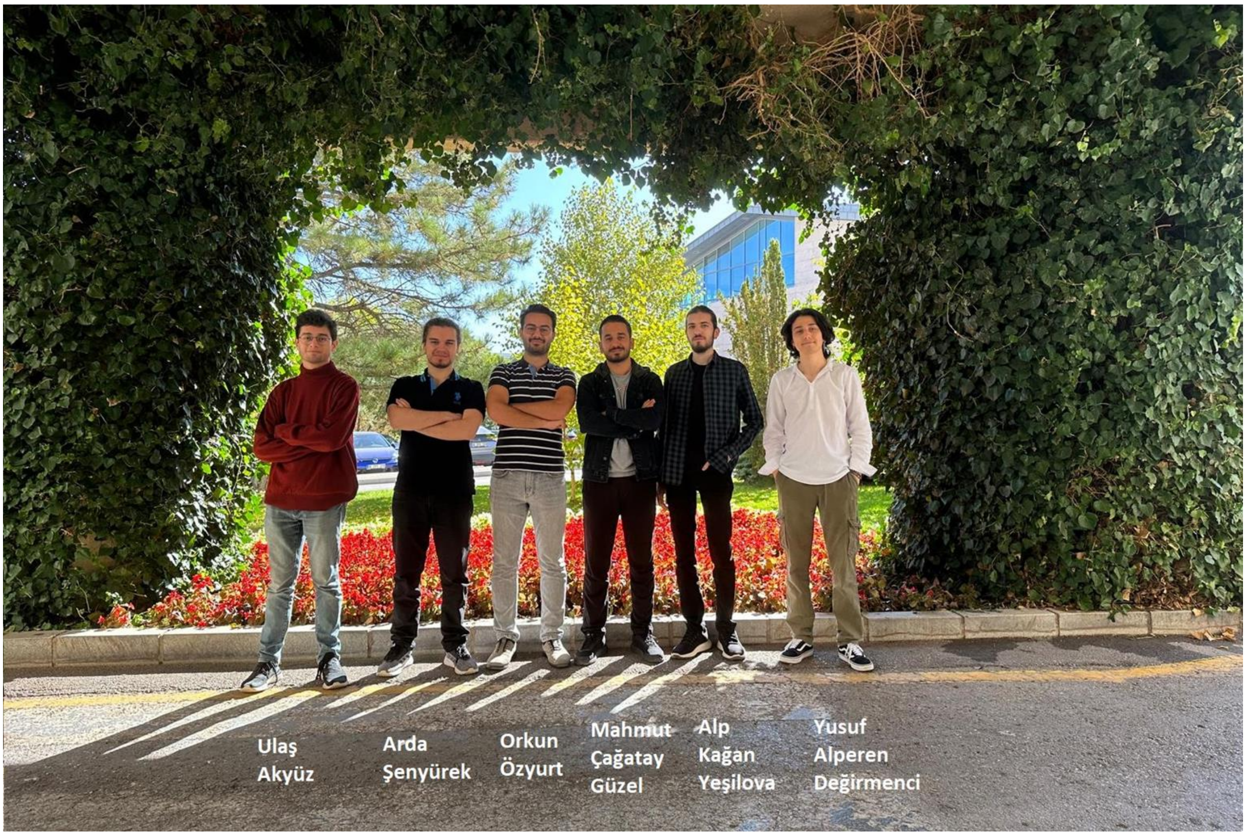
Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at dynamics, mechanics and mechatronics courses. It is done in several steps through the 2023-2024 academic year given as below:

•Literature and market research
•Determination of sub-systems according to requirements provided by Arçelik
•Engineering analysis including:
  -Linkage modeling
  -Kinematics analysis
  -Deformation analysis
  -Frequency response analysis
•CAD drawings
•Safety Analysis
•Sensor data collection
•Planning of manufacturing processes, assembly, design verification and testing of the system

Design and Production of an Open-loop Subsonic Wind Tunnel

Group KGT (2)



Academic Advisor : Asst. Prof. Dr. A. Alperen Günay
Industrial Advisor : Batuhan Taş
Teaching Assistant : Yusuf Uzun

ABSTRACT

The aim of this project is to design and produce a customized wind tunnel system tailored for aerodynamic assessment in the defense industry. Traditional wind tunnels, while effective, often present challenges in terms of cost and size, particularly for larger products. The proposed wind tunnel seeks to address these challenges by providing a versatile and cost-effective solution for assessing the aerodynamic characteristics of products developed by Meteksan Savunma A.Ş. The system must adhere to specified requirements, including maximum air speed, power source specifications, and safety standards. Additionally, the project aims to explore innovative methods for assessing aerodynamics, such as testing reduced-scale models and investigating airflow over printed circuit boards (PCBs) to optimize cooling performance and power consumption. The proposed solution involves the development of a tailored wind tunnel design capable of accommodating these objectives while ensuring reliable aerodynamic measurements.

Problem Definition

Wind tunnels are indispensable tools for analyzing fluid-structure interactions and assessing aerodynamic impacts on objects such as aircraft, automobiles, and other structures. This project focuses on constructing an open-loop wind tunnel for Meteksan Savunma A.Ş., tailored to specific requirements to ensure cost-efficiency and functionality. The design aims to deliver precise aerodynamic measurements for evaluating Meteksan Savunma A.Ş.'s products using reduced-scale models, as well as to explore airflow over printed circuit boards (PCBs) to optimize their cooling performance and power efficiency.

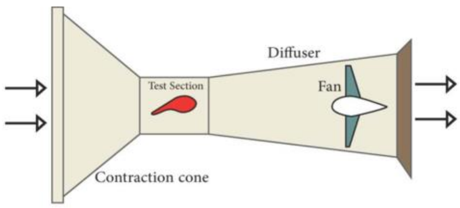


Figure 1: General Structure of Wind Tunnel [1].

The wind tunnel will support a maximum air speed of 15 m/s in the test section and will operate with a 220V, 50 Hz power source. The fan speed will be adjustable through voltage modifications, critical for managing airflow accurately. The design also includes features to mitigate flow leakage and accurately measure wind speeds, ensuring data integrity. Additionally, the system will incorporate passive isolation to reduce vibration interference and provide clear visibility of the test specimen during experiments.

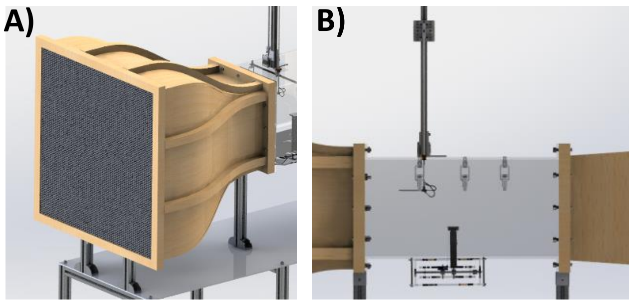


Figure 2: Sub Components of the Wind Tunnel A) Contraction Cone B) Test Section.

Safety protocols are integral to the design, including comprehensive safety instructions and the installation of a power and control panel on the side of the tunnel for easy access and enhanced operator safety. The tunnel will also allow for remote manipulation of the test specimen to measure drag and lift forces at various angles, up to 30°. For practicality, the design includes wheels for easy transport. This design bridges the gap between experimental flexibility and rigorous aerodynamic testing requirements.

Figure 3: Diffuser of Wind Tunnel.

[1] R. Dsouza, S. Salim, A. Shankar, M. Safwan, and S. Sa, "Wind Tunnels: State of Art Survey and Future Scope for Testing Micro Air Vehicles," American Scientific Research Journal for Engineering, Technology, and Sciences, vol. 19, pp. 25-41, 2016.

Design

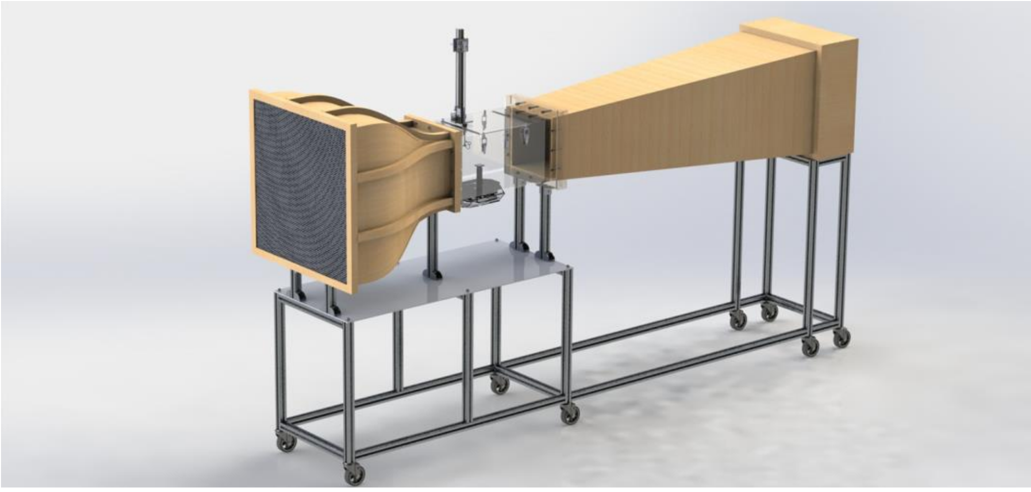


Figure 4: Overall CAD Design of Wind Tunnel

Our wind tunnel features a contraction cone, test section, and diffuser, all optimized for laminar airflow through computational fluid dynamics (CFD). A precise traverse system enables exact instrument positioning for detailed aerodynamic analysis. Key systems include robust velocity control and force balance mechanisms to measure dynamic forces accurately.

The structure is supported by an aluminum sigma table, enhancing stability and durability. Honeycomb and screen inserts further refine airflow, ensuring precise measurements. CAD drawings facilitate the exact manufacturing of all components, adhering to safety and performance standards. This design ensures the wind tunnel's reliability and efficiency.

Outcomes

This project involves a comprehensive mechanical engineering design that integrates knowledge from fluid mechanics, control systems, mechatronics and manufacturing. Scheduled for the 2023-2024 academic year, the project progresses through several stages:

- Conducting literature research.
- Identifying necessary sub-systems based on mechanical engineering requirements.
- Detailed engineering design and analysis, which includes:
    - Designing the contraction cone, diffuser, and test section.
    - Building a traverse system.
    - Developing and analyzing a velocity control system.
    - Constructing and analyzing a force balance system.
    - Creating an aluminum sigma table.
    - Designing and modeling the honeycomb and screen.
    - Performing computational fluid dynamics (CFD) for mathematical modeling of the entire system.
- Producing computer-aided design (CAD) drawings.
- Performing safety analysis.
- Outlining the manufacturing processes, assembly, design verification, and system testing.
- Manufacturing the complete system and its subcomponents.

