BILKENT UNIVERSITY

DEPARTMENT OF MECHANICAL ENGINEERING

INDUSTRIAL DESIGN PROJECTS

2021 – 2022

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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, 13 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.

Adnan Akay
Professor and Chair
Mechanical Engineering Department
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Motorized Bottom Spray Arm

dreaMErs (1)

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ABSTRACT

The purpose of this project is to design a motorized bottom spray arm for Arçelik A.Ş. Dishwasher Plant. Instead of using a hydraulic system, implementing a motorized spray arm could lead to having more control over the spray arm rotation, moreover, it also diminishes water usage and reduces acoustic problems. The system comprised of a transmission system with gears, a spray arm, a DC motor as well as Arduino (controller). The spray arm rotates in either clockwise or counter-clockwise; stops and stays in the desired location; sweeps the base. Thus, implementing a synchronous motor for spray rotation systems allows to control over the rotation of the bottom spray arm such as deep washing or regional intensive washing. The rotational speed of the bottom spray arm varies. The desired speed values are controlled by using a PID system. The temperature resistance of the designed system including spray arm, gears and motor is 50°C. The material of the spray arm is also resistant to the detergent. As a result, the project aims to increase the efficiency of washing process along with client pleasure.

Problem Definition

Spray arms are one of the significant parts of a dishwasher on the grounds that the cleaning of the dishes is provided by these arms. Currently, a hydraulic system is used in the dishwasher meaning that the rotation of spray arms is done with pressurized water coming through the inclined rotating nozzles.

The water flown through the rotating nozzles has a higher flow rate than the nozzles used for cleaning the dishes. Controlling the rotation of the spray arm hydraulically with rotating nozzles owing to the fact that the high flow rate of water hits the chamber of the dishwasher with a higher hydraulic power which leads to an increase in sound pressure level and to generate acoustic noises [1].

Furthermore, water consumption occurs due to the fact that these inclined rotating nozzles are used only for the rotation of the spray arm, not for washing the dishes.

One of the efficient solutions to eliminate these problems is using a synchronous motor for the rotation of a motorized bottom spray arm. The synchronous motor allows control of the rotation of the spray arms. The propeller can stand in the desired position and rotate in two directions with the motorized spray arm. Provided that a motor is implemented, there is no need for the inclined nozzles. Henceforth, the washing performance will be increased in the dishwasher by diminishing the water consumption and performing a better acoustic performance.

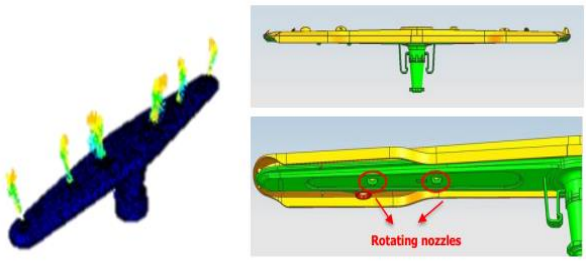


Figure 1: Bottom Spray Arm with Rotating Nozzles [2]

In short:

- The amount of water used during the washing process is more moderate compared to the hydraulic system.
- Because there are no angled nozzles, water is directed to the dishes instead of the walls of the dishwasher. Which prevents noise generated from water hitting the walls.
- Time-wise, the dishwasher achieves better performance compared to the hydraulic system.

The spray arm rotates in either clockwise or counter-clockwise; stops and stays in the desired location; sweeps the base with a size of 50cm x 50cm. The rotational speed of the bottom spray arm varies such as 15, 30, 45, 60 rpm. The temperature resistance of the designed system including spray arm, gears and motor is 50°C. The material of the spray arm is also resistant to the detergent.

The project contains usage for electrical components such as DC motor. Electrical circuits can be harmed as a result of improper component usage and selection, and expensive electrical components might be destroyed as well. Henceforth, the standards IEC 60335-1:2020 and IEC 60335-2-5:2012/AMD1:2018 are followed.

[1] “A. Gałęzia, L. Kanp, M. Jasiński, M.l Makowski, “An Investigation of Acoustic Noise Generated by Water Flowing Through Nozzles,” Proceedings of the Institute of Vehicles, vol. 5, no. 109, pp. 59–67, Dec. 2016.
[2] Motorized bottom spray arm. Ankara: Arçelik A.Ş., 2021.

Design

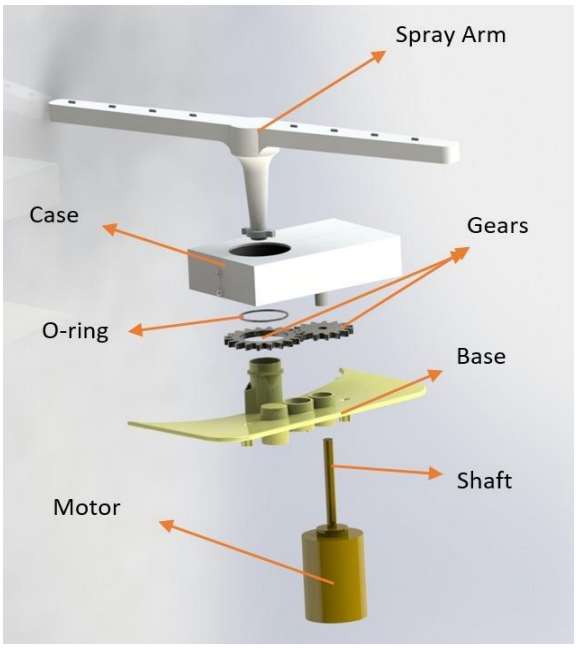


Figure 2 : Bottom Spray Arm System

The spray arm is produced from Polypropylene (PP) so as to resist the specified temperature and pressure. Gears are the main transmission unit of the system. Module 3 gears are used since gears will not withstand huge amounts of load. DC Motor is used with an encoder which enables speed control in order to rotate the spray arm.

In order to prevent the water leakage to the motor and food residues, an insulation box is designed.

Motorized bottom spray arm has some moving components as well as some stationary components. The desired rotational velocity is chosen by the user. Arduino converts the information from the coding environment to the physical space; therefore, it is the translator between the user and the motor. The DC Motor transfers the power to the gear driven transmission system. With spur gears, the torque and rotational speed that are created by the motor can be transferred to the spray arm. The water hits the dishes from the nozzles in the spray arm. The position control is measured with sensors placed in the gear. The speed control of the motor will be supplied by an encoder which is already provided from the DC Motor. The encoder measures the speed of the motor in real time and feed this information to the Arduino. If the motor speed decreases, Arduino will process this information and will correct the motor speed.

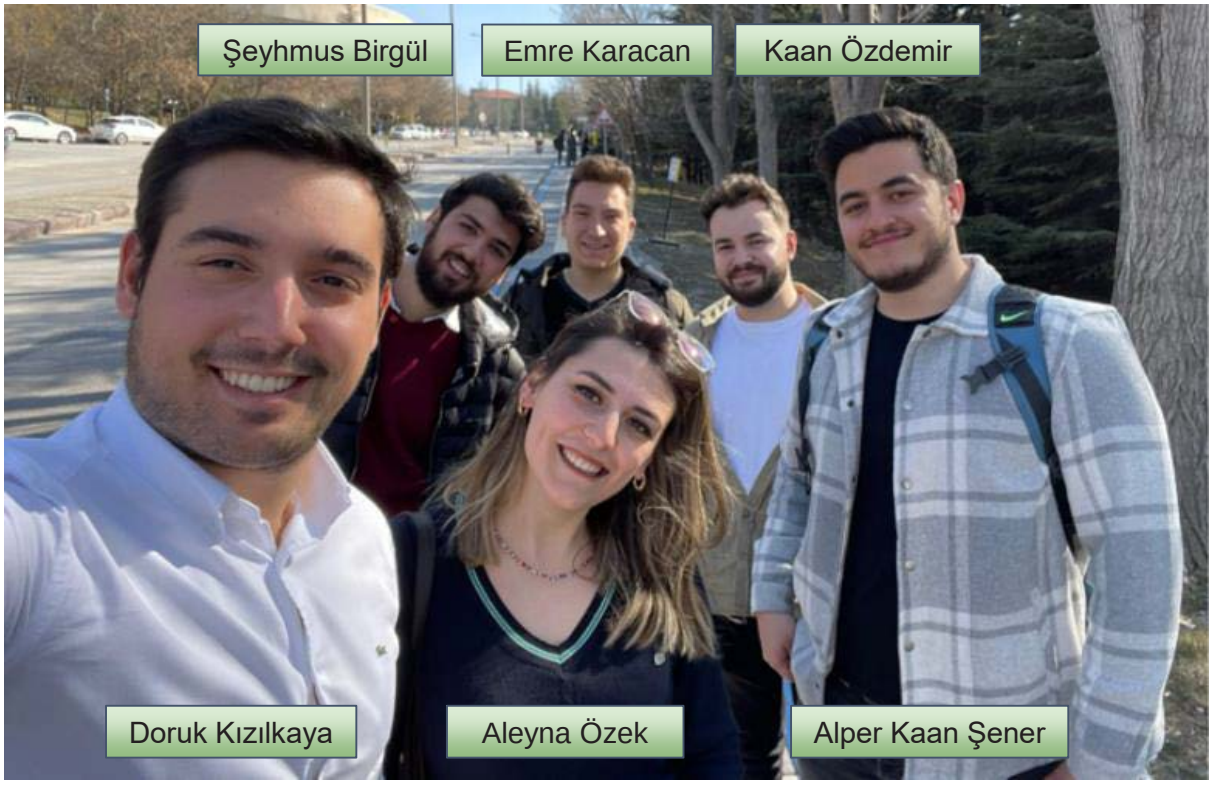
Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at mechatronics courses, dynamics and control systems. It is done in several steps through the 2021-2022 academic year given as below:

- Literature research
- Determination of concepts and components in terms of requirements and constraints provided by Arçelik
- Engineering analysis including:
  - Computational Fluid Dynamics analysis
  - Kinetic analysis
  - Control system analysis and simulation with MATLAB/Simulink
  - Arduino codes for rotation and position
  - Solidworks technical drawings
- Safety Analysis
- Manufacturing processes, assembly, design modifications, test and evaluation of the system

Designing a Double-Sided Rotating Spray Arm

PervaME (2)



Academic Advisor: Prof. Dr. Ömer Aka Anlağan
Industrial Advisors: Uğur Kan
Gökhan Ak
Tunahan Başer
Teaching Assistant: Sarp Ilgaz Koç

ABSTRACT

The objective of this project is to design and produce a double-sided rotating spray arm in order to achieve increasing the washing area of dishes for the ARÇELİK dishwashers. In conventional dishwashers, the spray arm can make only unidirectional rotation by using hydraulic power. Therefore, the water reaches to dishes from only one side of the dishes and it leads to longer times for cleaning operations. This type of unidirectional movement reduces the scanning of the cleaned areas and the washing performance. In this project, double-sided rotation was achieved by using only hydraulic power. In this booklet, the project definition, design, and outcomes for the double-sided rotating spray arm project are included. The rotational movement of the spray arm due to hydraulic power triggers the mechanism after every minute and provides bidirectional rotation.

Problem Definition

Commercial household dishwashers consume approximately 13 L of water in an operation and in current dishwasher machines, the spray arm is driven by the water used to get a unidirectional rotation [1]. In traditional dishwashers, the rectangular volume where the cage of the machine is cleaned by circular rotation and creates problems with the washing performance of the dishwasher. This process is driven by rotation nozzles where water leaves perpendicular to the spray arm center.

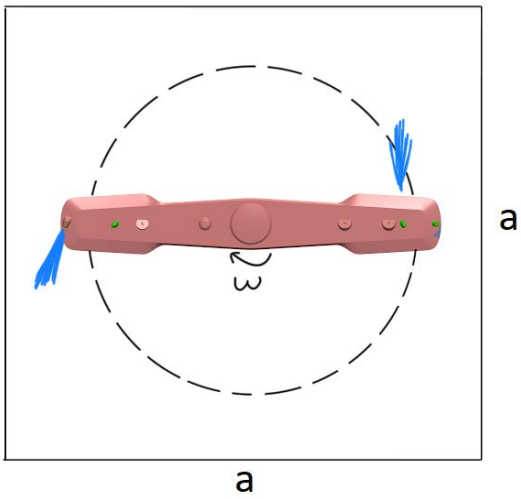


Figure 1: Representation of the Problem

The water coming from the nozzles causes one-sided rotation and the pressurized water reaches mostly one side of the dishes. Considering the optimum washing performance, some nozzles are positioned to reach the back sides of the plates. Since there is unidirectional rotation rather than bidirectional rotation, a longer cleaning time is required to ensure cleanliness. Therefore, more energy and operation time are consumed in a one-sided rotating spray arm.

