Industrial Graduation Projects 2018

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BİLKENT UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

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BILKENT UNIVERSITY
DEPARTMENT OF MECHANICAL ENGINEERING

INDUSTRIAL DESIGN PROJECTS

2017 – 2018

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CONTENT

PREFACE

The primary goal of university-industry collaboration is to provide future engineers with a broad understanding of industry and business. In support of this goal, we have a two-semester long design activity for the senior-level students. This year, fourteen groups, each consisting of 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, but also bring out their creativity in both the design phase, which is completed in the first semester, and in the manufacturing phase in the second semester.

At the project fair, the students are provided with a unique opportunity to present detailed design specifications of their products and the manufactured prototypes. The fair and this booklet demonstrate the design and manufacturing goals, constraints, challenges, and, of course, the students' efforts that led to their accomplishments. The continuous guidance and advice provided by their academic and industrial mentors, instructors, and teaching assistants are very much appreciated.

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.

Adnan Akay
Professor and Chair
Mechanical Engineering Department
Bilkent University

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KICKDOWN (A1)

RETRACTABLE LAUNCHER SYSTEM FOR AN ALL-TERRAIN MILITARY MOBILE COMBAT VEHICLE

Academic Supervisor: Asst. Prof. Selim Hanay
Industrial Supervisor: Nagehan Demirci
Teaching Assistant: Cem Aygül

- ABSTRACT-

This project aims to develop a retractable missile launcher system for all-terrain military ground vehicle. Two launcher mechanisms are mounted on all-terrain vehicle. In the attack mode, both launchers can rise to outside on the vehicle independently in order to ready to hit target. In a civil aspect, launcher mechanisms must be retracted inside when the vehicle is not deployed, for security and secrecy purposes. When the system retracts towards inside the vehicle, vehicle seems like an unarmed military vehicle. Additionally, these retractable launcher mechanisms can easily rotate 360^o in the azimuth direction and the head of the rocket launcher can move between -10^o and 30^o in the elevation direction independently from each other. This system derives the power from the harmony of the mechanic and electronic sub-systems. Also launcher system can be controlled either as manually or automatically by remote wireless electronic controller.

Problem Definition

In regular vehicle rocket launchers, the missile launcher systems are located on top of the vehicles and exposed to external environment and visual access. This makes these launcher systems vulnerable to prospective assaults and endangers the entire system and the military staff. Therefore, nowadays a need to hide those launcher systems inside the all-terrain vehicles has emerged in order to make the vehicle and military staff gains the capability of concealing the launcher system until the vehicle reaches the sufficient vicinity of the combat field.

In the Defense Industry of Turkey, there is not any terrain vehicle including tanks, light armored vehicles and any other kind of military transporter employing concealable missile launcher system. Therefore, a retractable missile launcher system is intended to be mounted on an all-terrain military combat vehicle for Turkish Military. The major goal of this project is to construct a launcher mechanism which can rise out of the vehicle and retract towards the interior of the vehicle and transport with other internal mechanical and electronic components in a compatible manner. Two independent missile launchers, which can adjust their individual positions of azimuth and elevation direction, will be located on the general retracting mechanism

To sum up, the main purpose of this project is to design, analyze and manufacture a lifting and rotating mechanism that is rigid and can withstand a recoil force (2MPa) of missiles, can lift and rotate the missile launchers smoothly according to given constraints with the maintenance, safety, sustainability and reliability requirements and adaptable to a prototype all-terrain vehicle.

Figure 1 : GAZ Tigr Russian Military Vehicle with Retractable Launcher Mechanism

The total dimensions of the vehicle shall be less than [1x1x0.5] m.
The total weight of the retractable launcher system shall be less than [25] kg.
The retractable launcher system shall rotate [360]° in azimuth direction.
The retractable launcher system shall rotate [-10]° to [30]° in elevation direction.
Each launcher arm shall rotate independently in elevation direction.
The retractable launcher system shall move with a velocity of [60] degrees/s in azimuth and elevation directions.
The azimuth and elevation accuracy shall be at least [0.5]°.
The ground vehicle shall move on an inclined terrain with a minimum inclination angle of [30]° without damage to the launcher system in deployed position.
The retractable launcher system shall remain safe under [2] MPa of blast pressure from the missiles.
The retractable launcher system shall carry at least 4 up to 8 missiles (missile shaped tubes).
The retractable system shall carry at least 1 electro-optic system.
The retractable launcher system shall not have any sharp surfaces that could cause harm to the personnel.
The ground vehicle shall be operable on rough terrain without causing damage to itself or the launcher.

Table 1: Requirements and Constraints that are given by Roketsan

Design

The retractable launcher mechanism has 3 main degrees of freedom that are lifting of all mechanism, elevation of rockets and rotation in azimuth direction of rockets' holder (inner shaft). Also, movement of these mechanisms is provided by 6 main elements; bevel gears, shafts, body holder, bearings, worm gear boxes and linear screw modules.