Test Setup for Clinching Points

MechJox (3)

Academic Advisor : Dr. Şakir Baytaroğlu
Industrial Advisor : Tuğrul Başeşme
Teaching Assistant : Emirhan İnanç

ABSTRACT

The objective of this project is to develop a specialized testing setup to evaluate the shear and tensile strength of clinching points used in the assembly of dishwashers by Arçelik, leveraging the clinching method patented by TOX® Pressotechnik. Arçelik implements this clinching technique for clinching the legs of the dishwasher to the main body. Clinching points, crucial in bonding metal layers in dishwasher structures, require precise mechanical testing to ensure resilience against shear and tensile forces, which could otherwise lead to structural failures like leaks, affecting product reliability and customer satisfaction. Addressing the lack of an automated and accurate testing system, the project designed a robust and mobile testing system capable of applying and precisely measuring shear forces up to 2500N and tensile forces up to 600N. The testing system integrates a mobile tensile testing machine, shear and tensile grip configurations, and an electrical system for data acquisition, whole system is controlled via an Arduino microcontroller. This solution not only provides Arçelik with an in-house capability to routinely assess the durability of clinching points but also facilitates data analysis to optimize product design and manufacturing processes.

Problem Definition

Dishwashers are one of the most crucial household appliances, and their ability to perform functions without errors or malfunctions depends critically on the fact that they must be stable and standing.

Arçelik utilizes TOX Clinching technology, a patented method by TOX® Pressotechnik, to ensure the stability and durability of their dishwashers. This technology involves joining two layers of sheet metal through cold forming to create connection points known as TOX points. These points are crucial for maintaining the structural integrity of the dishwasher, influencing factors like height adjustment and resistance to shear and tensile stresses, which are vital for preventing issues such as water leaks and transport damages.

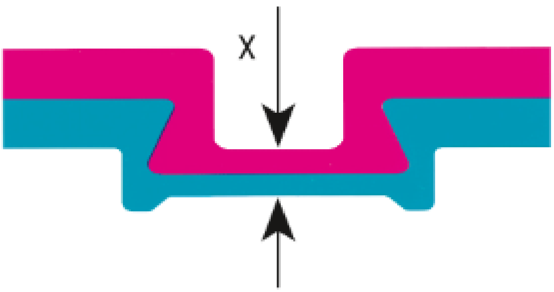


Figure 1: TOX point with control dimension X [1].

Currently, testing of these TOX points is done manually, leading to the disposal of entire units, which is costly and inefficient. Arçelik lacks a system for automated testing and data processing, relying instead on manual data collection.

Figure 2: Clinching points on an Arçelik dishwasher .

Arçelik is seeking to develop an internal test setup for more reliable and sustainable testing. This setup would initially focus on a specific TOX point configuration involving 1 mm thick DX51D + Z075A Galvanized Steel and 0.4 mm thick AISI Type 430 Stainless Steel. The potential for adapting the solution to different TOX point sizes with minor modifications is also being considered.

The design should prioritize ergonomic aspects and mobility to ensure operators can comfortably utilize and move the testing apparatus as necessary. It should efficiently transfer collected data to a computer platform, allowing data conversion into graphs illustrating pull force versus Control Dimension X and shear force versus Control Dimension X. The testing setup needs to accommodate control X dimensions ranging from 0.34mm to 0.46mm.

[1] TOX® PRESSOTECHNIK, "Clinching Overview," TOX® PRESSOTECHNIK, [Online]. Available: https://tr.tox-pressotechnik.com/applications/clinching/overview/. [Accessed: 14-Oct.-2023].

Design

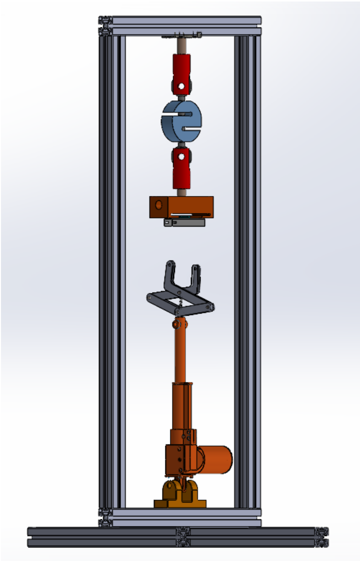


Figure 3 : 3D model of the tensile mode

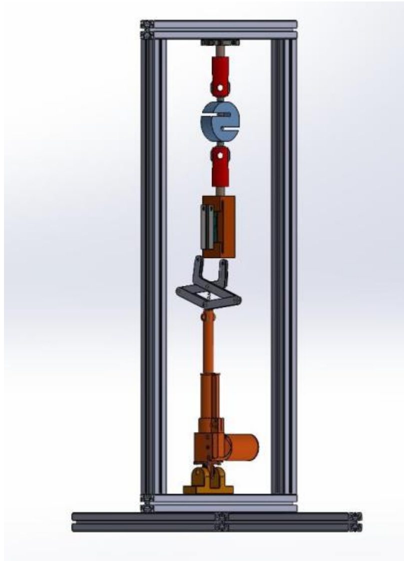


Figure 4 : 3D model of the shear mode

This system is designed to measure the tensile and shear strength of TOX points through a setup that operates in two orientations: tensile mode and shear mode. The system comprises both mechanical components, such as aluminum sigma profile, load cell mounting kit, plate grip, c-section grip, and motor holder, and electronic components, including a load cell, TR-4 Transmitter, Arduino Mega, power supply, and linear actuator.

In operation, the system secures the specimen between two grips: the plate grip linked to the load cell, which measures force, and the c-section grip attached to the linear actuator, which applies force. The force increases steadily until the specimen breaks. The load cell monitors force continuously, while the Arduino controls the increase in force. After the specimen breaks, the Arduino cuts power to the motor, stopping the system. Force data at the break point is recorded and analyzed after multiple tests for data visualization.

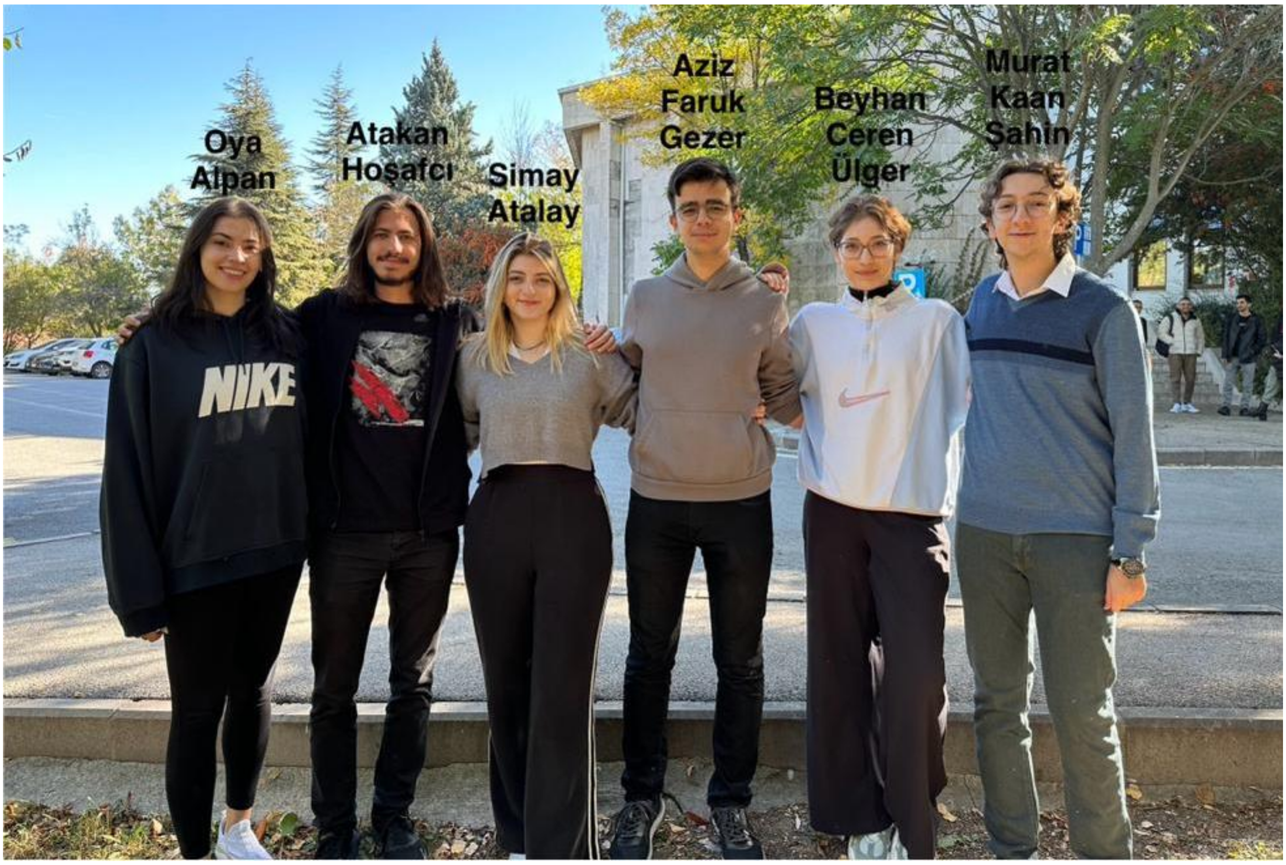
Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at dynamics, control systems and mechatronics courses. It is done in several steps through the 2023-2024 academic year given as below:

- Literature research
- Determination of constraints and requirements provided by Arçelik
- Preliminary and Detailed Design in Solidworks
- Engineering analysis including:
  - Static Analysis
  - ANSYS Analysis
  - Mathematical modeling
  - Control system construction and analysis
- Safety Analysis
- Risk Analysis
- Planning of manufacturing processes, assembly, design verification and testing of the system

Payload Elevation System

BitirMECH (4)



Academic Advisor : Asst. Prof. Dr. Gökberk Kabacaoğlu
Industrial Advisor : Yılmaz Tugay Şenol
Teaching Assistant : Altar Sertpoyraz

ABSTRACT

The goal of the Payload Elevation System (PES) project is to create a cutting-edge, transportable support system that will improve military personnel's operational capabilities. The motivation behind this program is the recognition of the need to enhance the current Mobile Adjustable Support Tower (MAST) systems. MAST systems are essential for raising payloads to support tasks related to surveillance, communication, and reconnaissance. Early field test comments indicated problems with these systems' installation simplicity, which prompted the creation of the PES project. The project's specific goal is to create a transportable, lightweight system that weighs less than 25 kg and can raise a 50 kilogram payload between 1.5 and 4 meters. The PES prioritizes user-centric design in order to guarantee simple setup, improved mobility, and intuitive use in a variety of outdoor settings. Moreover, it prioritizes operator safety and concentrates on performance and versatility, with the goal of supporting payloads on slopes as steep as 30 degrees and withstanding winds as high as 120 km/h. Should this technology be implemented successfully, soldiers' capabilities in a variety of field actions will be greatly enhanced.

Problem Definition

By addressing major issues with current Mobile Adjustable Support Tower (MAST) systems, the Payload Elevation System (PES) project seeks to improve the usability and mobility of military payload support mechanisms. Field feedback prompted the creation of a solution that makes setup easier and boosts operating effectiveness in a variety of contexts.