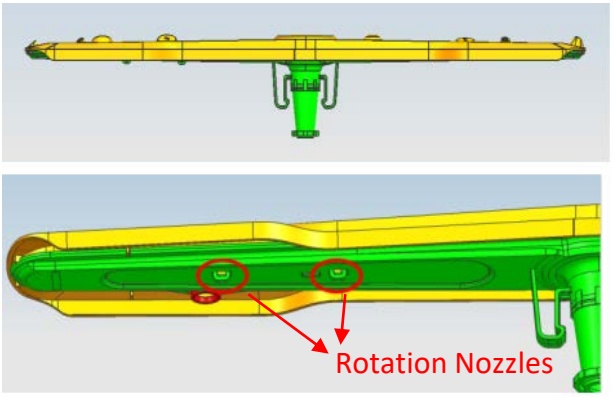


Figure 2 : General Structure of the Spray Arm

With the design of the double-sided rotating spray arm, the spraying angle that is reached to plates is doubled up. Moreover, since the reaching angles to plates are doubled by bi-directional rotation, the nozzles that spray the backside of the plates will be eliminated. Furthermore, the washing operation will be completed in a shorter time with higher washing quality due to doubled reaching angles. For that reason, the company desires to increase efficiency and washing performance in the washing process by having the capability of double-sided rotation for the spray arm. The objective of this project is to design and prototype a double-sided rotating spray arm for the bottom or/and an upper part that uses only hydraulic power to rotate.

[1] "6344: Bulaşık Makinesi: Beyaz Eşya: Arçelik," 6344 | Bulaşık Makinesi | Beyaz Eşya | Arçelik. [Online]. Available:https://www.arcelik.com.tr/bulasik-makinesi/6344-bulasik-makinesi. [Accessed: 01-Nov-2021].

Design

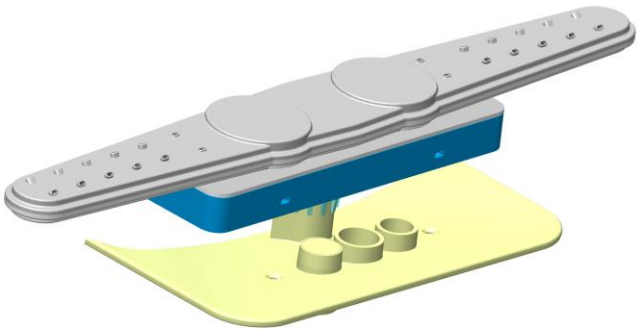


Figure 3: CAD Model of the Assembled System

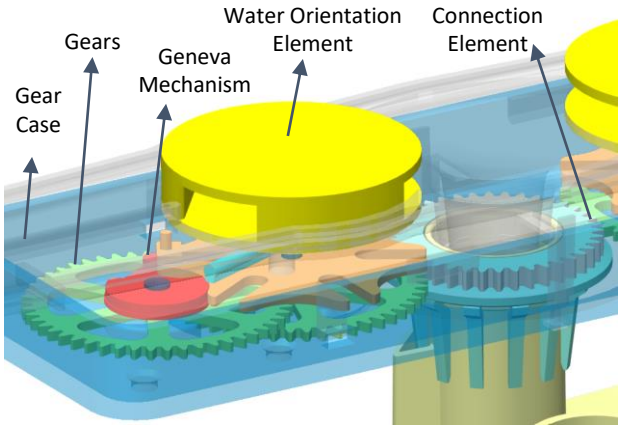


Figure 4: Inside View of the Mechanism

The design of the double-sided rotating spray arm consists of a compact gear mechanism with a Geneva mechanism, two water orientation elements, a connection element, and a spray arm body. This design allows a change of the washing direction in the desired time interval. Considering the easy mountability criterion, the gearcase is assembled to spray the arm body with clamps. For smooth gear operation properties, water drain holes are added to the gearcase for preventing the accumulation of water. The spray arm has cross-way water channels which enable the nozzles for bidirectional rotation.

The water orientation element in the spray arm is designed to change the direction of water flow suddenly towards the determined channel. When water comes out of the nozzles, the spray arm starts to rotate and that rotation drives the gear mechanism shown in **Figure 4**. After one minute of rotation, the pin on the Geneva wheel interacts with the water orientation element, and it causes the orientation element to rotate. Therefore, the water flow is passed to the other channel so that the reverse rotation is obtained and the process goes on until the water flow is stopped.

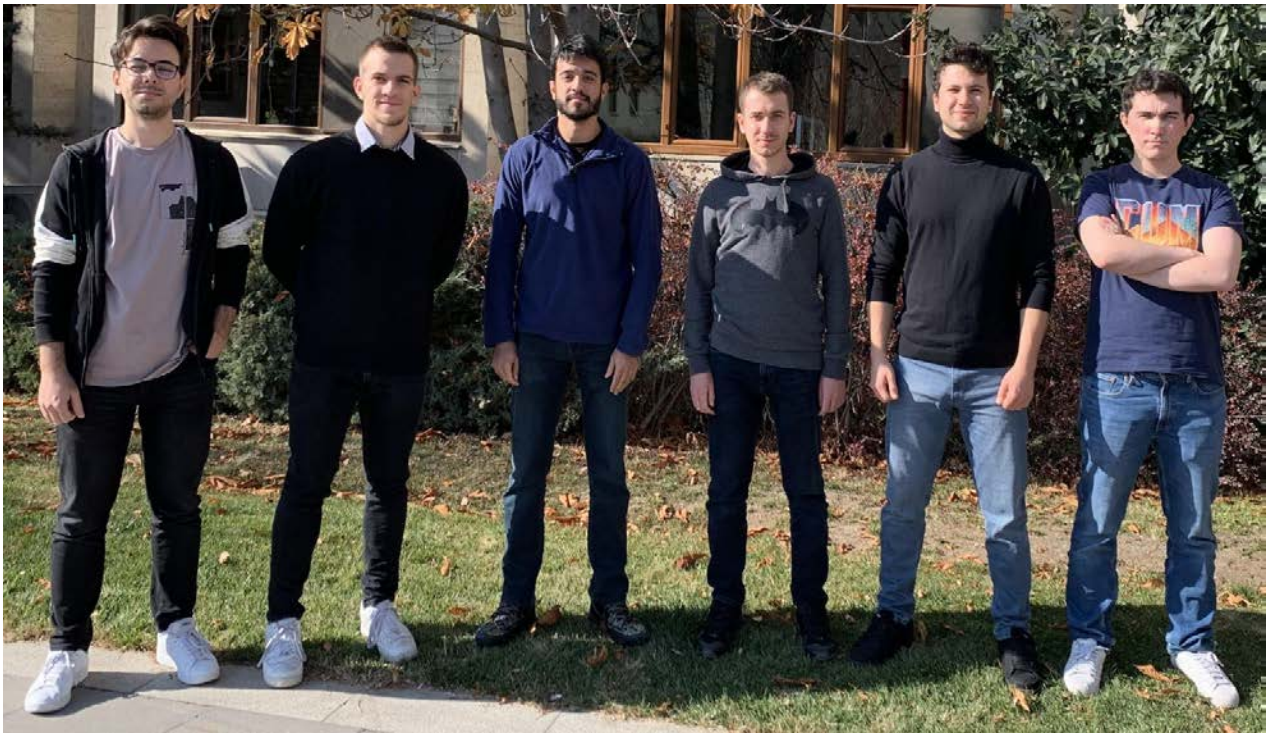
Outcomes

This system is a fully mechanical design project that covers the thermodynamics, fluid mechanics, strength of the materials, dynamics, and manufacturing subfields of the mechanical engineering discipline. The design and manufacturing studies of this project carried out for 2021-2022 academic year consisting of the following sub-stages.

- Patent and literature research of the similar problems, designs and related codes and standards
- Selection of the design concepts according to requirements and constraints determined by ARÇELİK
- CAD modelling and technical drawings
- Engineering analysis including:
  - Fluid analysis
  - Stress analysis
  - Kinematic analysis
  - Gear mechanism analysis
- Failure mode analysis and modification of the design
- Planning of manufacturing processes, assembly, design verification and testing of the system

Design and Production of Electric Autonomous Ground Vehicle with 4 Wheel Independent Steering and Driving

GRAVITY (3)



Kutay Şentürk | Doruk Şut | Yiğit Yaman | Yunus Altıntop | Enes Batıkan Özden | Ege Erdem

Academic Advisor : Asst. Prof. Dr. Melih Çakmakçı
Teaching Assistant : Kemal Köysüren

ABSTRACT

The aim of this project is to design and produce an autonomous ground vehicle with 4-wheel active suspension, drive and steering capabilities at 1:8 scale to be used in testing automotive control algorithms in research focused on comfort and drivability in emergency steering and braking. Testing these algorithms on simulations are cheap but inaccurate and tests performed on real scale vehicles are extremely expensive even though they provide the most accurate results. For this reason, small-scale ground vehicles are the optimal solution because they are both inexpensive and provide reasonably accurate results. Since currently available market solutions are slightly expensive and do not have all the desired specifications, manufacturing of the ground vehicle was decided. The proposed solution of the project is less expensive than the current market solutions and has the desired mechanical specifications (4-wheel drive, steering and active suspension) in addition to having autonomous driving capabilities using the popularly used NVIDIA Jetson NANO controller, a 2D LIDAR, a stereo camera, an inertial measurement unit (IMU) and optical encoders.

Problem Definition

In the modern understanding of mobilization, private vehicles dominate the market of passenger transportation. Hence the automotive industry is one of the world's leading sectors in the global economy. As a consequence of being a giant part of the economy, it results in a competition between the agents of the sector to increase their market share. It drives the agents to innovate new technologies and apply more appealing solutions to their vehicles to leave behind their competitors. Easy drivability, high comfort, and safety of the vehicles has become an appealing feature for the passengers. In order to meet the demand of the clients, the automotive industry and scholars have been conducting research to improve the drivability and comfort algorithms for vehicles.

Figure 1: Scaled Up CAD Model, Front View

One other aspect that is important for the clients and the relevant social groups is the clean energy usage. With the usage of diesel and fuel-powered the cars release carbon dioxide which results in a high effect on climate change. Due to this effect the governments and the companies aim to reduce the production of the diesel and fuel-powered cars and aim to create cars that use clean energy. Therefore the development of electric cars increases which is one of the energy sources that can be used.

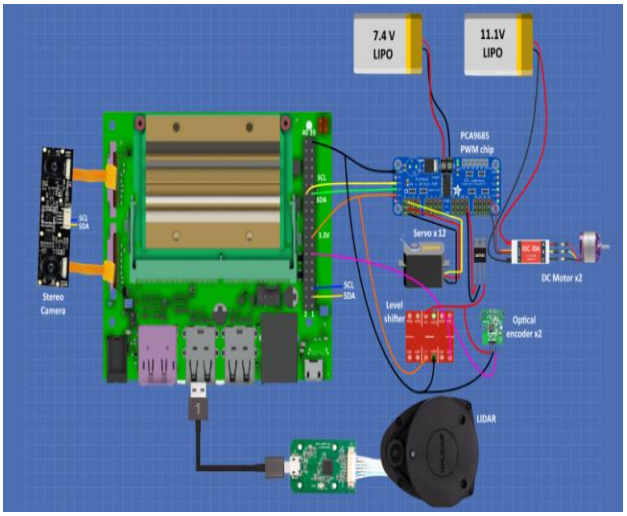


Figure 2: Electronic Structure of Autonomous Vehicles

The automotive industry focuses on the development of high maneuverable, comfortable autonomous cars with high torque working with clean energy. One of the solutions in the industry is to design four wheel driving and four wheel steering autonomous electric cars such as the Tesla models. Yet Tesla is not the only car company who is trying to develop drivability and comfort algorithms for the industry. However, budget constraints of the sector agents constrict them to train and improve their algorithms on more feasible platforms.

The objective of this project is to design a small-scale autonomous electric ground vehicle with four wheel driving and four wheel independent steering with active suspension and mechanical braking run by control algorithms which is capable of autonomous emergency evasion. This vehicle is going to be used as a testbed for the development and validation of new drivability and comfort algorithms. Therefore, it is expected to simulate various driving scenarios and harsh conditions to test the limits of the algorithm.