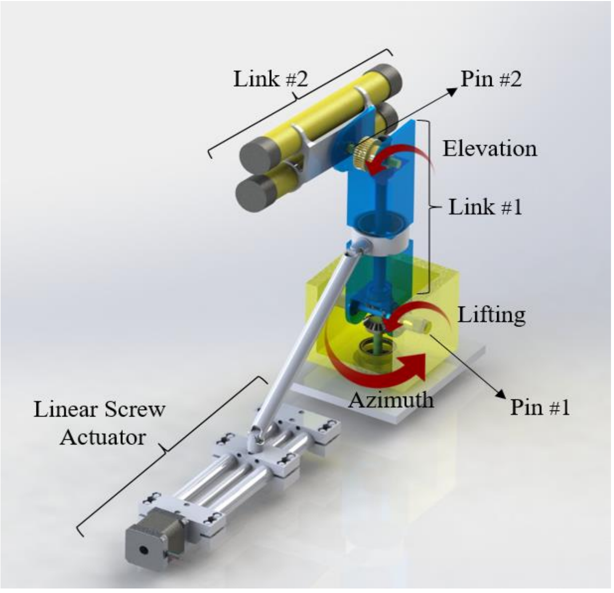

Figure 2 : Fundamental Motions and Notation of the system

Lifting Mechanism is actuated by stepper motor. When the stepper motor rotates the screw shaft, the screw nut will move linearly and push the arm that is connected to the link 1, and link 1 is lifted. The purpose of linear actuator is to provide rigidity and precise position through the lifting of the mechanism. Because arm that pushes the link 1 continues to hold the link 1 during shooting, it provides the rigidity for mechanism and it can resist a recoil force (2MPa blast pressure) during shooting. Also, because screw nut moves step by step in order of screw pitch, our link 1 will lift step by step in a more precise manner for its place. Stepper motor is used with a speed reductor to provide required torque to lift the system.

Elevation of rockets is provided by a stepper motor that is placed under the mechanism's base. When the stepper motor drives the bevel gears that are placed at the bottom side of link 1(figure 3), the force is transmitted by inner shaft to the worm gear that is placed at the top side of the link 1. Thanks to bearings, we can provide elevation of rockets without movement of outer shaft (link 1)

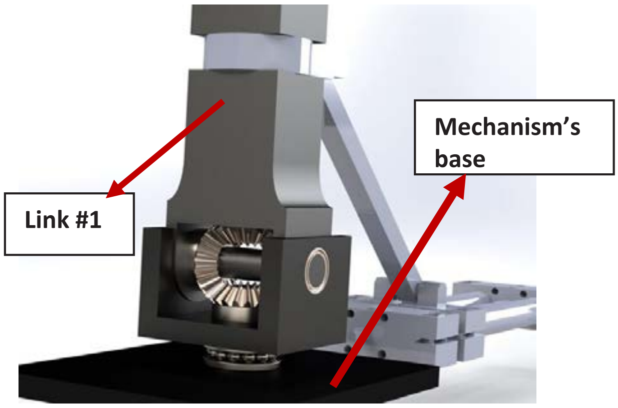

Figure 3: Bevel gears at the bottom side

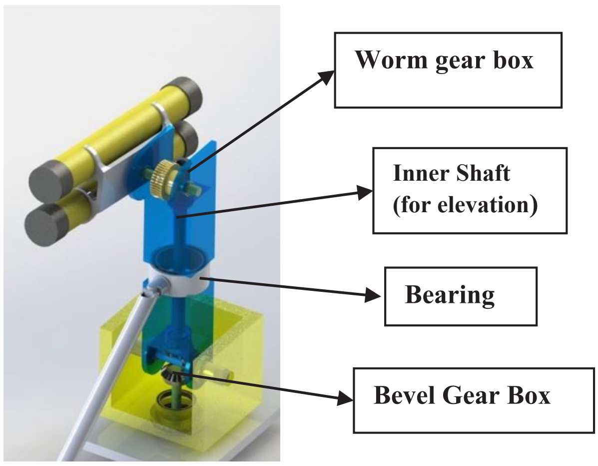

Figure 4: Fundamental Elements of System

Rotation in azimuth direction of link #1 is provided by a DC motor and spur gears that are placed under the mechanism's base. DC motor drives the spur gears that are attached to the link #1 and link #1 can rotate freely thanks to the bearing.