The device must be able to carry a 50 kilogram cargo up to 4 meters in the air and remain stable in a variety of weather situations, including wind speeds of up to 120 km/h and 30 degree slopes. In order to facilitate easy transport and quick, tool-free setup by a single operator—both essential for successful field deployment—the system's design limits its weight to less than 25 kg.

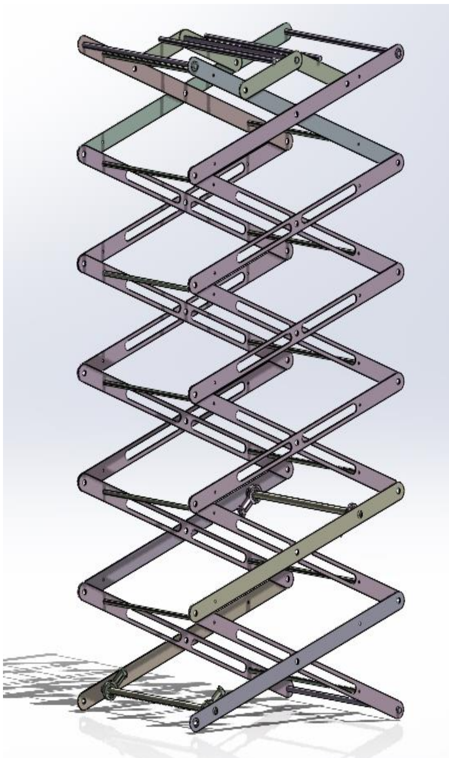


Figure 1 : 3D Model of the Scissor Lift Assembly of the System of the PES

For long-term dependability and functionality, the design must also provide physical durability and resistance to environmental deterioration. Operator safety is of utmost importance, and to guard against any operational hazards, integrated safety measures are required.

Complying with several military and international standards is essential to guaranteeing the system satisfies these demanding requirements. These include ISO-9001 for quality management, MIL-STD 810G for environmental durability, and MIL-STD 1472F for human engineering. These standards provide guidance on a range of design topics, from user interaction to structural integrity. Additionally, the production tolerances are guided by ISO 2768 standards, guaranteeing accuracy in fabrication that satisfies the rigorous specifications of the design.

Figure 2 : 3D Model of the Mounting Plate and Feet Mechanism of the PES

To improve military personnel's operational skills, it is imperative to address these issues through careful design and thorough testing. This will eventually result in a system that combines effectiveness, versatility, and ease of use under challenging field situations.

Design

Figure 3 : Rendered View of the Payload Elevation System

The scissors MAST system uses manual actuation devices, such as an electric compressor or a bicycle pump, and is designed with ergonomic functionality in mind. This option improves the system's suitability for isolated or energy-constrained situations by eliminating the need for external power sources and simplifying user operation.

The system's modularity and tool-free mobility, which enable quick deployment and simple transfer across a variety of operational contexts, are essential components of its design. The design incorporates durability by means of upgrades that can survive environmental adversities like wear, dust, and abrasion. This extends the operating lifespan and lowers the frequency of maintenance.

The design aimed to overcome production constraints, which included replacing the original piston components with cheaper, slightly heavier substitutes that nonetheless fulfilled the same requirements. The structural elements were modified using manual topology optimization approaches. Weight was optimized by carefully placing slots to make assembly and laser cutting easier while preserving the structural integrity of the system.

Outcomes

The Payload Elevation System (PES) project combined mechanical engineering concepts from courses such as mechanics and materials 1 & 2, and design and manufacturing, into a practical design executed during the 2023-2024 academic year. Key phases included:

- Literature research
- Determining subsystem designs based on the requirements provided by METEKSAN
- Engineering analysis including:
  - -Stress analysis
  - -Deformation analysis
  - -Wind stability analysis
- CAD drawings and prototyping
- Manufacturing and testing
- Safety and cost analysis

Design and Production of an Agricultural Vehicle

CentauBot (5)

Elif Göcen - Doğukan Kartal - Ahmet Emir Gökdereli - Kaan Yılmaz - Adem Berk Binici - Aslı Kınık

Academic Advisor : Assoc. Prof. Dr. Onur Özcan
Industrial Advisor : Ahmet Nezir Ertürk
Teaching Assistant : Doğa Dağ

ABSTRACT

In agricultural activities, harvesting can take a long time and be exhausting. This project aims to develop and manufacture a sustainable agricultural robot to reduce the workload on farmers and provide a more sustainable and agile alternative to tractors. With that aim, a four-wheel drive rover is designed to be used for deploying soil uniformly and harvesting and storing crops throughout its usage. The project's design is determined by several agreed-upon constraints, including mechanical and electrical. It is designed and manufactured by recognized standards. The components include solar power and a battery for energy, a remote-controlled system for operation, and an onboard storage unit deployment system for added functionality. With the help of this project, a more productive way of farming is proposed.

Problem Definition

The agriculture field requires working in dirty and heavy conditions with immense labor. To ease the workload on farmers, engineers have been developing machinery devices and vehicles such as drones, robots, measurement devices, etc. However, the dirty and heavy conditions also reflect the requirements of such machinery, making them obliged to withstand heavy loads, mud, harsh weather conditions, and cutting edges of branches. At the same time, its possible environmental effects should also be considered; making the system sustainable and eco-friendly to the soil and the plants is also necessary. This project aims to create a robot that can supply these requirements by sustainably carrying and deploying essential materials into the field.

Figure 1: Example of an Agricultural Vehicle [1].

Although existing solutions, such as tractors, provide this project's desired aim, since they are cumbersome, expensive and the greenhouse gasses they produce affect the ecosystem poorly, a green, cost-effective and light design is scarce in the market. This project aims for greener solutions. Also, by making our robot smaller, we can reach more farmers to help their labor. By having a relatively lightweight and smaller design with solar panel charging capability, our design offers a greener alternative.

Having a console communication system for motion control, and a unit for both soil deployment and storing crops it also enables farmers to perform several tasks through remote-control.

With respect to the aims of the project, several requirements and constraints have been decided, which can be named as: mechanical, movement, sensory, and power. In terms of mechanical requirements, our robot should be able to carry an additional 50 kg load, with a volume of 20-25L, embedded inside the chassis. The dimensions of the platform should not exceed 1000mm in width, 2000mm in length, and 750 mm in height. The maximum mass of the platform is 200 kg. An area for the robotic arm with a diameter of 50 cm is desired. The robot should have sensor poles. There should be a place for the solar panels.

When it comes to the constraints related to movement, the platform should be remotely controlled. The maximum velocity is at least 3 km/h on an inclination of +/- 4°. There should be safety bumpers to cut off the power and stop the platform. The maximum turning radius is 2 m. The robot should have 2 to 4 motors, with 4-wheel driving.

Constraints regarding sensors should include an Inertial Measurement Unit (IMU) to obtain the acceleration and gyro data. There should be a GPS sensor for more precise velocity and orientation.

In power-related constraints, the system should operate with 24V power sources. There should be an accessible battery compartment within the chassis.

[1] “Industrial Intelligence 4.0_beyond Automation.” *KUKA AG*, www.kuka.com/en-us.

Design

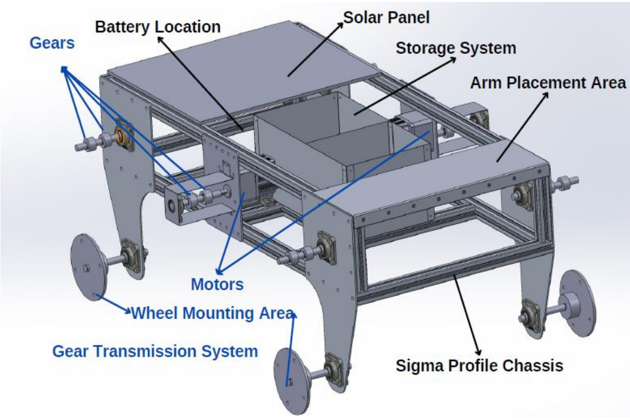


Figure 2 : CAD Drawing of the Prototype

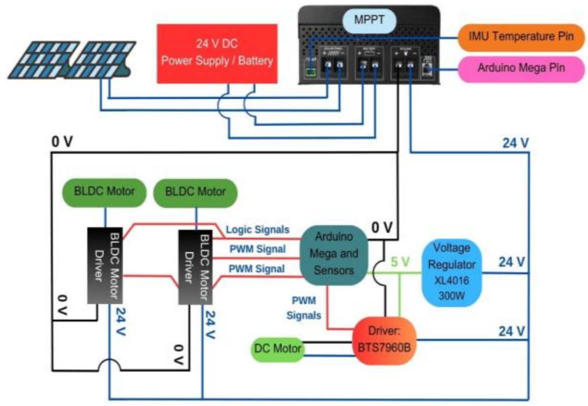


Figure 3: Electrical Scheme of the Prototype

The system consists of Sigma profiles as a chassis, sheet metals for casing and support, a storage unit, a gear transmission system, a battery, a solar panel, and an area for holding robotic arms that harvest crops. The system was designed with ease of manufacturing and maintenance in mind. The placement and removal of components were a priority during the design procedure, each are selected based on the dimensional and functional requirements and constraints.

The electrical parts of the design are motors, drivers, an Arduino board, communication devices, sensors, emergency buttons, lights, solar panels, and a battery. Two BLDC motors drive the wheels, and a DC motor is used for the deployment mechanism, all controlled via the FlySky controller. Sensors are used to collect position and velocity data of the motion for autonomous motion goals. Emergency buttons are used to stop the vehicle in case of contact with any obstacle. All electronics are powered by a 24V battery, which the solar panel can recharge.