Design

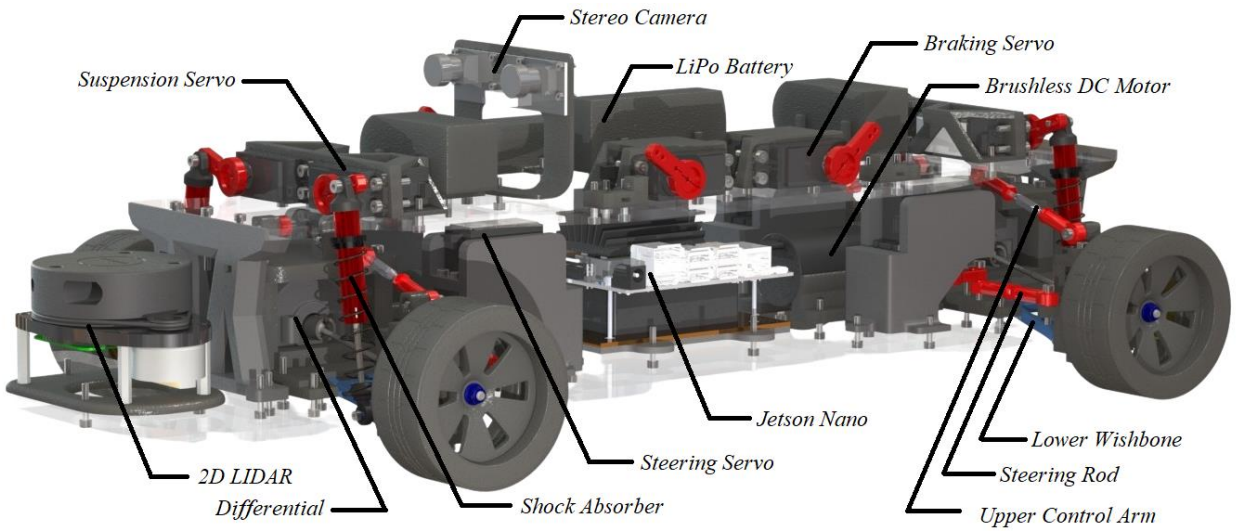


Figure 3 : CAD Model of Autonomous Ground Vehicle

The design of the autonomous ground vehicle was finalized as a system with independent active suspension, braking, and four-wheel driving and steering. The system consists of two main platforms, which are connected to the wheels by upper control arm and lower wishbones, for the installation of sub-systems. The level of each wheel can be adjusted by the servo motors. Mechanical disc brakes compressed by servos are installed onto each wheel. Front and rear wheels are driven with differentials each powered by brushless DC motor.

The Jetson platform is the brain of the ground vehicle by giving inputs to all 12 servo motors and 2 DC motors for suspension, braking, driving and steering, and processing the outputs of the LIDAR, stereo camera, IMU and optical encoders. The controller has the abilities of obstacle detection, localization (providing 6 DOF motion data) and the control of the motors based on the available information and the control algorithm under testing. Using the processed information, the vehicle autonomously creates a path to arrive a predetermined location.

Outcomes

The project requires a composition of background knowledge built in dynamics, control systems, mechanical design, mechatronics courses, and internships. The process of project development is as follows:

- Literature research
- Engineering analysis including:
  - 3DOF Lateral System modeling
  - Mathematical modeling
  - Control system development and simulation
  - Object avoidance and localization algorithms
  - Stress and deformation analysis on commercial analysis packages
- CAD drawings
  - Consideration of components to be purchased and iteration of CAD design
- Consideration of Codes and Standards, with Safety measures
- Manufacturing processes; including assembly, design verification; and testing of the mechanical system and software

Design and Production of an Passive Magnetic Bearing

Sixers (4)

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Prof. Dr. Ömer Aka Anlağan
Industrial Advisor : Kutay Edis
Teaching Assistant : Hande Nur Açıkgöz

ABSTRACT

The main goal of this project is to create an alternative to conventional ball bearings used in white goods. Primary appliances of interest will be dryers. It is observed that the front sealing in the shaft deteriorates during lifetime and starts to leak detergent involving washing water. As a result, lubricant in the bearings washes away in time and “pitting” fatigue occurs. Due to the lack of physical contact, with the help of magnetic levitation methods, magnetic bearings are planned to be retrofitted into dryers. Since the magnetic bearings require no contact, the total contact area will come from single ball bearings in the front. As a result, frictional forces applied on the shaft will be reduced and more efficient appliance working conditions will be generated for current and future projects. Since sustainability of the project is also crucial, decrease in contact area will aim to increase efficiency in white goods. Moreover, malfunctions due to moisture and chemical leakage in the ball bearings will be reduced and only be faced in the front bearings. Throughout the report, explanations contributing to geometry of the shaft, permanent magnets, reaction forces applied on mechanical bearings, mathematical formulas related to magnetic levitation, mathematical calculations, manufacturing of the permanent magnets and cost will be discussed. Project cost is limited to 20000 TL.

Problem Definition

Magnetic bearings are alternatives to the mechanical ball bearings where less frictional losses are desired with high rpms. Due to the physical contact that is present with current conventional ball bearing systems, time dependent malfunctions occur. Conventional ball bearings require lubricants. However, they lack lubricant recirculation [1]. Therefore as the time passes, lubricant applied on the ball bearings starts to dissolve due to exposure to various solvents, moisture and liquid mixtures resulting in maintenance. In dryers, due to the present evaporation and condensation in the drum, ball bearing lubricants start to deteriorate and lose their lubricating characteristics. This causes increased friction and reduced efficiency. This was the exact problem Arçelik faced in their washing machines and dryers. Designing a system that contains no lubricants but allows rotational motion is feasible using the magnetic levitation principle.

Figure 1: Bearing Failure

Thus, magnetic bearings are desired due to their [2];

- Quieter structure
- Lubricant lacking structure
- Design variations
- Increased efficiency
- Time independent service life
- Dynamic stiffness values

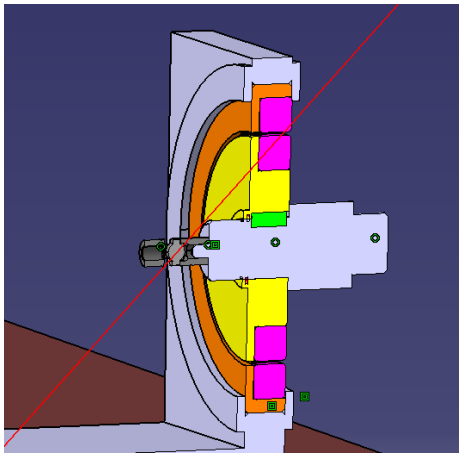


Figure 2: Crossectional Area of Magnetic Bearing System

Current bedding solutions use ball or roller bearings that rely on relative motion between the inner ring and outer ring. While the outer ring is fixed and stationary, the inner ring rotates in couple with the shaft applied. Cage contains the steel balls that allow rotational motion as in figure 1. Due to the rotational motion of the steel balls between the inner and outer rings of the bearing, rolling elements and the cage rotate slowly when compared to the inner ring. This phenomenon generates conditions for rotational motion without sliding and with reduced frictional energy losses. However, since physical contact is present, so does friction. Due to the frictional forces present during rotational motion, temperature elevations or drops change the lubricant's viscosity values besides contamination. Due to the time and temperature dependent structure of the lubricants, frictional losses increase in time. It is possible to apply different grease types such as mineral, diester, ester, silicone, fluorosilicone or perfluorinated ones as stated in figure 2. Even though changing the type of the lubricant is possible for wider operating temperatures, loading capacity and angular velocity values start to bottleneck the system in general, which is not desired.

[1] M. A. Mian, “Design and analysis of Engine Lubrication Systems,” Design and Analysis of Engine Lubrication Systems, 24-Feb-1997. [Online]. Available: https://www.sae.org/publications/technical-papers/content/970637/. [Accessed: 19- Nov-2021].
[2] Internet Archive. 2021. An Overview of Magnetic Bearing Technology for Gas Turbine Engines : Clark, Daniel J. : Free Download, Borrow, and Streaming : Internet Archive.

Design

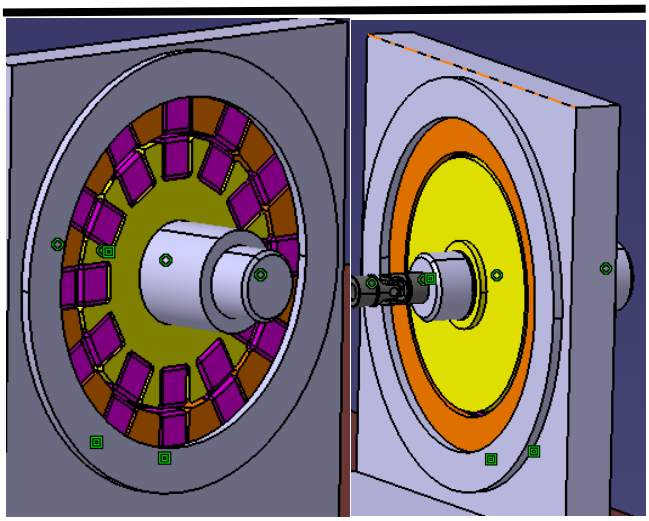


Figure 3 Passive Magnetic Bearing System

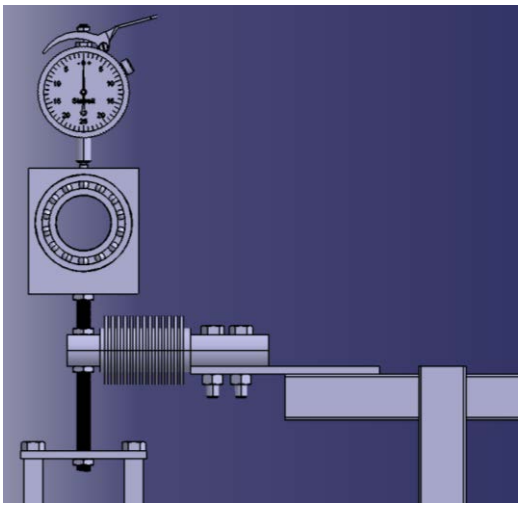


Figure 4 : Measurement System

With an integrated passive magnetic bearing system into the White good of interest, due to lacking physical contact between surfaces, friction levels will be significantly decreased. In addition to that, applying grease on bearings will no longer be necessary causing a lubricant free system.

The radial excitation force that is coming from the uneven mass from the original system was achieved via a screw system. With the help of a Load Cell, exact radial force would be monitored by data acquisition systems. By the implementation of a dial gauge, eccentricity values of shaft during operation and under radial force would be calculated. The probe of dial gauge and the force direction was aligned in order to get accurate readings for both by following the Abbe Principle.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at machine elements, machinery dynamics and measurement and instrumentation courses. It is done in several steps through the 2021-2022 academic year given as below:

- Literature research
- Determination of sub-systems according to requirements provided by ARÇELİK
- Engineering analysis including:
  - Mathematical modeling
  - Magnetic Field Analysis
  - Magnetic Force Analysis
  - Trial & Error Confirmation
- CAD drawings
- Safety Analysis
- Planning of manufacturing processes, assembly, design verification and testing of the system

Design and Implementation of an Industrial 6DoF Robotic Arm

COMBAT (5)

Barış Kırmızıgül | Kayra Dernek | Taner Üzer | Ozan Sercan | Asım Can Şahin | Musa Herdem

Academic Advisor : Asst. Prof. Dr. Onur Özcan
Industrial Advisor : Selim Bağcı
Teaching Assistant : Mustafa Uğur

ABSTRACT

The purpose of this research is to design a six-axis robotic arm that will be used in the manufacturing process. Six axis robotic arms are used in the industry due to their high flexibility of applications. The main design problem is to design a six-axis robotic arm that can effectively change its dimensions in order to make it possible for the design of a variety of robotic arms with different dimensions. The necessary kinematic equations and torque calculations are made to observe the requirements for the design. According to these results, the proposed design is modified in a way that could satisfy the load requirements without creating a risk, and consequently, the design is manufactured, and the contral equipment and motors are assembled.

Problem Definition

Mass production companies are equipped with plenty of robotic arms to obtain flawless and faster production lines. Robotic arms contribute to having more accurate, cost-effective and more predictable outcomes. Operating robotic arms can also avoid work accidents by freeing humans from jobs that have injury risks.

Figure 1: Production line equipped with robotic arms

Although robotic arms can be utilized for many different applications, there are a variety of robotic arms needed for different workpiece sizes and tasks. Automation branch of Arçelik PCI aims to handle production lines mostly with robotic arms rather than humans. In the plant there are lots of robotic arms with a wide variety of dimensions and workloads. Picking and placing, labeling, quality testing and welding are some examples for usage of robotic arms in Arçelik. It is discussed that because of the difficulty of finding industrial arm in desired dimension and power, some of the manufacturing processes needs to be altered according to dimensions as long as six months. In addition to problems that are caused by inadequate dimensions, purchasing these robots also contribute to that cost of manufacturing. Being able to manufacture

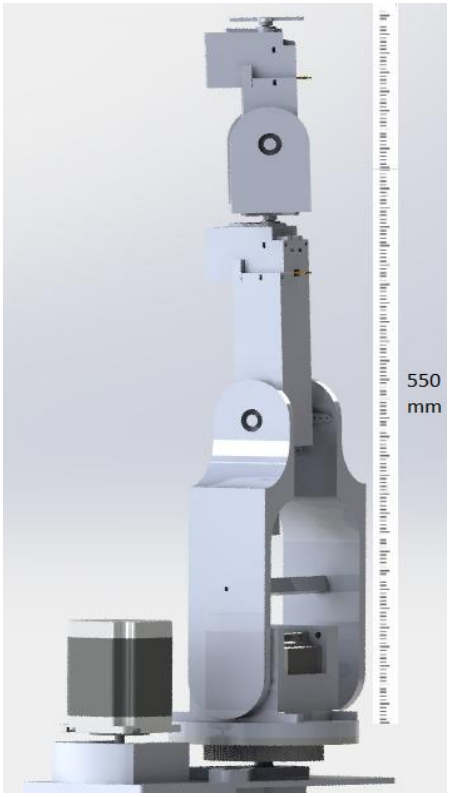


Figure 2: Robotic Arm Reaching Maximum

these robots in house would contribute to cut down on the cost of manufacturing in their many different production lines.

To overcome these problems such as finding the right dimension for a specific application, lowering spendings on robotic arms and waiting almost a year for a purchase delivery, Arçelik decided to initiate a project of designing a 6 DoF robotic arm. The requirements and constraints of the robotic arm are determined arbitrarily by Arçelik. However, the main goal was to have an adaptable design for different dimensions and powers. For this project, requirements and constraints are set as 3 kg of payload, 550 mm maximum reach, running on AC power supply, repeat accuracy of 10 mm and the weight of the robotic arm was expected not to go over 25 kilograms.

[1] *Top trends robotics 2020*. IFR International Federation of Robotics. Retrieved April 9, 2022, from https://ifr.org/news/top-trends-robotics-2020/

Design

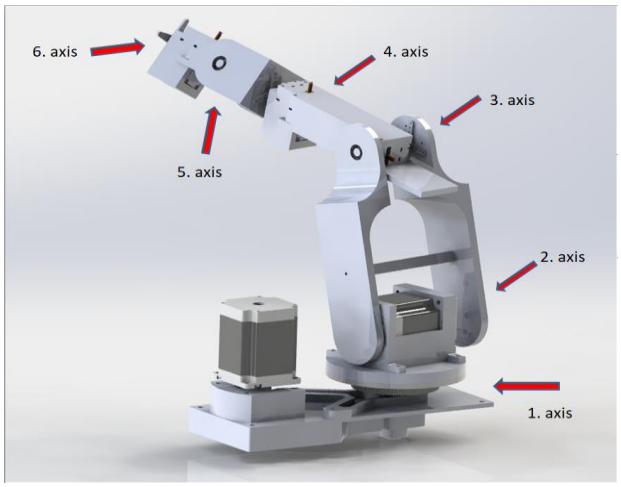


Figure 3: 3D Model of Robotic Arm

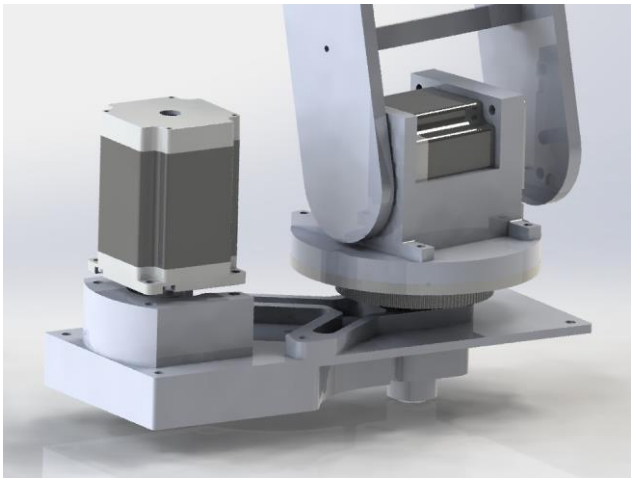


Figure 4: First Axis of Robotic Arm

The robot has 6 different axes, and motors, to be controlled. For the first and second axes Nema 23 stepper motors are used. First axis motor power is transferred to the second axis with a belt system. The ratio of the belt system is 4:1. It increases the torque and decreases the speed by a factor of 4. Second axis motor is connected to the link directly. For the remaining 4 axes, PDI 6221MG servo motors are used. These motors are connected to the links directly as well. However, since the power of the motor is not enough to satisfy the need of the third axis torque value, a balance place is left behind the third axis. The balance weight will carry the center of gravity to the center of the motor itself, which will decrease the torque. Also, to provide the movement of every axis, bearings are used with an inner radius of 8 mm and outer radius of 16 mm.

In the control part, Arduino is used with micro drivers. Every motor has its own driver. These drivers can control the power given to the motors, their torque and speed values. In total, all drivers are connected to Arduino, giving inputs in the correct order and range.

Outcomes

This system is a mechanical design project that brings together the mechanical engineering knowledge acquired at design and manufacturing, dynamics, control and mechatronics courses. It is conducted in several steps through the 2021-2022 academic year as given below:

Literature research

- Pre-design calculations regarding the requirements provided by ARÇELİK
- Engineering analyses:
    - Forward/ Inverse Kinematics in 6 DOF Systems
    - Torque Analysis
    - Power Transmission System Construction
    - 3D Drawings and Stress Analysis
    - System Control Construction
- Safety Analysis
- Planning the manufacturing and assembly process

Design of a Quick Coupling for Fluids and Gases

Nexum MEchanica (6)

Academic Advisor : Asst. Prof. Dr. Onur Özcan
Industrial Advisor : Mehmet Yıldırım
Teaching Assistant : Mustafa Uğur

ABSTRACT

The aim of this project is to design and manufacture a quick coupling for fluids and gases. Filling and securing leakage in missile fuel systems is an important topic. Quick couplings can provide fast and stable flows with minimal effort and time. The equipment consists of 3 main parts following; plug, socket & protective cap. Fuel filling operation will be done by plug-socket couple whereas plug will be mounted on the missile system and socket will be providing fuel through fuel system. After filling, the plug-protective cap assembly will be securing the leakage. Plug will stay mounted on the missile while cap will be mounted on to the plug. In order to ensure the success of the design, each element is subjected to individual analysis and calculations. These include spring calculations, pressure loss analysis, pressure vessel calculation, thermal expansion analysis, seal and housing calculations. For test setups, necessary equipment designs have been created. Test tools are designed in order to cooperate with the existing test setups used in ROKETSAN according to MIL-STD 810H Standards.

Problem Definition

The main problem in this project is that the quick couplers ROKETSAN currently uses can't operate in the required temperature range and they are also not validated with the tests which ROKETSAN requires. Stated quick coupling project is both a reverse engineering and a new/improved design project. It is expected from the group to create a product which is indigenous and conforming the need statement conditions.

As an additional added-value for the project; in the defense industry, some of the parts are only available abroad. Therefore, Turkish military power is currently dependent on foreign countries for this critical quick coupling product. As a result of this condition, the production of rockets could be in corsair in the light of political disagreements and thus, stall might happen. Additionally, with the monopolization of quick coupling designs, a large amount of money is paid for the necessary critical parts manufactured with military grade standards. Thus, provided with the new design, quick coupling can be modified and used in similar projects.

Figure 1: Detailed design of the quick coupling

The main design problem of the project is to secure the product from leakage while operating it in the fueling and flight environments. The design should be meeting mass and dimension regulations of the current missile system while having an optimum life expectancy.

Design

The system of the design was finalized according to selected five main concepts. These concepts are, seal material, material of the main body, locking mechanism, connection mechanism and protective cap. Every single of them evaluated according to their own criteria in order to achieve the best fit for the given concept so that in the end the overall design can be successful.

The final product is composed of three parts: socket , plug, and protective cap.

Figure 2: Socket

Figure 3: Plug

Figure 4: Protective Cap

Seal is the crucial element to provide leakage prevention. Since the design should be able to work in low and high temperatures, the choice of O-ring material is critical. Thus, fluorosilicone, which is compatible with JP-10 fuel to avoid chemical reactions, is chosen to be the best choice.

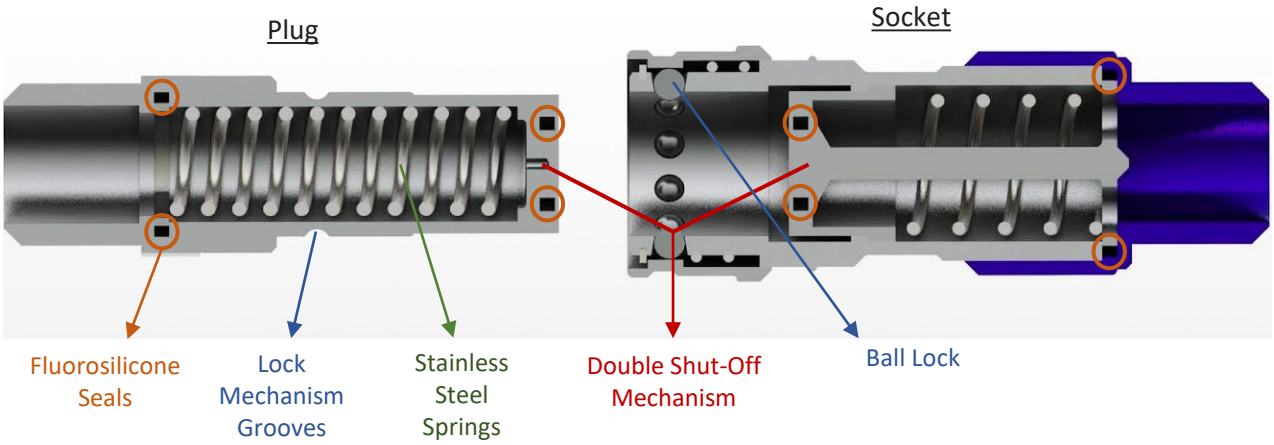


Figure 5: Rendered Image of the Final Product

For main material 6061 aluminum is selected as it is lightweight, easy to machine and widely used in the aerospace industry. Locking mechanism is another important topic as it secures the overall connection. Ball lock mechanism is determined as it is easy to use, gives zero operator error margin and provides good security. For the connection mechanism the double shut off concept is selected as it has shut-off valves on both ends of the plug and socket preventing any unwanted contaminant leakage. It is the only connection type that meets the requirements.

The protective cap is a crucial element in securing leakage, it works as a barrier. When the socket is disconnected, a protective cap is attached to the plug so that zero leakage can be achieved during the operation. Furthermore, springs which are suitable to encounter the forces both during the operation and the fuel-fulling process are determined through conducting detailed engineering analysis and solving an equation with five unknowns.

The final product is subjected to MIL-STD-810H standard.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at mechanics, thermodynamics and machine elements courses. It is done in several steps through the 2021-2022 academic year given as below:

- Literature research
- Understanding of the requirements and design constraints provided by ROKETSAN
- CAD drawings
    - Mechanical design
    - Machine elements selection
    - Test tool design
- Engineering analysis including: thermal and mechanical analysis
- Cost analysis
- Safety & Reliability analysis
    - Testing according to Military Standards (MIL-STD 810H)
- Design verification

Electric Motor and Propeller Test Stand

Manualis Architecti (7)

Academic Advisor : Asst. Prof. Dr. Mehmet Selim Hanay
Industrial Advisor : Kaan Aykol
Teaching Assistant : Mehmet Hakan Sarı

ABSTRACT

The objective of this booklet is to illustrate the key points of the “electric motor and propeller test stand” project that is offered and monitored by the VESTEL Savunma company. To reduce cost, time and risks, test units are essential and being one of the leading UAV companies in Turkey, VESTEL Savunma had a need for a test device to evaluate the specifications of the RC motors and their compatibility with propellers such as rpm values, thrust forces, voltage and current behaviors, etc. Thus, they have a done market research and comprehended that the only reliable product in the market is exceedingly expensive. Therefore, we are requested to produce a high-quality, low-cost product. Over the process, conceptual designs have been made and evaluated according to the results of extensive engineering analyses in accordance with the advisors. After having consensus on the final design, a prototype has been manufactured and comprehensive tests have been made on the product. Lastly, the project has been finalized with verification. Throughout the booklet, you can find a brief explanation of the problem and concise description of the system constraints. Following, key characteristics of the design have been presented and the outcomes of the project has been clarified.