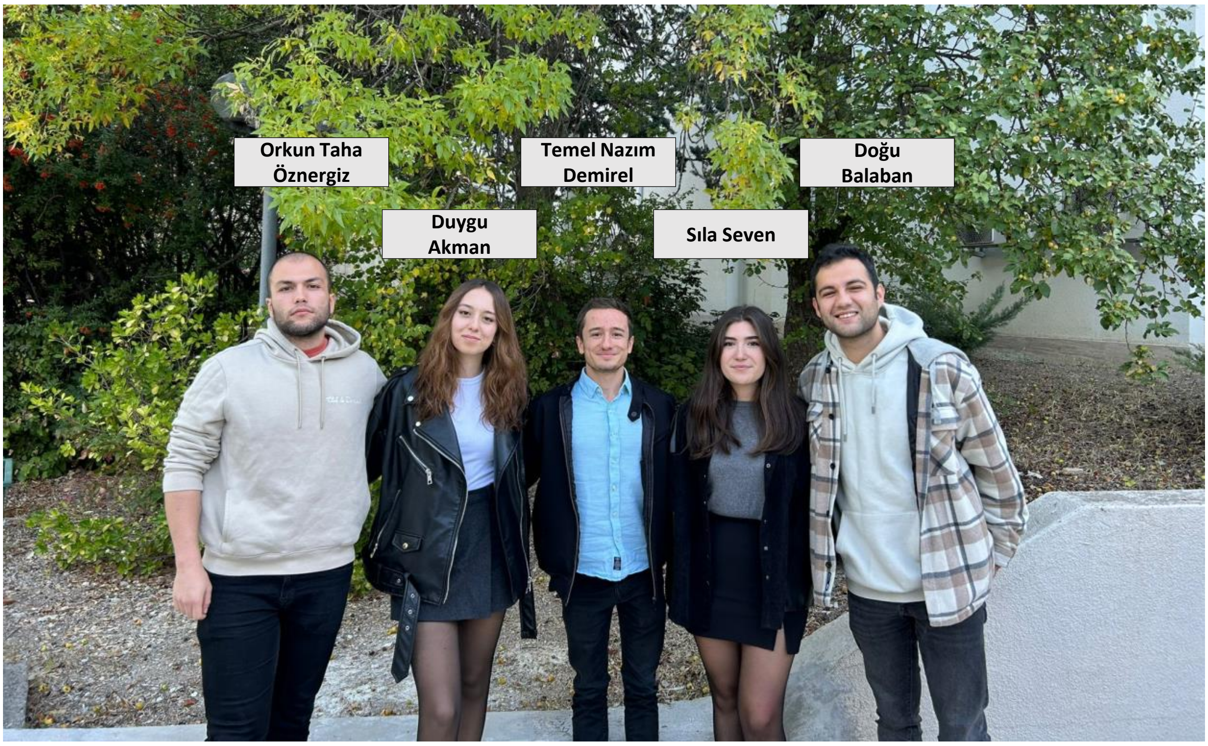
Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired in dynamics, control systems, and manufacturing courses. It is done in several steps through the 2023- 2024 academic year, given as below:

- Literature research
- Market research
- Creating an appropriate design from the requirements provided by OTONOM Technologies
- Engineering analysis including:
  - Structural Analysis
  - Motion Analysis
  - Multibody Dynamics Analysis
  - Frequency Range Analysis
  - Mathematical Modelling of the Electronics
- CAD drawings
- Safety Analysis
- Planning of manufacturing processes, assembly, design verification, and testing of the system

Design and Production of a Miniature and Precise Azimuth/Elevation Rotator

SaTrackers (6)



**Academic Advisor : **Assoc. Prof. Barbaros Çetin
Industrial Advisor : Barış Temel
Teaching Assistant : Muhammed Yusuf Uzun

ABSTRACT

This project focuses on the design and construction of a compact, high-precision Azimuth/Elevation Rotator, tailored for efficient satellite tracking at ground stations. The rotator is envisioned to streamline the process of aligning communication equipment with orbiting satellites, a critical task for maintaining the continuity and reliability of data transfer. By addressing the need for rapid and precise positional adjustments, the system promises to significantly reduce the signal latency and tracking errors currently faced in satellite operations. The mechanism is designed to operate within a stringent set of spatial constraints, optimizing the available workspace without compromising the range and fluidity of motion. During the development phase, emphasis was placed on integrating mechanical and electronic components to enable precise dual-axis movement, crucial for tracking satellites in LEO. The design features durable materials and sophisticated motion control techniques, ensuring stability and longevity. As the project advances towards prototype manufacturing, efforts are concentrated on optimizing agility, precision, and robustness. This initiative is set to enhance ground station capabilities significantly, improving global satellite communication networks.

Problem Definition

The Miniature and Precise Azimuth/Elevation Rotator project is designed to enhance the tracking capabilities of ground stations for Low Earth Orbit (LEO) satellites. It aims to develop a compact, highly efficient rotator capable of swift and precise positional adjustments to maintain optimal alignment with satellites, which is crucial for maximizing data transfer effectiveness.

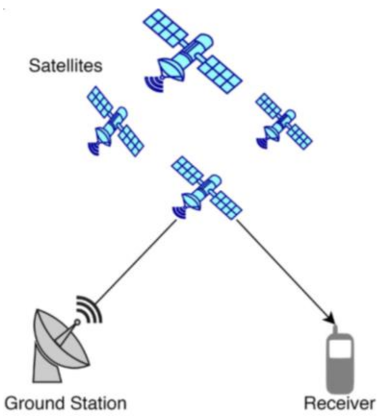


Figure 1: Satellite communication [1]

A critical aspect of the project is the integration of functionality within a compact form. The rotator must support extensive azimuth and elevation movements (+/- 185 ° in azimuth and +/- 90 ° in elevation) while confined within dimensions of 250x250x200 mm. This design challenge necessitates innovative solutions to house all mechanical and electronic components, including actuators, gear sets, transmission elements, and control units, efficiently and effectively.

Power efficiency is paramount, as the rotator is often deployed in remote areas lacking conventional power sources. The design leverages solar energy, requiring the system to operate under minimal power conditions without compromising performance.

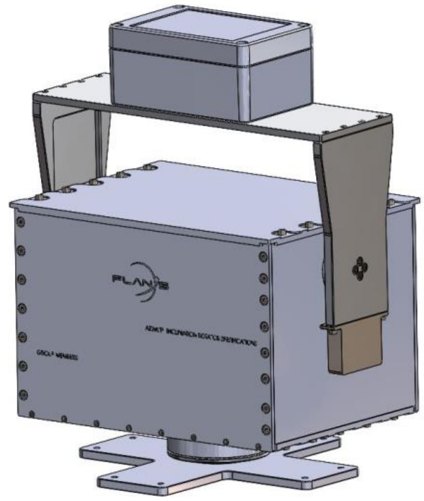


Figure 2: CAD model of the system

The rotator is also built to withstand diverse environmental conditions—from temperatures between -20 to +50 °C and is engineered to be rust and corrosion-resistant. Durability is tested through rigorous cycles, ensuring the rotator can handle at least 50 full rotations without performance degradation.

Technical requirements dictate that the rotator achieves axial speeds between 0.2 ° /sec (minimum) and 5.0 ° /sec (maximum), allowing for precise and rapid tracking of satellites. This speed range is crucial for maintaining continuous contact with satellites during their orbit.

Moreover, the project adheres to MIL-STD-810G and IP65 standards, which guarantee robustness against environmental stressors and offer protection against dust and water, enhancing operational integrity under varied conditions. This adherence not only fulfills essential technical and operational benchmarks but also advances mechanical integration and environmental resilience in satellite tracking technology.

[1] M. K. Mondal *et al.*, "A CPS based social distancing measuring model using edge and fog computing," *Computer Communications*, vol. 194, pp. 378–386, Oct. 2022. doi:10.1016/j.comcom.2022.07.029

Design

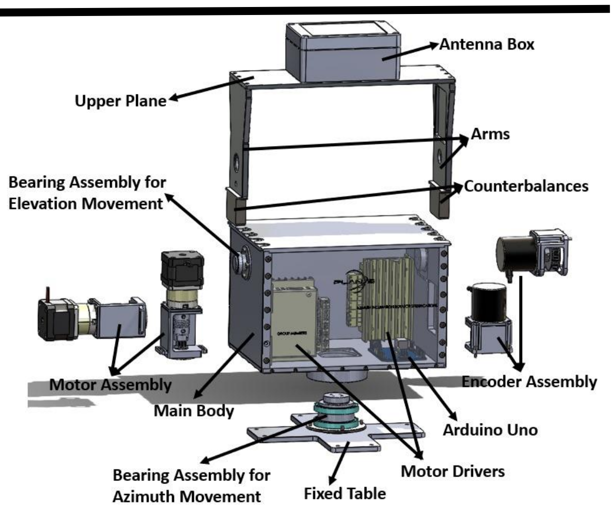


Figure 3 : Exploded view of the CAD model

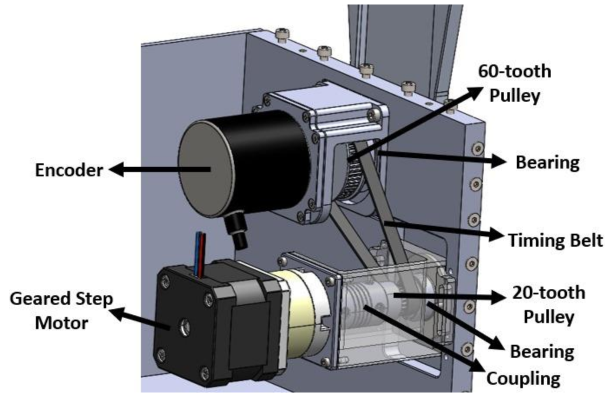


Figure 4 : CAD model of the movement system

The design is conceived with dual-axis functionality to enhance the precision of satellite tracking from ground stations. The system employs a robust lower fixed table that anchors the azimuth rotational shaft, ensuring minimal deflection and maximum operational stability. The elevation mechanism is engineered with precision side abutments and load holders, providing a stable platform for tilting movements. The integration of bearings ensures that radial and axial loads are evenly distributed. The incorporation of a belt pulley coupled with an encoder, which, together with the motor's gearbox, facilitates exact control over the movement.

Electronically, the system is governed by a close-loop control setup centered around an Arduino microcontroller, which processes signals from sensors including high-resolution encoders, and modulates the stepper motor drivers using a PID control algorithm. This setup is part of a carefully crafted electric circuit designed for seamless integration and peak performance. The assembly process is orchestrated to secure each component into its precise position, ensuring the entire system aligns perfectly for accurate and reliable tracking.

Outcomes

This project integrates advanced mechanical engineering techniques and standards acquired through specialized courses. Executed over the academic year 2023-2024, the project entailed a systematic approach detailed below:

- Literature Review and Concept Development
- System Requirements Specification in collaboration with Plan-S
- Engineering Calculations and Simulations:
  - Multi-axis (2D) mechanical and dynamic simulation
  - Electrical and control system integration
  - Development of mathematical models for system behaviors
- CAD and Technical Drawings
- Prototype Development:
  - Manufacturing and system assembly
  - Testing and optimization
- Verification and Validation
- Safety and Compliance Checks

Design and Production of a 6-DoF Robotic Arm for Agricultural Applications

Makine Elemanları (7)

Academic Advisor : Asst. Prof. Dr. Onur Özcan
Industrial Advisor : Ahmet Nezir Ertürk
Teaching Assistant : Doğa Dağ

ABSTRACT

The scope of this project is to design and produce a robotic arm assembly to be mounted on a mobile platform for collection and manipulation of farm objects such as fruits and vegetable in order to increase the efficiency of agricultural applications. In conventional robotic arm systems, degree of freedom represents the number of independent parameters to define the mechanism’s posture and kinematics and is directly related to the maneuverability of the end effector (gripper) of the robotic arm. To ensure the maneuverability of the gripper, the system is constructed of six independent joints, each driven by open loop stepper motors. Unlike industrial robotic arms that operate in indoor areas, to ensure the resiliency against environmental factors, rubber sealing elements are used at junctions. The project aims to have a minimum reach of 1.5 meters reach with respect to base of the robotic arm and minimum payload capacity of 1 kilograms. The proposed solution of the project is to design a six degree of freedom robotic arm with a sensitive gripper to prevent any damage on the object of interest, and design cycloidal gearboxes with high speed reduction rates to achieve high torque and precise control of the joints.