Problem Definition

Unmanned Aerial Vehicles (UAV) constitute an integral part of army forces. It is relatively a new subject of research and still in development and resources are respectively limited, thus it is very important for producers to test their equipment before use. Moreover, trials in instruments can reduce the risks, time and consequently the cost for the projects.

VESTEL Savunma is a Turkish company that produces a variety of UAVs for militaries, and they needed a test stand to try RC motor and propeller systems. There are few options in the market for this purpose, however, there is only one company that is capable of producing a reliable product that can give accurate and precise results and their products are expensive due to the state of the company in the market. They constitute a monopoly currently. Needless to say, there are some other options, but these are China-based big companies that has no specific proficiency on this subject.

Figure 1: KARAYEL-SU UAV by VESTEL Savunma [1].

Figure 2: Inspiration for a motor/propeller test stand [2].

Our goal is to design and produce an alternative high-quality product that has a lower cost, more user-friendly interface and can give reliable results. During this procedure, we are considering some requirements and constraints that are given by VESTEL Savunma and Bilkent University.

Maximum measurement constraints for thrust, torque, voltage, current and revolution are 45 kgF, 30 Nm, 55 V, 100 A, 25000 rpm, respectively. Maximum propeller diameter that is to be used is 800 mm and to assure proper airflow, minimum distance from nearby surfaces is 1600 mm. There are also time and finance constraints which are 24 weeks and 5000 TL, respectively. Finally, the system is required to measure, and display given specs simultaneously, be controlled manually by the software, be able to export data, have variable mount interfaces for different motor types and have calibration sequences.

[1] Wdtajans.com. “Vestel Savunma Yeni Teknolojileri Ile IDEF 2019'Da.” *SAVTÜRK*, 2019, https://www.savturk.com/tr/vestel-savunma-yeni-teknolojileri-ile-idef-2019-da.
[2] “Tyto Robotics, Formerly RCbenchmark: Motor & Propeller Thrust Stands.” *Tyto Robotics*, https://www.tytorobotics.com/.

Design

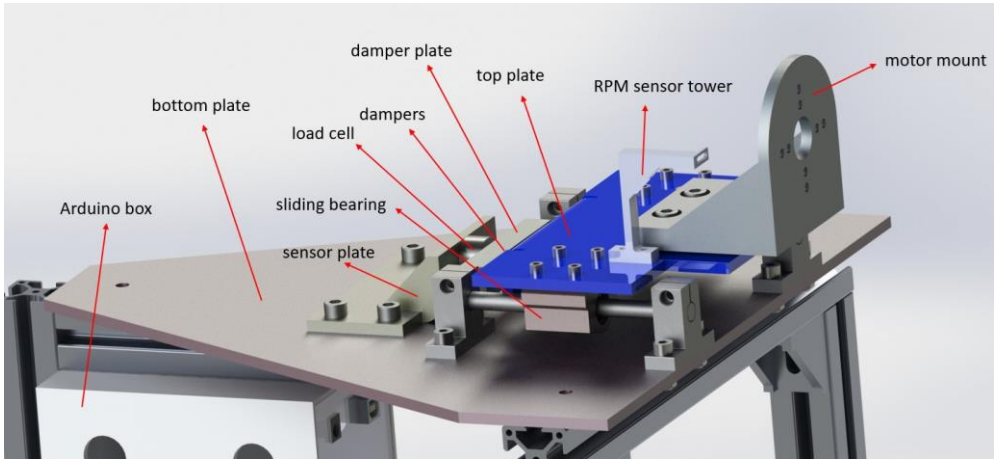


Figure 3 : Final design with part names

The motor that is to be tested with the appropriate propeller is mounted to the motor mount (headpiece). The headpiece is connected to the top plate which sits on top of a sliding bearing mechanism that limits the motion to one direction. The RPM sensor is placed near the motor to measure the RPM. The load cell is placed in the back and is connected to the top plate with a damper plate and two dampers to reduce vibration. Other smaller damper pieces were used throughout the connection points to also reduce vibration.

All the systems sit on top of the bottom plate which has a profile support structure that is connected to the table. When the motor starts rotating, it pushes the top plate which, after damping, pushes into the load cell. The load cell and the RPM sensor then transmit the information to the Data Acquisition System which consists of Arduino Uno located in the Arduino box. The Arduino calculates various parameters using the measurements and displays the parameters through the custom-designed UI.

Outcomes

This system is an interdisciplinary project that combines the mechanical engineering knowhow acquired from mainly mechanical design courses, DAQ design that is obtained from mechatronics and measurement courses and a software development which we had to learn the basics by ourselves. It is done in several steps throughout the 2020-2021 academic year given as below:

- Literature research
- Development and determination of conceptual designs according to requirements provided by VESTEL Savunma.
- 3D CAD drawings and engineering analyses including:
  - FMEA
  - Random vibration tests
  - Static structural analysis and buckling test
- Production of components and assembly
- Calibration and integration of the sensors
- Real life tests on the prototype for verification

Power Soccer Chair

Mecanum (8)

Academic Advisor : Prof. Dr. Adnan Akay
Dr. Müjdat Tohumcu
Phil Weaver
Industrial Advisor : Dr. Şakir Baytaroğlu
Teaching Assistant : Ayten Gülce Bayram

ABSTRACT

The goal of the project is to improve the power soccer chair, a wheelchair designed for soccer players with physical disabilities. Current power soccer chairs are unable to move diagonally and do rotation around itself. Thus, the aim is to provide the multi-directional movement capability to the chairs, mainly diagonal motion and the rotational motion around itself. In order to provide the multi-directional motion, a system with four mecanum wheels (which consists of ten rollers and two flanges) and four brushed DC motor that drives these mecanum wheels are proposed. Brushed DC motors are driven by motor controllers that is controlled with Ardunio Mega, and powered up with a battery. For the chassis a platform consists of sheet metal, strengthened with a PCV pipes is designed. Furthermore, the project includes the designing and the manufacturing of the mecanum wheel. Therefore, a mecanum wheel with an appropriate number of rollers, flange geometry are designated by trial and error procedure to ensure that the wheels provide the multi-directional motion as desired. For the manufacturing of the mecanum wheels, flanges are produced with additive manufacturing with the material being PLA, and rollers are manufactured via CNC machine with the material being Delrin covered by a heat sink tube to provide the required friction.

Problem Definition

With current power soccer chairs, it is not possible to perform most football movements with the battery powered chairs used for power soccer. Power Soccer game plays an important role for disabled people to integrate into society. Thanks to Power Soccer Chairs, disabled individuals can socialize by participating in sports activities and moreover, they can create a new career for themselves by playing this game professionally. With increasing the mobility and the smoothness of the game, the sport will be more attractive and popular. Hence, it increases the number of people integrated into society and increases motivation. Currently, the power soccer wheel chairs are only able to move like a car. Thus, lack of maneuverability makes it hard for players to perform many of the tricks that soccer players without disabilities perform. In order to eliminate this constraint, the goal is to allow the power soccer chair to move in every direction. In particular, the chair should be able to make diagonal movement as well as it should be able to rotate around itself.

Figure 1: Power Soccer Chair [1].

In order to provide this motion, a mecanum wheel is used. Due to its high cost, a mecanum wheel consists of two flanges and ten rollers, is designed and manufactured instead of purchasing it.

Figure 2 : Designed Mecanum Wheel

While designing the mecanum wheel, the main concern is its manufacturability since its manufacturing is an arduous task and requires high tolerances. Therefore, the flange geometry is selected in accordance with that consideration. Moreover, the number of rollers should be selected carefully as lack of roller number may cause the jumping of the wheel while rolling. Additionally, rollers should provide enough coefficient of friction, as lack of friction could cause the slipping of the wheel. Therefore, for the material, delrin covered by a heat sink tube should be used to provide enough friction to avoid slippage.

To operate the chair, a brushed DC motor needs to be connected to each four mecanum wheels. Accordingly, the control system should be adjusted (with Ardunio Mega) such that different combination of wheel rotations would lead to different motions. For example, for right lateral motion, left front and right rear wheel should rotate in forward direction while others should be rotated in backward direction.

On the other hand, the chassis of the chair should be designed with respect to the dimensional constraints set by the power soccer federation. Additionally, the chassis should be strong enough to carry the players as well as the components of the chair.

[1] P. M. Larson, E. the Editor, and Other Articles by: Paula M. Larson, “The rise of power soccer,” *New Mobility*, 01-Sep-2021. [Online]. Available: https://newmobility.com/the-rise-of-power-soccer/ [Accessed: 13-Oct-2021]

Design

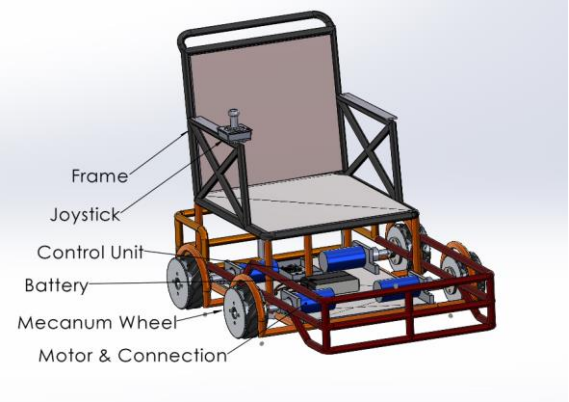


Figure 3 : 3D Model of the System

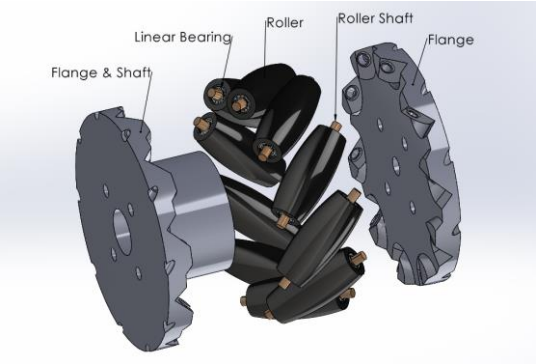


Figure 4 : 3D Model of the Leg Subsystem

The System is composed of mecanum wheels, motor & connection elements, battery, controller, chassis and frame. Mecanum wheel was designed with ten rollers and two flanges which hold the wheel together. Number of rollers were chosen according to the optimal continuity criteria. Since rollers are the contact point with the ground and 500N load occurs, linear bearings are placed the inside of the rollers. These bearings provides the load transmission and rotational motion around roller shaft.

Roller shafts are fixed inside of flanges with fasteners. In order to distribute the load on wheel and motor connection, additional shaft was used in between motor and wheel. This shaft is connected with motor coupler and wheel coupler. Besides, connected to chassis through two ball bearing units. For controller Arduino and motor drivers were used and joysticks are chosen as an user interface. Necessary power is supplied by rechargeable battery. Finally, chassis are formed by aluminum tubes and rest of the items were placed.