Problem Definition

Our project aims to enhance the efficiency and productivity of farming applications by reducing reliance on human labor. We propose the implementation of a 6 degree of freedom (6 DOF) robot arm, which will later be integrated on top of a fully electrified mobile platform. This system will ensure precision and robustness in farming operations and it will be capable of withstanding extreme field conditions such as rain, dust, humidity and severe temperatures. This 6 DOF robot arm must perform crucial functions such as cutting organic materials like tree branches and reaching objects that are both attached to trees and on the ground. In addition, it also needs to be lightweight in order to avoid causing any drawbacks on the mobility of the electrified mobile platform that it will be mounted on.

Figure 1: Conceptual Robot Arm [1]

The 6 DOF robotic arm operates through a harmonized system of stepper motors, servo motors, gears, and the Arduino R1 Giga Wifi microcontroller. Stepper motors that are positioned at each joint, facilitate controlled angular movement by converting electrical pulses into incremental mechanical steps. These motors dictate the rotation and positioning of the arm's segments, while integrated gears serve to amplify torque, enabling the arm to handle tasks demanding substantial force, such as cutting branches or lifting agricultural produce.

Additionally, servo motors provide finer control and nuanced movements, managing the multifunctional gripper mechanism at the end effector. The gripper, incorporates a versatile design capable of gripping, cutting, and picking objects. It operates through a combination of servo motors and specialized mechanisms, allowing it to adapt to various shapes and sizes of agricultural materials.

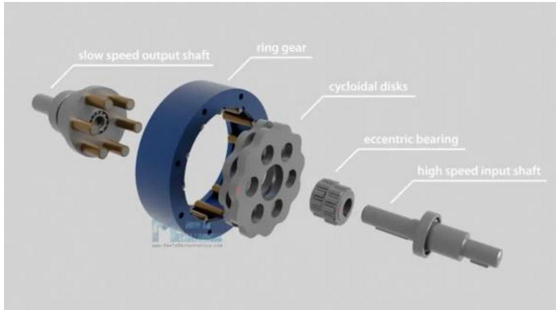


Figure 2: Cycloidal Gear Assembly [2]

The cycloidal drive is composed of five main components, a high-speed input shaft, an eccentric bearing or cycloidal cam, two cycloidal disks or cam followers, a ring gear with pins and rollers, and a slow speed output shaft with pins and rollers. The input shaft drives the eccentric bearing, and the eccentric bearing drives the cycloidal disks around the internal circumference of the ring gear housing. The eccentric motion makes the cycloidal disks teeth or lobes to engage with the rollers of the ring gear housing in a way that they produce reverse rotation at a reduced speed.

The constraints of the projects are to have a payload capacity of 1 kg, six degrees of freedom, and a weight range of 25 to 33 kg. Electrical power consumption is targeted between 800W to 1kW, with provisions for dust and water protection adhering to IP standards. The robot should be mounted area constraint of 500mm by 500mm.

[1] - online store, https://isralovevs.live/product_tag/13053491_.html (accessed Apr. 18, 2024).
[2] D. Elliott, Hakan, “What is cycloidal driver? designing, 3D printing and testing,” How To Mechatronics, https://howtomechatronics.com/how-it-works/what-is-cycloidal-driver-designing-3d-printing-and-testing/ (accessed Apr. 18, 2024).

Design

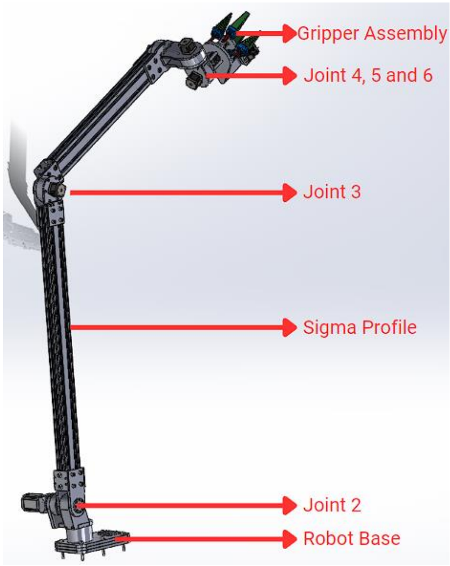


Figure 3 : 3D Model of the System

The design of the system was finalized as a 6 DOF system that relies on a pulley and belt mechanism for joint one, a planetary gear for joint two, and cycloidal gears for the other joints. Stepper motors are used for actuation. Sigma profiles are employed for the links. The system was designed based on a number of concepts, measurements and calculations such as torque calculations, machine element analysis and finite element analysis.

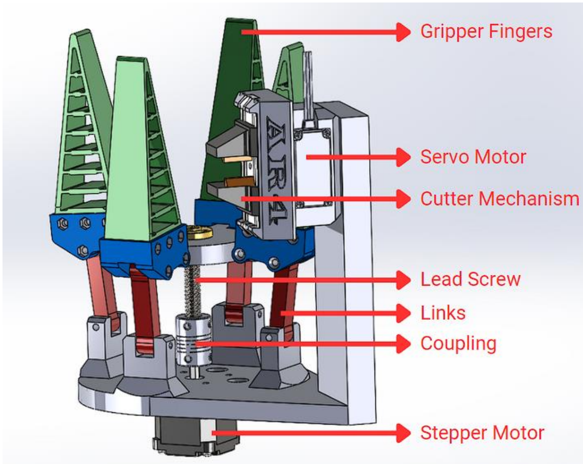


Figure 4 : 3D Model of the Gripper Subsystem

In the gripper assembly, a soft filament (TPU) is employed for the fingers, allowing them to conform to the shape of the object and securely wrap around it for improved grip. A single stepper motor, coupled with a lead screw, drives all four fingers simultaneously. Prior to implementation, a comprehensive four-bar analysis was conducted to ensure the optimal trajectory of each finger.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at dynamics, control systems and mechatronics courses. It is done in several steps through the 2023-2024 academic year given as below:

•Literature research

•Determination of the concepts, components and working principle of the system according requirements provided by OTONOM Teknoloji

•Engineering analysis including:

- Mathematical modeling
- Control system design and analysis
- Dynamical analysis and torque calculations
- Finite element analysis
- Machine element analysis

•CAD drawings

•Microcontroller programming

•Risk and safety analysis

•Manufacturing, assembly, design verification and testing of the system

Design and Production of an NC-Bending Machine

(8)

Academic Advisor : Asst. Prof. Dr. Gökberk Kabacaoğlu
Industrial Advisor : Barış Çetin
Teaching Assistant : Assoc. Prof. Dr. Barbaros Çetin

ABSTRACT

The project aims to develop a numerically controlled (NC) bending machine that transcends the limitations of traditional industrial sheet metal benders, which are typically bulky, costly, and not suited for small-scale operations or easy transport. The NC bending machine is designed to be lightweight and portable, capable of bending AL6xxx series aluminum sheets to specified angles between 90°-160° with a high precision tolerance of ±5°, supporting plates up to 300x300 mm in size and 3 mm thick. The structure will utilize aluminum sigma profiles to keep the total machine weight between 60-100 kg, enhancing transportability and usability. Adherence to international standards such as ISO 1472, ASTM B209, and ISO 12100 ensures compliance with all required dimensional, mechanical, and safety regulations. The machine incorporates advanced control systems featuring linear actuators, rotary encoders, and an Arduino-based PID controller for accurate angle adjustments. Scheduled for completion in Spring 2024, the project will conclude with a presentation at the university's engineering project exhibition. This initiative not only meets industrial needs for compact and automated bending machines but also enriches student education through practical engineering challenges.

Problem Definition

The objective of this project was to engineer and construct a sheet metal bending machine tailored to meet the specific requirements of METEKSAN. The essential function of this machine is to mold sheet metals into predetermined angles and radii, which are subsequently utilized across a wide spectrum of manufacturing applications such as automotive body parts, signage, irrigation systems, aerospace components, maritime constructions, pharmaceutical tools, food processing equipment, and artistic decor. Traditional bending machines, while functional, often suffer from drawbacks including excessive weight, bulkiness, and high costs which complicate operations and accessibility.

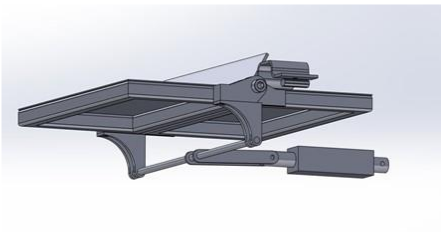


Fig. 1: CAD Design of the Bending Mechanism

In response, METEKSAN commissioned a machine designed to overcome these limitations by being lightweight, user-friendly, and precise—ideal for small-scale projects and reducing the dependency on manual labor. Specific criteria set by METEKSAN included: the machine's portability by 4-5 individuals with a weight range of 60-100 kg, the capability to bend AL6xxx series T0 aluminum sheets measuring 300x300 mm and at least 3 mm thick, and the ability to accurately bend within angles of 90°-160° with a tolerance of ±5°. Furthermore, this machine is required to support various bending axes and ensure a seamless operation without manual intervention during the bending phase, though manual tasks such as positioning and securing the metal sheets are permitted.

A critical feature of the design is its numerical control interface that allows operators to input specific parameters and achieve precise outputs automatically, thereby streamlining the bending process. Power for the machine is sourced directly from the city grid (220V – 50Hz), ensuring consistent operational capacity. The design also incorporates safeguards such as an Actuation Manual override to manually eject the workpiece in the event of a power failure, ensuring continuous productivity and safety.

Fig. 2: Working NC-Bending Machine Prototype

Moreover, the operational integrity of the machine stipulates that the workpieces must not only exhibit a reasonable bending radius but also maintain their structural integrity without visible cracks or notches post-process. This set of comprehensive functionalities and safety measures ensures that the machine not only adheres to METEKSAN’s operational exigencies but also enhances the efficiency, accessibility, and quality of metal bending practices in various industrial applications. Overall, this project reflects a significant step forward in the design and functionality of bending machines, aligning with modern industrial needs and setting a benchmark for future innovations in manufacturing technology.

Design

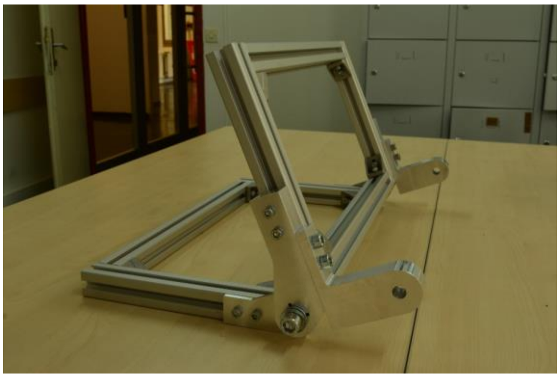


Figure 3 : Moving and Rotationary Plates

Figure 4 : Frame of Bending Machine

The LA40 linear actuator, selected from LINAK, stands out as a precise and safe force arm for the NC Bending Machine due to its mechanical stop and emergency halt functions. Its reliability and controllability are crucial for operational accuracy and efficiency. The machine's structure comprises a chassis designed from 40x40mm Aluminum Sigma profiles, with a height facilitating comfortable use by an average adult and is equipped with silicone table shoes to prevent vibration during high-power tasks.

The actuator pin, crafted from robust AISI 4140 carbon steel, ensures force is evenly distributed and transferred without component deformation, maintaining the system's functionality. This design integrates three main sub-components: the chassis, mounting apparatus, and connectors, all fastened with M8 bolts and fabricated from durable Aluminum alloys. High-strength materials are similarly employed for the hinge and connector components to guarantee a seamless assembly with the actuator pin.

Outcomes

Mechanical Engineering Design-I course at Bilkent University has culminated in the creation of an NC Bending Machine, demonstrating the practical application of academic theories and principles from dynamics, control systems, and mechatronics. This project was carried out by Group G8 under the supervision of Dr. Gökberk Kabacaoğlu and industry supervisor Barış Çetin. Throughout the 2023-2024 academic year, the group followed a systematic approach which included:

- Research and Analysis: Conducting thorough literature research and engineering analysis that encompassed system modeling, control system design, mathematical modeling, and inverse kinematics, along with frequency response analysis.
- Design and Development: Determining the sub-systems required by METEKSAN, followed by the creation of detailed CAD drawings which addressed the specific design needs.
- Construction and Testing: Planning and executing the manufacturing processes, which entailed selecting materials like Aluminum Sigma profiles for their ease of assembly and reliability. A prototype was built to include a mechanically innovative linear actuator for precise metal bending.
- Safety and Standards Compliance: Undertaking a rigorous safety analysis to ensure compliance with relevant codes and standards, such as ISO 1472 and ISO 12100, among others, to reduce risks associated with the machine's operation.

Design And Production of a CubeSat Solar Panel Rotation Mechanism

(9)

Academic Advisor : Assoc. Prof. Dr. Onur Özcan
Industrial Advisor : Eren Özgün
Teaching Assistant : Muhammed Yusuf Uzun

ABSTRACT

This project aims to design a rotational mechanism for solar panels in CubeSats, which are known for their small size and difficulty producing power because of the limited space that solar panels may cover. This project is to develop and implement a solar panel moving mechanism for CubeSats to overcome this difficulty. Utilizing moveable and movable solar panels may significantly increase the power output of CubeSats. The single-axis rotator at the center of the proposed system makes it easier to arrange multiple panels together to expand the size of the solar array. Furthermore, by adding maneuverability, the solar panels can efficiently track the path of the Sun, maximizing the efficiency of electricity generation.

Additionally, the system will function using a technique different from electric motors, ensuring low power consumption under CubeSats's restricted power generation capacity. The system will rotate between 0.1deg/s to 0.5deg/s to provide sensitive motion. This project highlights the significance of creative technical solutions to improve the functionality and performance of tiny satellite platforms for space research and communication missions. The proposed solution is to design a mechanism that includes Nitinol Shape Memory(SMA) springs, heat them using the Joule heating method, and control them.

Problem Definition

CubeSats can be defined as small satellites that weigh more than 30 kg. Furthermore, CubeSats' shape, size, and weight are controlled by specific standardized criteria. Standardized criteria help companies to mass-produce and reduce the transporting and deploying costs. Due to their relatively small size, regulated by standardized criteria, CubeSats are both cost- and time-efficient in manufacturing, transporting, and deploying compared to customized satellites.

This project focuses on innovatively addressing the challenges faced by CubeSats, a class of small-sized satellites, in harnessing solar power for their operations. These satellites rely on solar panels to generate energy in space. However, their compact dimensions, typically cube with a form factor of 10 cm and a mass of around 2 kilograms, impose constraints on the solar panel area, limiting the power output. The project proposes using deployable and movable solar panels to overcome this limitation. Deployable panels can be stacked vertically before deployment in orbit, effectively increasing the surface area available for solar energy absorption.

Figure 1: General Structure of the 3U CubeSats [1].

Furthermore, a single-axis rotator mechanism will be designed to enable the solar panels to harness maximum sunlight, optimizing the energy harvesting process by rotating the panels so that the light intensity and solar energy generated are at maximum available. Crucially, this mechanism will be engineered to operate with minimal power consumption, a maximum of 1 watt.

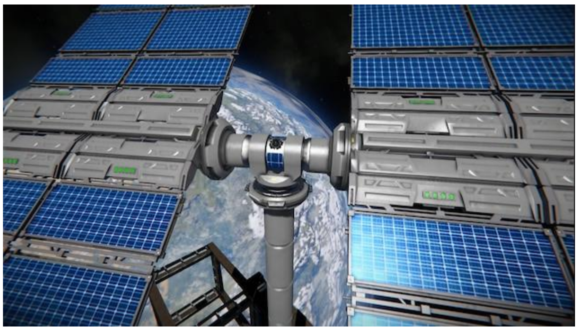


Figure 2: Solar Panel Rotation Mechanism of Large Satellites [2].

Given the satellite's limited power production capacity, this approach is essential to ensure efficient utilization of available resources. This project is unique in exploring an alternative method for the rotator's drive, deviating from the conventional electric motors commonly used in such systems. This project aims to maximize the energy harnessed within the satellite through solar panels. By integrating this innovative solar panel maneuvering mechanism, CubeSat Satellites can significantly enhance their power generation capabilities without compromising their size and weight limitations. This advancement represents a significant leap in the field of small satellite technology, making space missions more sustainable and energy-efficient.

[1] "3U CubeSat Platform," Available:https://www.satcatalog.com/component/3u-cubesat-platform/. [Accessed: 14-Apr-2024].
[2] "Space Engineers Satellite Mode "l. [Online]. Available: https://steamcommunity.com/sharedfiles/filedetails/?id=1728457223. [Accessed: 14-Apr-2024].

Design

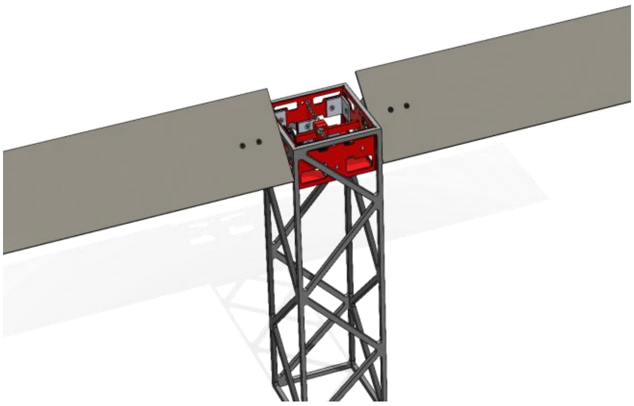


Figure 3 : 3D Model of the System

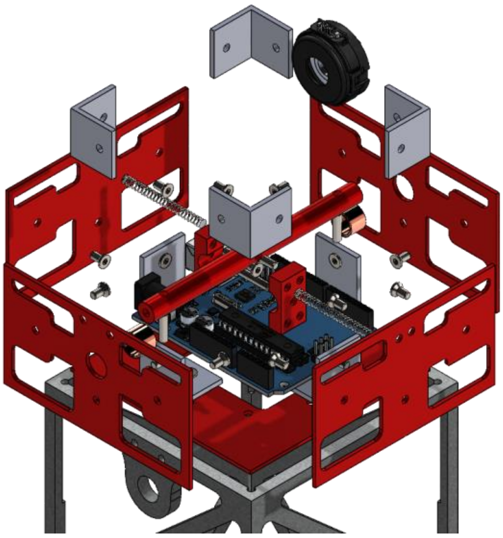


Figure 4 : Detailed Look to Model

The design mainly includes two SMA springs, one shaft, and some sensors. The system has been designed based on concepts, analyses, and simulations such as thermal analysis, kinematic, and control models. Firstly, the mechanism is connected to the top of the satellite. The SMA springs are connected with screws to the shaft; concerning the position of the sun, the system will be triggered, and the current pass on the SMA springs.

Thereby, springs will compress, and the shaft will rotate. Finally, the optimum angle of solar panels will be determined. To determine these data, photoresistors on the sonal panels and an encoder on the shaft are to be used to find the data.

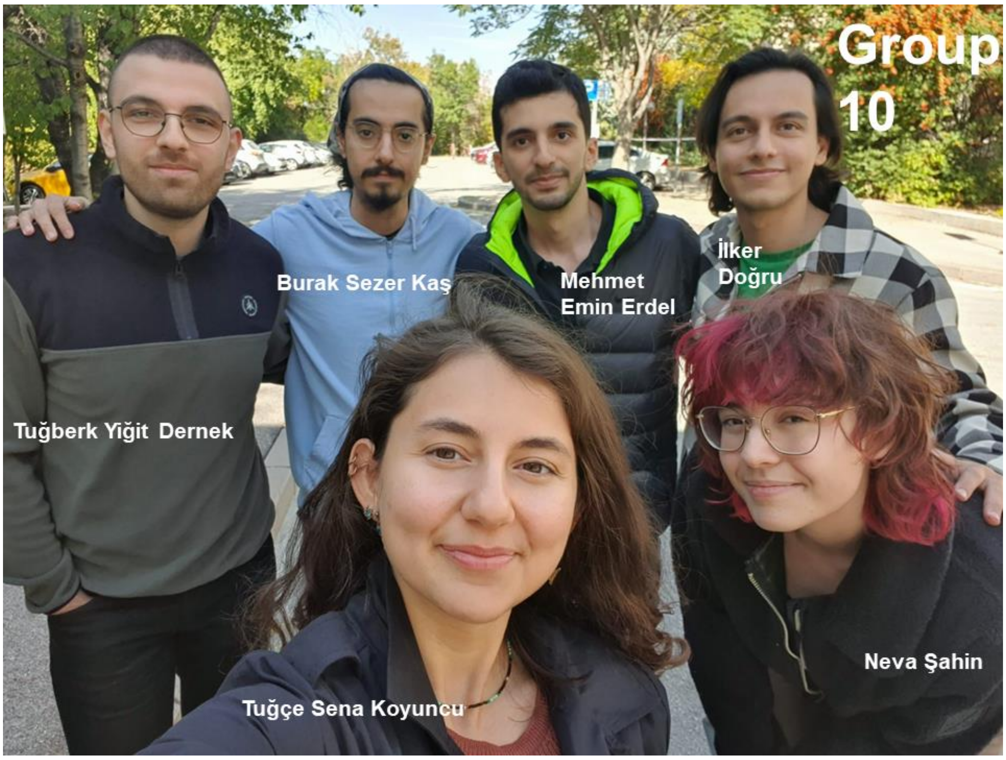
Outcomes

The mechanism is both a thermal and mechanical design project that combines the mechanical engineering knowledge obtained, thermo-fluid engineering, dynamics, material, and control courses. Some steps through the 2023- 2024 academic year are given below:

- Literature Review
- Determination of sub-systems according to requirements provided by Plan-S
- Engineering analysis
  Thermal Analysis
  Force Analysis
  Mathematical Modelling
  Control system construction and analysis
- CAD Drawing
- Manufacturing processes, assembly, design Verification
- Prototyping and Testing

Floating Surface Mine Detection System Integrated To Surface Vessel

(10)



Academic Advisor : Asst. Prof. Dr. Onur Özcan
Industrial Advisor : Mert Ali İhsan Kalın
Teaching Assistant : Altar Sertpoyraz

ABSTRACT

This project aims to develop a prototype capable of autonomously detecting and documenting the locations of surface mines in bodies of water. The system utilizes a combination of sensors, including LIDAR, radar, cameras, and IMUs, to accurately identify mines while avoiding physical contact. The surface vessel, equipped with a single azimuthing thruster and rudders, maneuvers through the test pool grid pattern to locate simulated surface mines. Key hardware components, such as controller boards, sensors, motor controls, and batteries, are carefully selected and integrated into the vessel. Software functionalities include SLAM algorithms, image processing, and PID controllers for path-following and object avoidance. The project involves rigorous testing in a specially designed test pool, adhering to a defined grid pattern, and considering environmental factors. Through a comprehensive risk analysis using FMEA methodology, potential failure modes are identified and mitigated, ensuring the reliability and effectiveness of the prototype. The proposed system addresses critical challenges in maritime security, offering a promising solution for the detection and safe navigation around surface mines, thereby safeguarding maritime operations and environmental well-being.

Problem Definition

Sea mines are explosive devices put in the water for military reasons. They're used in naval warfare, coastal defense, and to block access. When used defensively, they protect harbors and coastal areas, creating barriers to stop enemy ships. Offensively, they're placed where enemy ships are expected, causing damage and disruption.

Countries under the threat of sea mines work hard to detect and clear them. This is mainly to keep maritime operations, both military and civilian, safe. Sea mines are dangerous for naval vessels, fishing boats, cargo ships, passenger ferries, and other maritime traffic. Clearing sea mines reduces the risk of ship damage, loss of life, and environmental disasters from mine explosions. So, finding sea mines is a big deal for national security, economic well-being, and protecting the environment.

A big challenge is that removing a mine costs a lot more and takes much longer than making and placing one. The importance of sea mines is clear from historical examples. In the Civil War, Confederate forces sank a lot of Union vessels with mines. In World War I, mines limited the movements of German submarines in the North Sea.

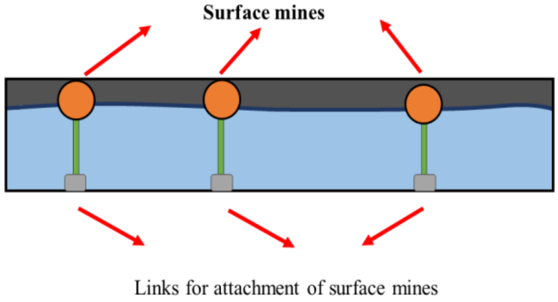


Figure 1: Surface Mines.

Our project focuses on addressing the challenge of detecting and documenting the locations of surface mines in bodies of water without physical interaction. The importance of this task lies in enhancing maritime safety and security by preventing accidents and minimizing the risks posed by sea mines to naval vessels and civilian maritime traffic. Our proposed solution aims to achieve precise detection and documentation of surface mines while adhering to strict prohibitions against physical contact, ensuring the safety of both the vessel and the surrounding environment.

To fulfill these objectives, we have developed a comprehensive design for a Floating Surface Mine Detection System Integrated to Surface Vessel. The system is designed to operate autonomously or under remote control and is equipped with advanced sensors and communication capabilities. Key components of our design include a surface vessel capable of navigating within a designated test pool, a grid-patterned pool floor for experimental testing, and representative surface mines emulating real-world scenarios.

Figure 2: Surface Vessel.

Design

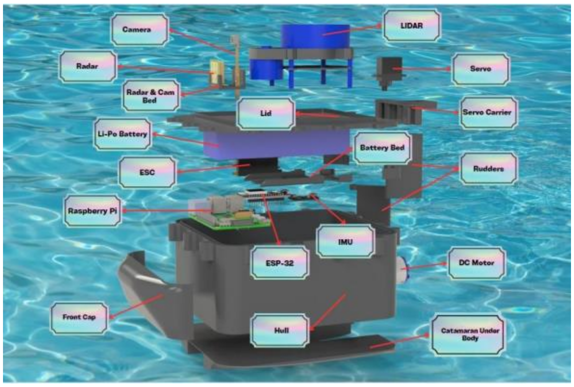


Figure 3 : 3D Model of the System

The finalized design has several subsystems: a test pool, vessel structure, sensors, and software interface. The test pool, constructed from aluminum sigma and reinforced with a 1.5*2-meter plexiglass frame, serves as the environment for experimental operations. The vessel's hull adopts a catamaran configuration, enhancing stability and maneuverability. Integrated within the hull is a powertrain system, featuring a toroidal propeller and a servo-controlled rudder. This setup ensures precise control and efficient propulsion. At the center of the system lies a Raspberry Pi 4. An ESP32 module manages the thruster and rudder servo operations.

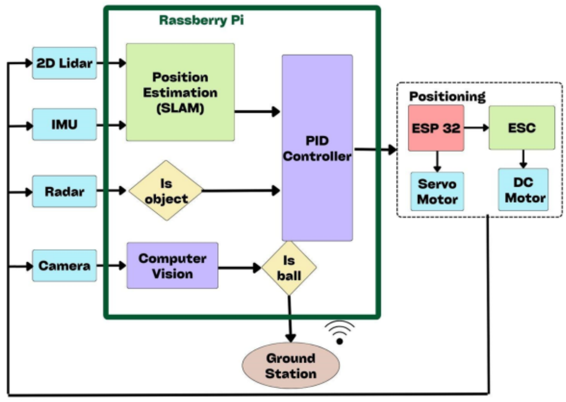


Figure 4 : Components of the system

An IMU, an electronic speed controller for brushless DC motor, and a 4S LiPo battery with a UBEC to power the system are placed inside the hull. The components are protected with a sealed cover. Additionally, a LiDAR, a camera, and a radar are placed, which are responsible for mine detection and determining the placement of the mines.

In terms of software, our design incorporates sophisticated algorithms for simultaneous localization and mapping (SLAM), image processing, and machine learning. These algorithms enable the vessel to navigate autonomously, follow predefined paths, and avoid obstacles such as surface mines.

Outcomes

This system is a mechatronics and mechanical design project that combines the mechanical engineering knowledge acquired at dynamics, control systems and mechatronics courses. It is done in several steps through the 2023-2024 academic year given as below:

- Literature research
- Determination of sub-systems and components according to requirements provided by METEKSAN Savunma
- Engineering analysis including:
  - 1 DOF/3 DOF System modeling and simulation
  - Power Calculations
  - Control system design and analysis
  - FEM analysis for static responses
  - Torque Calculations
- CAD drawings and 3D Printing of Components
- Sensors and Electronics communication and Signal processing
- Cabling of electronics and safety Analysis
- Planning of manufacturing processes, assembly, design verification and testing of the system

Adjustable Range Hood Panel
Hinge System Design

MachineMarvel (11)

Alp Mercan; Sıla Titiz; Merve Kızılkaya; Gökberk Kaya ;Tuna Cem Uzuner; Taygun Taylan

Academic Advisor : Asst. Prof. Dr. Müjdat Tohumcu
Industrial Advisor : Kadir Usta
Emre Yunus Gülcan
Teaching Assistant : Emirhan İnanç

ABSTRACT

The objective of this project is to design and fabricate a hinge system for a range hood that allows it to maintain a fixed position at any selected angle. The aim is to enhance the efficiency of kitchen appliance range hoods in extracting scents. Arçelik's existing systems are limited to fully open or closed positions and do not support intermediate angles. To enable the range hood to remain stable at any angle, friction forces will be utilized to produce torque that counterbalances the torque exerted by the range hood (max 4.8Nm from mass + 15N opening force equals around 10Nm) . A specific hinge design will be developed that produces exact friction torque through the use of shrink-fitted hinge systems. The mill and leaf components will be produced separately and assembled via heat treatments. Unlike damping-based systems, which merely smooth the opening and closing actions, or spring-based systems, which exert a constant pulling force, the shrink-fitted hinge design has been chosen to fulfill Arçelik’s specific requirements and successfully achieve the project's goals.

Problem Definition

Arçelik provides an extensive array of solutions for mitigating undesirable scents in the kitchen. Several of Arçelik's common range hoods feature adjustable openings that effectively capture scents based on their position and distribution.

However, these range hoods are constrained to fully open or closed positions, which restricts the adjustability of the opening and reduces the efficiency of the hood.

Additionally, these systems contains hydraulic dampers, which elevate the cost of the range hoods. Consequently, a stay-at-lid system design will be proposed to address these limitations.

Figure 1: Arçelik's Common Range Hood [1].

The range hood weighs 2.5kg and measures 595 x 450 x 4 mm. It is designed to operate within a range of -30° to 60 °. The maximum torque is experienced in the fully opened position (60°) which is approximately 5Nm. Also, it is expected to have an opening/closing force between 15 and 35N, which will be applied from the bottom end of the panel.

The system must also adapt and offer varying torque values depending on the position of the range hood, like providing maximum torque when fully opened.

To attain this desired functionality, friction systems will be utilized owing to their effective motion-stopping capabilities. The torque produced by these friction forces will counterbalance the inherent torque values of the range hood, ensuring stability and precise control over its positioning.

A shrink-fitted hinge design will be implemented to capitalize on friction forces. In this design, the mill component will be slightly larger than the leaf. Upon assembly through heat treatment, the leaf and mill will interlock tightly, creating friction that generates the requisite torque for the system. This method ensures a reliable and adjustable mechanism to maintain the range hood in various positions.

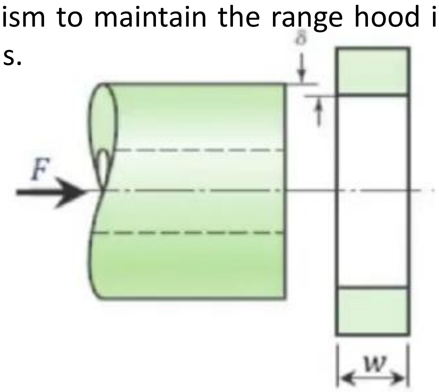


Figure 2: Shrink-fit Diagram [2].

When the system reaches its upper limit at the maximum position (60°), the friction will generate the necessary torque to neutralize the system's mobility. The design, where the mill is larger than the leaf, prevents the occurrence of a freewheeling effect, thereby ensuring a robust connection. This configuration enhances the durability and extends the lifecycle of the project, providing a reliable and long-lasting solution.