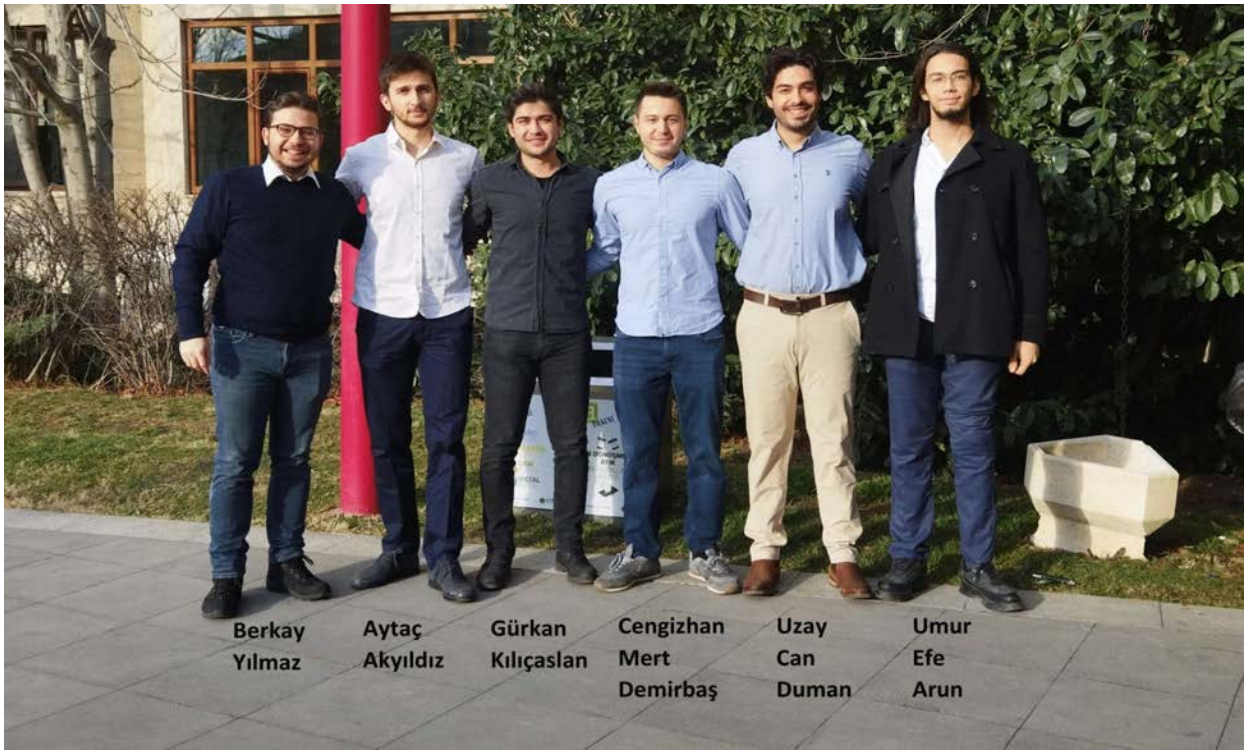
Outcomes

Implementing Mecanum Wheel concept to Power Soccer Chair is a mechanical design and manufacturing project that requires the mechanical engineering knowledge acquired at manufacturing, statics, mechanics, dynamics, control systems and mechatronics courses. It is done in several steps through the 2021-2022 academic year given as below:

- Literature research
- Determination of project's constraints and requirements provided by the needs of people with disabilities
- Engineering analysis including:
  - Dynamic and mathematical System modeling
  - Control system construction and analysis
  - Static analysis by ANSYS
  - Kinematics analysis by using Adams
  - Crash test analysis for the chassis by ANSYS
- CAD/CAM and technical drawings by SolidWorks, CATIA V5
- Safety and reliability analysis
- Control system and algorithm construction related to mecanum wheel
- Organizing a manufacturing schedule, assembly, quality control of the produced parts
- Meeting with different suppliers and companies in Ostim, İvedik, Saray industry

TWO-AXIS (YAW-PITCH) GIMBAL

HORUS6 (9)



Academic Advisor : Asst. Prof. Mehmet Selim Hanay
Industrial Advisor : Serter Yılmaz
Anıl Erdem Derinöz
Teaching Assistant : Emirhan İnanç

ABSTRACT

This project aims to design a yaw-pitch gimbal used in missiles. The general function of the gimbal is providing stabilization and target tracking ability to cameras or sensors used in rockets. The main problem for this project is to design a mechanical system within the given height, width, and weight limits, develop a mathematical model including disturbances and develop a controller for precise target tracking and stabilization. The working principle of the gimbal is based on measuring disturbances continuously with a sensor. Then, the controller sends rotation commands to yaw and pitch axis motors based on the measured sensor information. A gyroscope measures the disturbances and gimbal rotation, and encoders control the motor positions on each axis. Mechanical design is conducted considering the smooth motion of the axis, manufacturability, and dimension limits constrained by the missile.

Problem Definition

Gimbal systems are members of target tracking and stabilizing systems. Generally, Inertially Stabilized Platform (ISP) systems are used in military and scientific products with target-tracking application, communication application, and missile guidance as in this project. Usage of gimbals is changing according to their usage areas and the usage field of gimbals determines the ability of gimbals.

In order to give visual feedback to a missile regarding its environment, an imaging system that can maintain Line of Sight (LOS) to a target has to be integrated into it. However, such an imaging system needs to be mounted on a gimbal to adapt to the changes in the missile's motion or the environment. Therefore, a gimbal that can be integrated into another system is needed. The gimbal needs to be able to rotate in the yaw and pitch axis which is shown in Fig 2. to adequately perform target tracking and stabilization.

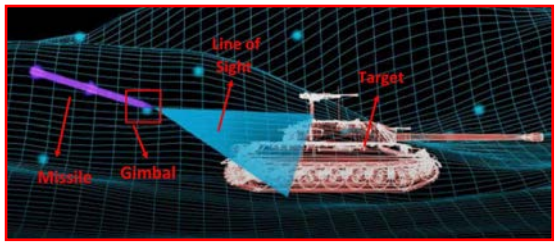


Figure 1: LOS of a Gimbal Mounted on a Missile.

Mechanical design of the system needs to be done in such a way that the assembly would be able to perform yaw and pitch motions and be within a certain size and weight range. The design of the gimbal needs to be robust such that it can still perform target tracking and stabilization missions even under the effects of disturbances.

Figure 2: Example of a Gimbal [1].

The mathematical model, therefore, has to account for these nonlinear disturbances such as cable tension and friction torque, in addition to the equations of motion of the undisturbed system.

The project aims to provide a prototype of a gimbal with properties provided by Roketsan company so that it can be used at upcoming projects and cooperative research with İhsan Doğramacı Bilkent University. Since Roketsan cannot provide the gimbal systems that are integrated at their systems because of non-disclosure agreements (NDA), a new system should be designed and produced so that it can be developed and new goals according to the concept can be accomplished.

The design is made as it will be subject to test fıt group of MIL-STD-810 standards to consider the effects that it will experience during its usage. The solution product will be subjected to MIL-STD-810 G standard. This standard is the Department of Defense Test Method Standard which is used for Environmental Engineering Considerations and Laboratory.

[1] Huhai Jiang, Hongguang Jia, and Qun Wei, "Analysis of zenith pass problem in a roll-pitch optics seeker," Proceedings of 2011 International Conference on Electronics and Optoelectronics, 2011.

Design

Figure 3 : 3D Model of the System

Mechanical design was finalized to provide the necessity requirements while considering the ones that are provided by industry as well as the ones that are brought by the implementation of the concepts selected. The design of the system consists of a main frame, yaw and pitch gimbals, shafts and selected concepts that were provided. The concepts implemented on the system was selected based on research and accessibility. Assembly of all components is in the consideration of mechanical design.

The main frame is carrying all system units with sufficient strength. Two rotating frames which are yaw and pitch frame are controlled by an electric motor and an encoder on the opposite side. The payload is carried by the pitch frame and it hosts a gyroscope on it. Manufacturability and cost limitations was considered during the design and the most feasible decisions were made. Aluminum 6061 alloy is the material used in the gimbal parts, because of its material properties and parts were produced with 5 axis CNC machining.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at mechanics, dynamics, control systems and mechatronics courses. It is done in several steps through the 2021-2022 academic year given as below:

- Literature research
- Determination of sub-systems according to requirements provided by ROKETSAN
- Engineering analysis including:
  - -Mechanical design
  - -Control system construction and analysis
  - -Mathematical modeling
  - -Electrical design
  - -Target tracking and stability
- CAD drawings
- Structural Analysis
- Planning of manufacturing processes, assembly, design verification and testing of the system

Design and Production of Quality and Cost-Effective Bracket for Hermetic Compressor

(10)

Academic Advisor : Prof. Dr. Ömer Anlağan
Dr. Şakir Baytaroğlu
Industrial Advisor : Ali Subay
Teaching Assistant : Mehmet Hakan Sarı

ABSTRACT

The aim of this project is to design a quality and cost-effective bracket for hermetic compressors. In order to decrease energy consumption of a refrigerator, working range of the hermetic compressors must be decreased. When natural frequency is reduced to the working range of the compressor, which is approximately 15-75 Hz., resonance occurs. The problem is to avoid resonance and to decrease the natural frequency of the suspension system of the compressor by decreasing the number of springs in the compressor from 4 to 3. The solution product is a bracket made of steel consisting a TPU material in the middle of two wings. TPU material has a vibration absorbing feature as a result of the advantages of its structure, which prevents the compressor from being deformed and contributes to its long-term use.

Problem Definition

The main purpose of a hermetic compressor is to increase both the pressure and temperature of the refrigerant entering from the evaporator to have the appropriate pressure and an approximate temperature in favor of the operation of the condenser. The second task of a hermetic compressor is to circulate the refrigerant fluid in air-conditioning systems, thereby not expecting to observe any leakages in the system. This type of compressor is commonly located under the cabinet of the refrigerator.

The compressor inside the refrigerator was runned at high speed; however, this situation creates two crucial problems which are over-deformation and over-energy consumption. Arçelik AŞ decided that the compressor will work at much lower speed than previous usage, which will decrease the energy consumption significantly. Yet when they decreased the speed of the compressor, they noticed that at the working frequency range, resonance occurs due to the natural frequency. The easiest way of decreasing the natural frequency of the system is to decline the number of the spring from 4 to 3 in the system.

Figure 1: *Refrigerator of Arçelik AŞ [1]*

Figure 2: *Hermetic Compressor*

When compressor operates under the name of low rpm, resonance is observed since the system has a natural frequency in the range of 15-75 Hz. Thus, the appropriate way of decrease the natural frequency of the compressor is to reduce the spring number. In the design made before the project, reducing the spring number caused some chaotic situations, therefore, the bracket design should emit the vibration caused by three dimensions.

The mathematical limits required for the position of the third spring, except for the two springs kept fixed, for the bracket to be produced to fit on the springs and for lowering the natural frequency, have been taken into account. The mass was determined as 2.5 kg and the spring constant as 1.15N/mm. The budget provided by Arçelik for the prototype production of the bracket is 7500 TL. The steel plate utilized for the bracket may spoil the electrical flux of the motor and create an arc flash on the output of the motor coil. Since the materials used in refrigerators are most commonly metal and conductive materials, the risk of an electrical arc flash occurrence is high. Clearance of the design with respect to electric motor and electric sensitive components will be designed at least 3 mm far and fixed parts should be in range 5 mm and 6 mm at Maximum Material Condition (MMC).

[1] "574561 eb | no frost buzdolabı | beyaz eşya | arçelik." [Online]. Available: https://www.arcelik.com.tr/no-frost-buzdolabi/574561-eb-buzdolabi. [Accessed: 07-Apr-2022].

Design

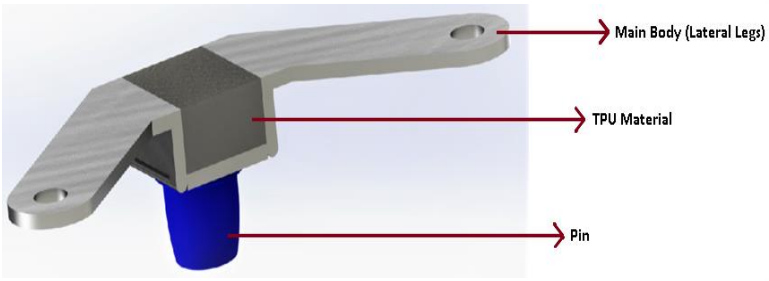


Figure 3 : 3D Model of the System

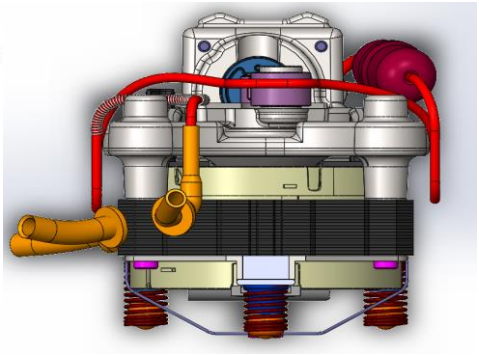


Figure 4 : Bracket in Assembly Front View

The design of the system was finalized with a TPU material utilized as a vibration absorber in x axis. Since 2 DOFs movements are observed, it is the utmost concern to reduce the vibrations. The system is designed accordingly to provide absorption generated by the motor. Lateral legs are designed to move whenever the motor is initiated. A natural alike hinge system is designed by utilizing 2 junction parts at the bottom of the middle part. The blue pin seen in the figure has a diameter of 7.86 mm and a length of 4.8 cm.