[1] Arçelik, "Ade 607-2 g | Ankastre Duvar Tipi Davlumbaz | Fiyatını Gör, incele, Satın al | Arçelik," Arçelik, https://www.arcelik.com.tr/ankastre-duvar-tipi-davlumbaz/ade-607-2-g-ankastre-davlumbaz (accessed Apr. 19, 2024).
[2] Dr. M. Andalibi, "How much force is needed for a press fit?," YouTube, https://www.youtube.com/watch?app=desktop&v=ArP4FJ6Itao (accessed Apr. 19, 2024).

Design

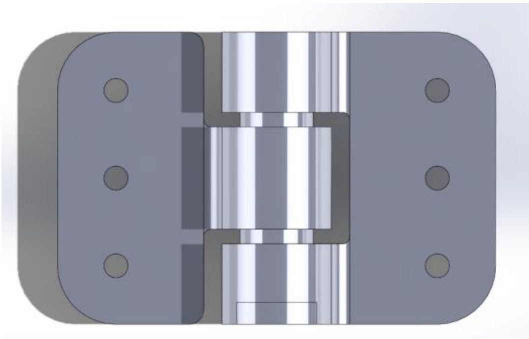


Figure 3 : 3D Model of the System

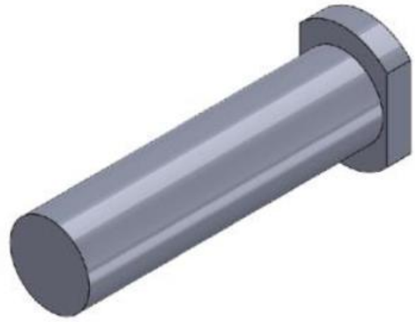


Figure 4 : 3D Model of the Shaft

The finalized version of the systems as can be seen in figure 3. The shaft connects the body and panel leaf. The panel leaf makes the interference with the shaft to generate torque while body leaf is connecting the body of range hood while the body leaf connects its with the hood.

The 3D model of the shaft, as provided above, features a specifically designed rectangular end to ensure a robust connection. This design element is critical for maintaining the integrity and stability of the connection, allowing the shaft to effectively transmit torque and resist mechanical stresses during operation.

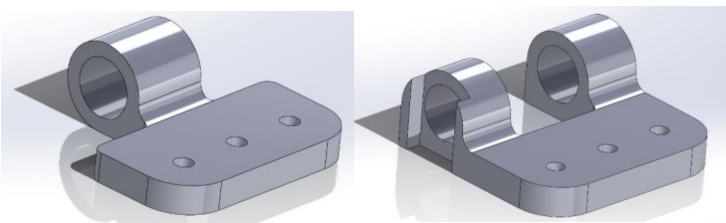


Figure 3 : 3D Model of the panel and body Leafs

The 3D model of the leafs, as shown beside, functions to connect the system with both the range hood and the hood itself. These components are interconnected via a shaft, and the holder for the panel leaf is smaller than that of the body to ensure a tight shrink fit. This configuration is designed to provide a secure and stable assembly, optimizing the mechanical connection for effective torque transmission and enhanced durability.

Outcomes

This project represents a mechanical engineering design initiative that incorporates theoretical concepts such as statistics and Finite Element Method (FEM) into practical applications. The steps executed during the 2023-2024 academic year are detailed as follows:

- Literature research to establish foundational knowledge and current technological standards.
- Comprehensive engineering analysis, encompassing:
    - Torque analysis to evaluate the mechanical forces involved.
    - Static analysis utilizing FEM to assess structural integrity.
    - Motion analysis to understand the dynamics of the system during the movement.
- Development of CAD drawings to visualize and refine the design.
- Implementation of safety procedures and the formulation of alternative plans.
- Execution of the manufacturing process, supplemented by iterative feedback for continuous improvement.

Design and Production of a Pin-on-Disc Tribometer

FNSS BME (G12)

Academic Advisor : Assoc. Prof. Dr. Barbaros Çetin
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ABSTRACT

This project aims to design and manufacture a pin-on-disc tribometer for testing purposes. These purposes are friction tests, wear tests, and lubricant tests. A pin-on-disc tribometer is a device that operates by applying force on a disc specimen through a pin specimen and then spinning the disc specimen to inflict friction on the system. Through this friction, one can calculate the friction coefficient, analyze the specimen's wear characteristics, or measure a lubricant's effectiveness. The main challenges of this project are the measurement of the friction force and the accuracy of the readings. The solutions offered for these challenges are using a Wheatstone full-bridge strain gauge and extensive calibration methods for the sensors in the system.

Problem Definition

Tribometer is a device designed to measure the coefficient of friction between two surfaces and evaluate the wear coefficient of materials. These devices usually perform friction testing between a sample and a counter sample. The samples to be used in this project will be in the form of pins and disks [1]. An example for a pin-on-disc tribometer is depicted in Figure 1 [3]. Tribometers have a wide range of uses, from industrial applications to the automotive industry. Some of these applications are given below [2]:

- Wear tests of brake discs and pads used in brake systems
- Determination of wear resistance of gearboxes and bearings
- Testing the friction and wear resistance of parts used in turbines
- Testing the friction resistance of surface coatings used in industrial applications

The schematic diagram of the pin-on-disc tribometer is shown in Figure 1.

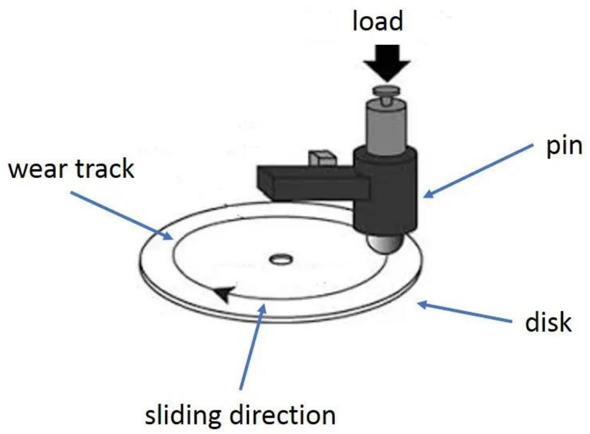

Figure 1: Schematic diagram of the tribometer [4]

Tribometers are devices that have been previously manufactured by various institutions in different countries. However, such devices have yet to be produced in Turkey. The goal of this project is to produce and integrate it within Bilkent University for educational purposes. The long-term hope for this project is that it acts as a pioneer for other endeavors in tribology.

A device was designed and produced for use in the mechanical engineering department of Bilkent University. The requirements and constraints for the final product are given below:

- A range of 0-1400 mm/s linear speed at the edge of the disc
- 30 mm disc diameter
- 6 mm ball holder (pin diameter)
- A range of 0-10 N normal load is applied on the pin
- Maximum torque of 150 $N \cdot mm$ is applied
- Device is expected to fit into a $30x30x20$ cm box

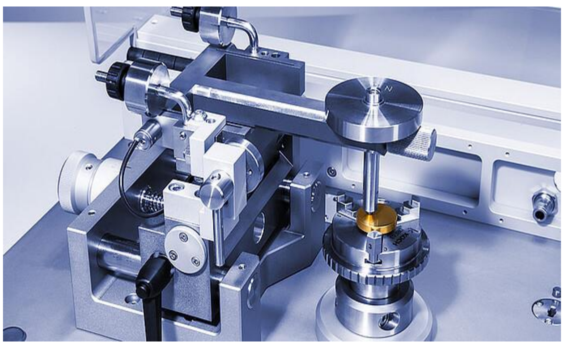

Figure 2: Pin-on-Disc Tribometer[3]

[1] G. W. Stachowiak, A. W. Batchelor, and G. B. Stachowiak, "3 - Tribometers," *ScienceDirect*, Jan. 01, 2004. https://www.sciencedirect.com/science/article/pii/S0167892204800191
[2] "Tribometer | Study interaction of surfaces," *ST Instruments*. https://www.stinstruments.com/mechanical-testing/tribometer/
[3] "Pin-on-disk tribometer: TRB^{3}," *Anton Paar*. https://www.anton-paar.com/corp-en/products/details/trb3-pin-on-disk-tribometer/
[4] Y. G. says:, "Pin on disc test," About Tribology, https://www.tribonet.org/wiki/pin-on-disk-test/ (accessed Apr. 2024).

Design

In pin-on-disc design, there are some major hardware components. These components are numbered. Numbered components are depicted in Figure 3.

1. Lathe Chuck
2. Disc
3. Pin
4. Support Arm
5. Pivot Arm
6. Adjusting Lever
7. Slider Mechanism
8. Motor (Under Lathe Chuck)
9. Top Plate

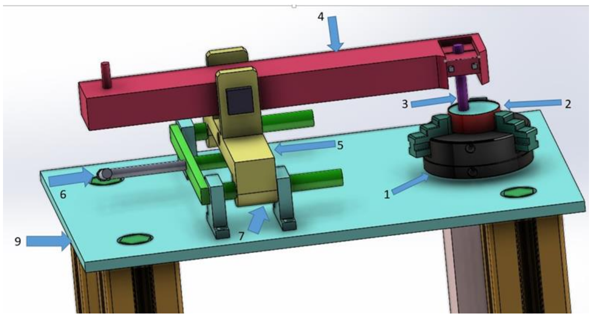

Figure 3: Design of the Pin-on-Disc Tribometer

The design is particularly notable for its wrench-like load arm, which tightly locks the pin to the disc, reducing vibrations during testing. The mobility of the load arm allows users to adjust the contact point of the pin relative to the specimen, providing rapid adaptability to different testing conditions.

Different weights are stacked centrally on top of the pin in the load application mechanism. This method allows for precise and easy adjustment of the normal load, enabling accurate friction and wear tests on various surface hardnesses and materials. The central placement of the weights keeps the pin balanced and ensures an even distribution of force.

The specimen needs to be securely fixed during the test, so a lathe chuck is used. This chuck also serves as the rotating disc, continuously in contact with the pin during testing, and is connected to a motor that rotates the specimen. The motor controls the disc's rotational speed, which can be adjusted according to the test parameters.

Proper speed control enhances the understanding of material friction and wear characteristics. These design features ensure high performance during testing, making the tribometer ideal for a detailed examination of material friction and wear properties. The data collection and analysis capabilities further enhance the usefulness of the tribometer.

Outcomes

This system integrates methods and techniques from mechanical engineering disciplines such as mechanics of materials, dynamics, control, and mechatronics. The steps taken throughout the project process in the 2023/2024 academic year are listed below:

- Literature research
- Determination of sub-systems according to requirements provided by the department and FNSS
- Engineering analysis including:
  - Load analysis
  - Vibration analysis
  - MATLAB modeling
  - Uncertainty analysis
- CAD drawings
- Structural Analysis
- Planning of manufacturing processes, assembly, design verification and testing of the system