The TPU material is clamped behind the two lateral parts of the bracket and fixed to the lower part with the help of screw. To analyze the finalized part; modal, frequency, deformation, static and dynamic analysis are performed. With the analysis and previously offered constraints, the adjustability of the bracket for rough conditions and applicability of it are checked. In order to lower the costs, the bracket is chosen to be 2 mm in thickness. Different tests methods are applied in order to observe the real life behavior of the bracket explicitly.

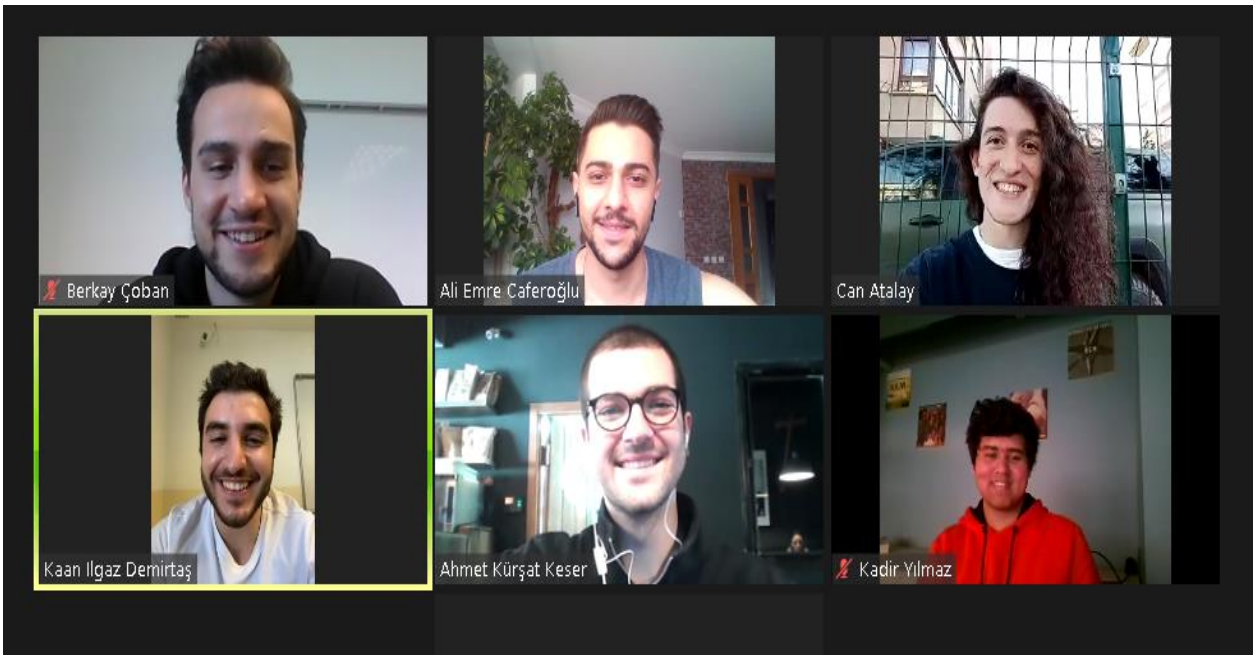
Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at dynamics, static structural, transient structural, modal, and harmonic response analysis. It is done in several steps through the 2021-2022 academic year given as below:

- Literature research
- Determination of design and production methods according to requirements provided by ARÇELİK AŞ.
- Engineering analysis including:
  - Modal Analysis
  - Control system construction and analysis
  - Mathematical modeling
  - Static structural, harmonic response and transient structural analysis
- CAD drawings
- Safety Analysis
- Planning of manufacturing processes, assembly and design verification.
- Life, Sound and Vibration tests.

Designing a Collision-Preventing Mechanism for Integrated Dishwasher Panels

OCEAN'S 11 (11)



From top left to bottom right: Berkay Çoban, Ali Emre Caferoğlu, Can Atalay, Kaan Ilgaz Demirtaş, Ahmet Kürşat Keser, Kadir Yılmaz

Industrial Advisor : Ahmet Onur Moza
Fatma İdil Aldı
Teaching Assistant : Emirhan İnanç

ABSTRACT

This project aims to design and produce a collision-preventing mechanism to integrate Arçelik dishwashers into modular kitchen designs. Wooden panels are installed in front of the outer doors of Arçelik dishwashers for aesthetic purposes. Drop-down front panels create a collision problem between the added wooden panel and the dishwasher chassis for integrated dishwasher doors. This project aims to prevent collisions by converting the rotary motion of the dishwasher door into the linear slide of the additional wooden panel. The solution to the problem is a pulley-and-wire mechanism. The system solves the low-plinth collision problem and makes the end product more cost-effective, user-friendly, and reliable than other commercially available options. The proposed solution of the project is to design a pulley and rail system where the wire rope connected to the door rolls around the pulleys to pull the rail system and initiates a sliding motion of the panel on the rail.

Problem Definition

Integrated domestic appliances help to establish aesthetic harmony indoors. Additional complementary mechanisms may be necessary to generate various essential paths or functions when blending challenging domestic appliances (such as dishwashers) into specific kitchen designs.

Wooden panels are attached to the front panels of Arçelik dishwashers (see **Figure 1**) for the full integration of these appliances into various modular kitchen designs. This leads to a collision problem (see **Figure 2**) where the added wooden panel collides with the dishwasher chassis.

Finding a solution to this problem is critical for the growth of the company since Arçelik is a top 10 player in not only the global domestic appliances market but also the global integrated appliances market . Moreover, nearly 25% of the entire global domestic appliances market's total revenue comes from integrated appliance sales

Figure 1: A Fully ntegrated Dishwasher [1].

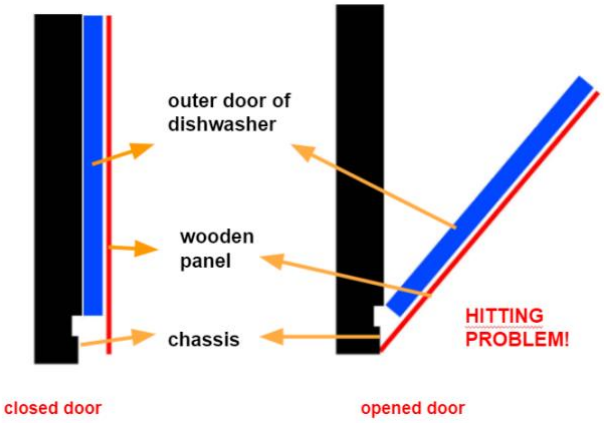


Figure 2: The Collision Problem [2].

In terms of operation, the system must allow a full rotation of 90 degrees with no toggle positions within the range of motion of the dishwasher door. A slip amount of 80 mm must be facilitated by the mechanism. The force input required to open the door must be less than 100 N. The 9 kg additional wooden panel must be supported effectively. The system must be able to withstand 100,000 cycles of loading. The system must be functionally compatible with the Arçelik dishwasher hinge system.

ASTM A931-18, ASTM A853-19, and ASTM D695-10 standards will be used for the testing of the material properties. Dimensional compatibility and sizing will be checked considering IEC 436/DIN 44990/EN 50242 standards. Finally, the mechanical efficiencies for the pulleys will be extrapolated from the API RP-9B standard.

[1] "Fully integrated dishwashers," *Miele*. [Online]. Available: https://www.mieleusa.com/e/fully-integrated-dishwashers-1022134-h. [Accessed: 29-Nov-2021].
[2] Arçelik Dishwasher Plant, "Industry Project Proposal Form." [Online]. Available: https://moodle.bilkent.edu.tr/2021-2022-fall/pluginfile.php/11671/mod_resource/content/1/15%20AR%C3%87EL%C4%B0K%20BLM%2001%20Sliding%20door.pdf. [Accessed: 06-Oct-2021].

Design

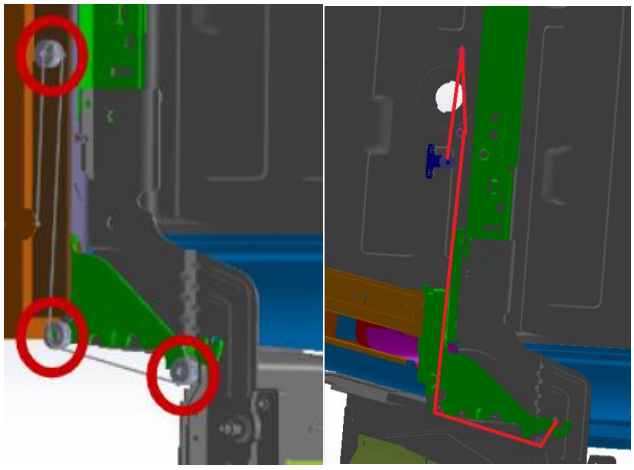


Figure 3 :Wire-and-Pulley Mechanism a) pulleys, b) rope route

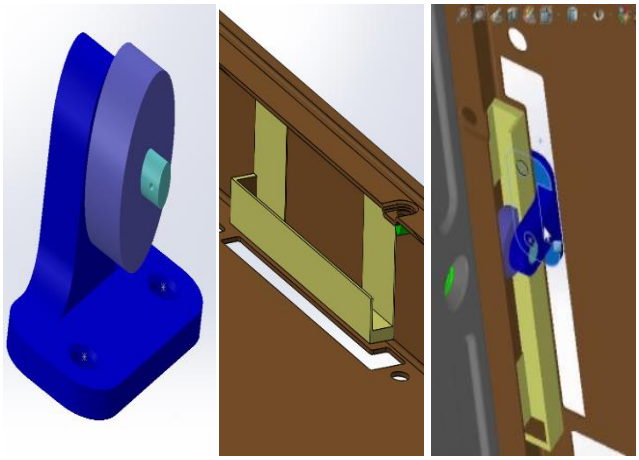


Figure 4 :Slider Eye-Bolt Subsystem

A pulley-and-wire system has been designed to solve the collision problem. As the door is opened by the user, the rotary motion of the door is converted to the linear slide of the added wooden panel by a wire that has constant length (see **Figure 3**), preventing the collision.

A wire rope is attached to the added wooden panel, as well as the dishwasher frame (see **Figure 3-a**). Since this wire rope does not elastically deform, as the door opens, this wire is forcefully pushed back (guided by the pulleys, see **Figure 3-b**) by the rotation of the dishwasher door. This movement directly pulls the added wooden panel away from the collision area.

The added wooden panel is also made to move smoothly via an eye-bolt and slider guide subsystem (see **Figure 4**). In addition, the force input required from the end-user is decreased dramatically due to the leverage gain from the dishwasher-door height. The mechanism is also vertically symmetrical and compatible with Arçelik hinge-break systems.

Outcomes

This system is a mechanical design project that utilizes the engineering knowledge acquired at mechanics and materials, machinery dynamics, and machine elements courses. Project is conducted through 2021-2022 academic year consisting the following steps:

- Literature research
- Concept selection according to the existing problems of the project in the guidance of the requirements that are provided by ARÇELİK.
- Engineering Analysis including:
  - Static Structural Analysis
  - Fatigue Loading Analysis
  - Spring Calculations
- CAD Drawings
- Design verification of the system by manufacturing the parts and testing the subsystems

Design of Active Vibration Isolation Using a Voice Coil Actuator with Absolute Velocity Feedback Control

Complex Roots (12)

Academic Advisor : Dr. Şakir Baytaroğlu
Industrial Advisor : Şamil Akaslan
Teaching Assistant : Hande Nur Açıkgöz

ABSTRACT

The aim of the project is to design and manufacture an active vibration isolator by using voice coil actuator and feedback control mechanism. Active vibration is needed to get better results in sensitive measurements. In military vehicles and devices, vibration isolation system plays a crucial role, and it is implemented to the sensitive measurement devices.In addition, these sensitive measurement devices such as atomic force microscope suffers from building vibrations Since already existing solutions are not sufficient to damp resonance at some frequencies, active vibration isolation is required. Thus, the project aims to damp vibrations in the range of 1-100 Hz by using voice coil actuator and absolute velocity feedback control system. The feedback control system and other equipments/parts of the system such as vibration measurement sensor were chosen in accordance with the aimed damping frequency.

Problem Definition

Machining and measuring tolerances for machine components are continuing to become gradually more restrained as the tasks demand strict precision. These restrictions in tolerances bring along highly accurate machine tools and measurement apparatus to such an extent that magnitudes of the tolerances are expressed in proportions of micrometers. These precision equipment are immensely sensitive instruments (e.g., atomic force microscopes) suffering from random vibrations. Floor vibrations are an inevitable fact that is undesirable for the performance of precision equipment because they excite relative vibrations in the measurement zone or in the joints comprising the dimensional set-up chain. Yet these equipment require a stable environment to work properly, because any deviation from the required state might cause the precision payloads to work inefficiently. Therefore, vibrations must be dampened to a certain extent.

Figure 1: Active Vibration Isolation System [1].

Passive damping methods are widely used in vibration isolation of structures. It does not need a power input, but the performance may be limited because of the resonance at some frequencies, and also affected by the environment and the material. The structural parameters may not be modified for different situations after being produced.

Figure 2: System Used with Measurement Device [2].

On the other hand, the active approach can provide a suitable force that depends on the sensor's feedback. In some cases, the active approach may allow a simpler structure to get the same effect compared with the passive approach.

The project aims to damp vibrations in the range of 1-100 Hz by using voice coil actuator and absolute velocity feedback control system. An active controller is needed to create a feedback system. The controller is chosen as LQR due to its benefits and longevity. The domain of frequency and the domain of amplitudeat which the device can isolate and provide stabilization is 1-100 Hz and 300-1000 µm respectively. The device is be able to withstand/stabilize 8 kg of payload.

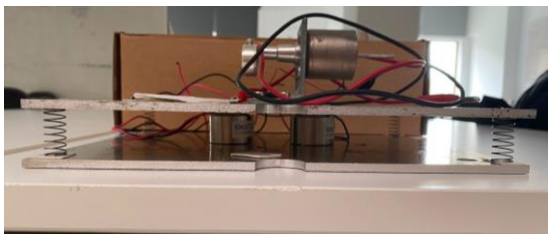


Figure 3: Testing Prototype

[1] "Active vibration isolation systems," *DAEIL SYSTEMS CO.,LTD.*, 30-Mar-2022. [Online]. Available: https://www.daeilsys.com/products/active-vibration-isolation-systems/. [Accessed: 08-Apr-2022].
[2] "Vibration isolation by the experts," *Bilz Vibration Technology AG*, 23-Mar-2022. [Online]. Available: https://www.bilz.ag/en/. [Accessed: 08-Apr-2022].

Design

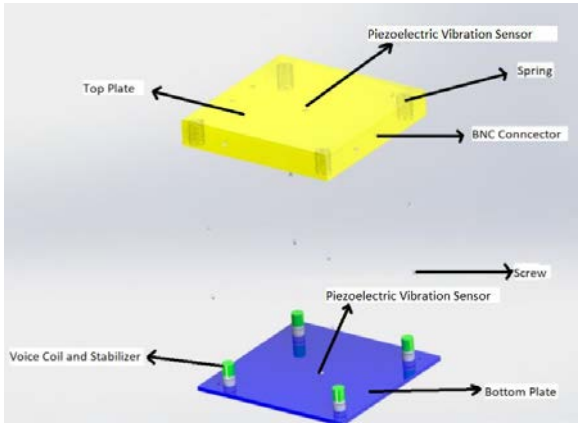


Figure 4 : Model of the System

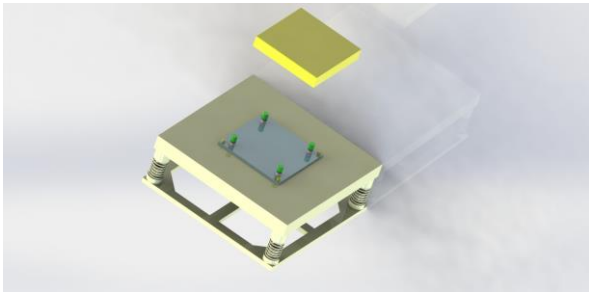


Figure 5 : System is on the Optical Table

The design of the system consists of the top and bottom plates which house the internal equipments of the system. The system contains 4 voice coils as actuator, 4 springs, vibration measurement sensors on both top and bottom plates. The geometric constraints of the top platform are adjusted considering the aesthetics and balance as 400 x 400 mm which is enough space for an average sized precision equipment to stand upon.

The top and bottom plates are laser cutting of aluminum 3003 with desired dimensions. Four compression springs, which are designated to carry the load of the system and force created by the voice coil, are mounted by Metric 10X1.5x15 screws to the top and bottom plate. Voice coil stabilizers are used to fill the gap between bottom and top plate caused by voice coil length. BNC connectors are used to prevent any electrical leakage. 2 Piezoelectric vibration sensors are mounted to measure vibrations.

Outcomes

The project contains combinations of the works of mechatronics, dynamics and control, mechanical design which we have learned throughout the mechanical engineering courses. It is accomplished by the steps as below:

- Literature research
- Determination of sub-systems according to requirements and constraints
- Engineering analysis including:
  - System modeling
  - Feedback Control system construction and analysis
  - Mathematical modeling
  - Deformation analysis
  - Experimental measurements
- CAD drawings
- Safety Analysis
- Manufacturing of the project, and test and verifcation of the system

Design of a Rotary Fatigue Testing Machine

Group 13

Academic Advisors : Assoc. Prof. Müjdat Tohumcu
Asst. Prof. Yıldıray Yıldız
Project Advisor : Dr. Şakir Baytaroğlu
Teaching Assistant : Mehmet Hakan Sarı

ABSTRACT

The objective of the project is to design a rotary bending fatigue testing machine. The machine will be analyzing fatigue criteria of tested specimens. While a bending is acting on the cylindrical test specimen, it will be rotating by an AC motor. Calculating the stress on the tested specimen and the number of revolution, S-N curves will be created to analyze metals' fatigue property. It will be used by Bilkent University Mechanical Engineering Department. The design of the main aluminum body consisting of sigma profiles and an upper carrier table made from aluminum. A linear actuator, load cell, and load applying puller are used as specimen loading mechanism. Testing specimen is located between two shafts which are driven by an AC motor. A magnetic encoder is used to receive the number of revolution until the specimen is broken. Whole system is being controlled with an HMI screen and received data is being analyzed with a MATLAB GUI (graphical user interface). The proposed solution of the Project is to design a rotary bending testing machine in order to use it as an experimental tool for fatigue testing in the Mechanical Engineering Laboratory.

Problem Definition

Fatigue is a type of failure that occurs due to a cyclic loading on the material. While a load applied once on a material may not cause failure, cycling this load weakens the material with each cycle, and the material may fracture with a load that would not cause fracture with no cycling. Fatigue applies to all materials, but current interest in this project is metals as they are the most common industry-used materials as machine elements. The objective of this project is to create a fatigue testing machine for Bilkent Mechanical Engineering Department. Currently, the department does not employ a fatigue testing machine, and considering the longevity and operation of the materials used, fatigue testing is an essential aspect of quality control testing.

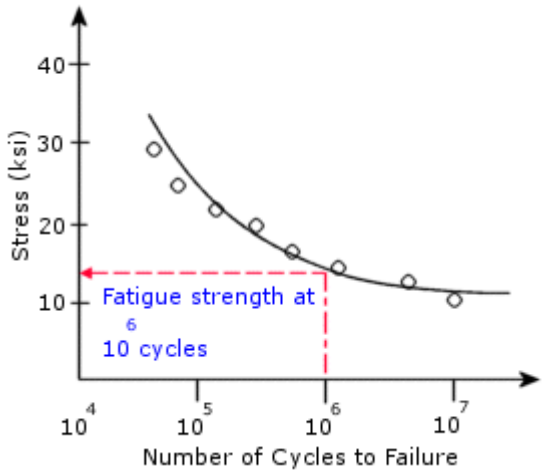


Figure 1: Stress-Cycle Curve Example [1].

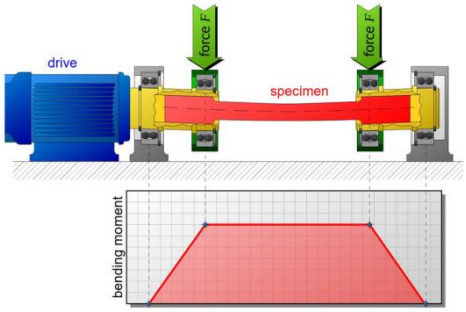


Figure 2: Rotary Bending Fatigue Case[2].

Bilkent University's Mechanical Engineering department started to accept students in 2009. Its mission was to be a department that could keep up with changing technology thanks to its innovative structure, internationally recognized without sacrificing educational quality, and built on solid foundations. For this purpose, the department's educational strategy aims to employ experiments and projects to visualize and complement the theoretical material that students are given. They allow students to use the department's machine shop to learn how to apply their knowledge in a technological setting. On the other hand, it aids students in seeing and comprehending the material covered in class.

However, no equipment exists for examining bending fatigue and determining the lifecycle of rotating shafts. It will display the tested material's S-N graphs (S stands for stress, and N stands for number of cycles). The topic is covered at school in mechanics and materials classes. Students should also create designs and compute the lifecycle based on failure criteria such as bending fatigue for this course. Despite this, there is no machine available for students to analyze bending fatigue in their projects. As a result, the rotational bending fatigue test machine is required to solve these issues.

[1] “Dmitry Shulgin | Air Force | Modern Weapons | Page 178,” Available:http://www.dmitryshulgin.com/author/wagner666/page/178/. [Accessed: 21-Dec-2019].

[2] G1700 Inertial Measurement Unit", *Aerospace.honeywell.com*, 2019. [Online]. Available: https://aerospace.honeywell.com/en/learn/products/sensors/hg1700-inertial-measurement-unit. [Accessed: 13-Oct-2019].

Design

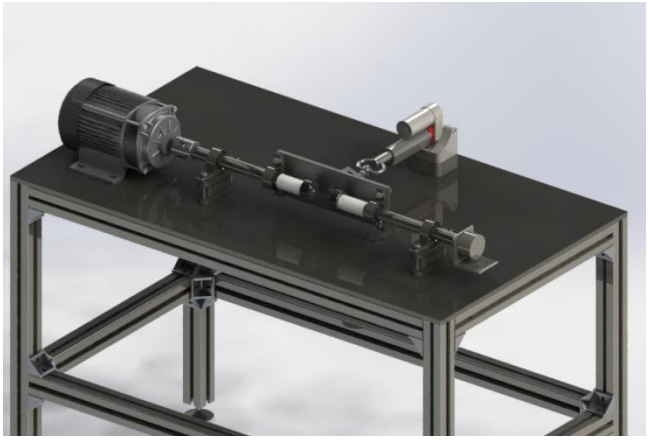


Figure 3 : 3D Model of the System

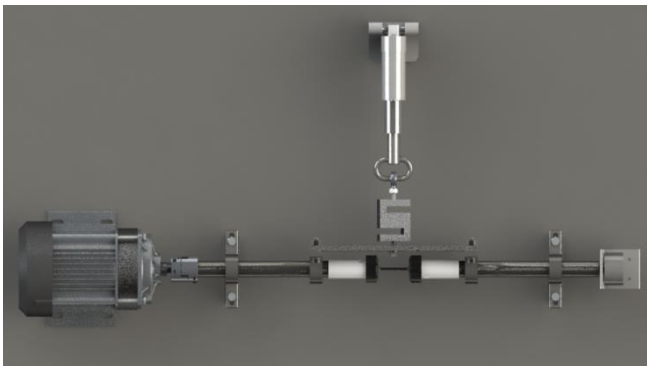


Figure 4 : 3D Model of the mechanism

The working principle of the machine comes as a combination of a BLAC, a linear actuator, and a load cell working together. Once a specimen is set in position for testing, the actuator retracts itself; applying a bending moment on the specimen. The retraction stops when the load cell reading is met with the wanted value of the load. Once the specimen is bent and the actuator is locked in place, the BLAC forces the misaligned shaft to rotate. It should be noted that the power transferring shafts have angle allowances achieved by jaw coupling and bearings. These do not allow the shafts to bend but allow them to tilt.

BLAC runs until the specimen is fractured and the encoder on the other end of the shaft records how many cycles it took for the fracture to occur. With the stress known from the load applied, and the cycles known from the encoder; an S-N curve data point is achieved. Multiple testing under different loads will provide more data points, eventually leading to a complete S-N curve.

The machine is controlled with an HMI screen, stress and number of cycle data is being transferred to a MATLAB GUI (graphical user interface) to analyze the data and draw the S-N curves.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at mechanics & materials, statics, and mechatronics courses. It is done in several steps through the 2021-2022 academic year given as below:

- Literature research
- Determination of sub-systems according to requirements provided by the ME Department
- Engineering analysis including:
  - -Mathematical modeling
  - -Static Simulation & Bending Analysis
  - -Vibration Analysis & Simulation
  - -Fatigue Analysis & Simulation
- CAD drawings
- Safety Analysis
- Planning of manufacturing processes, assembly, design verification and testing of the system