Outputs

Results:

- The main purpose of the design is developing and manufacturing a retractable launcher system for an all-terrain military mobile combat vehicle that will be completed in Turkey by Turkish engineering candidates.
- Two independent missile launchers, which can adjust their individual positions of azimuth and elevation directions, are constructed on a prototype all-terrain vehicle.
- The prototype and the test mechanism should work as required by constraints of the Roketsan.
- The requirements defined in the problem definition part are fulfilled successfully

Outcomes:
In each step of the project, problems are solved with engineering approach. After the design step, engineering analyses is applied to optimize the design. The engineering analysis contains dynamic modeling and its calculations, machine elements calculations, usage of computer programs like Comsol and Ansys for static and dynamic analysis. The steps of the project are listed as follows:

- Design Matrix
- Design with a CAD program
  - SolidWorks Design
- Engineering Analysis
  - Matlab and Simulink Analysis
  - Static Structural Analysis with Comsol
- Manufacturing and Modifications
- Electronic Control
  - Arduino microcontroller is used to control the mechanism and drive the motors.
- Tests and Developments

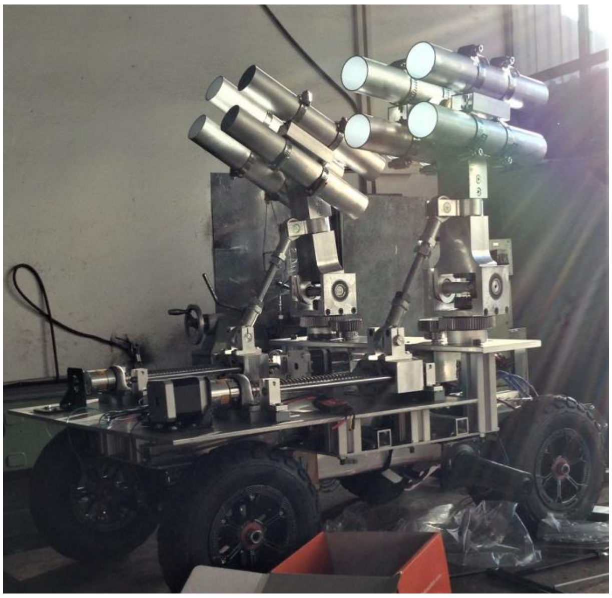

Figure 6: Prototype of Rocket Launchers and Vehicle

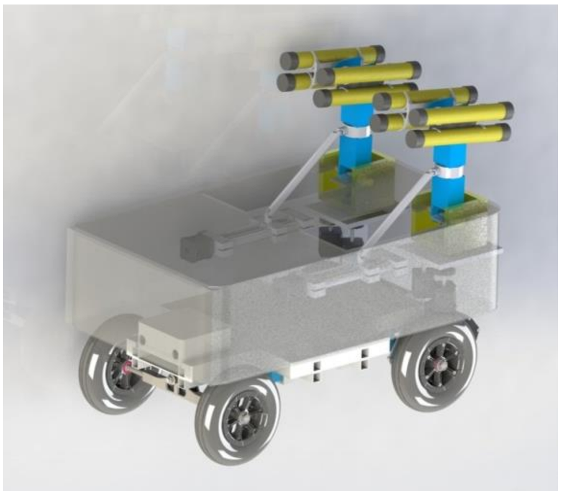

Figure 5: Constructed Design of Rocket Launchers and Vehicle

AGE OF MACHİNES (A2)

Step Motor Brake System Applicable for Cylindrical Shafts and Encoder Development

Academic Supervisor: Asst. Prof. Dr. Onur Özcan

Industrial Supervisor: Erdem Çağatay

- ABSTRACT-

The aim of this project is to design a brake system coupled with encoders to stop the rotation of two cylindrical shafts. Project objectives involve: achieving sufficient braking force, recording rotation of the two shafts by encoders; while also keeping the cost and power draw at minimum. Final product is required to be durable, low maintenance and reliable. The product is to be implemented on ArtıBoyut's 3D printers, therefore the brakes and encoders are able to fit inside the printer without disrupting the design of the printer or occupying any operational volume inside the printer.

Problem Definition

During loading and unloading of the tray small amount of force is applied by an operator to remove the 3D printed product. This results in disruption of calibration of two stepper motors which govern the motion of the tray on the vertical z-axis. ArtıBoyut has requested brakes that can keep these shafts stationary during these processes and encoders to record the rotary position of these shafts.

The printer in the figure below operates with a printing a nozzle on the top of the frame, that moves in x and y directions and prints on the tray, as layers are completed two stepper motors that actuate the rotation of the threadded rods govern the motion on the z-axis. These two stepper motors have to be syncronized so that the tray is level at all times. Even though it is fixed by four additional vericle sleeved guide pillars, it sometimes pivots due to the rotational difference between the two threadded rods. Based on the acceptable tolerances desired by the company the utmost difference acceptable between these two rods is calculated to be 1/400 of a complete rotation.

The problem arises due to loads on the tray disrupting the syncronized rotation of two threaded rods that govern the z-axis (height) of the print tray. To solve this problem, ArtıBoyut demands a brake system that locks the threadded rods in place during loading and unloading of the tray. In addition, two encoders that will measure the rotational displacement of the pillars so that both pillars which have stepper motor actuators on them are locked in place while the tray is under load.

Therefore researching, designing and manufacturing the clutch system in the same country where it will be used is crucially important.

In the military vehicles, the currently used clutch system is electro-mechanic clutch system that controls the rotation of the target system in different directions by both automatically and manually. In the domestic production of the military vehicle, the electro-mechanical clutch system is desired to produce with all national R&D and manufacturing techniques. In this context, the location of electro-mechanical clutch in the military system is shown in the Figure 2.

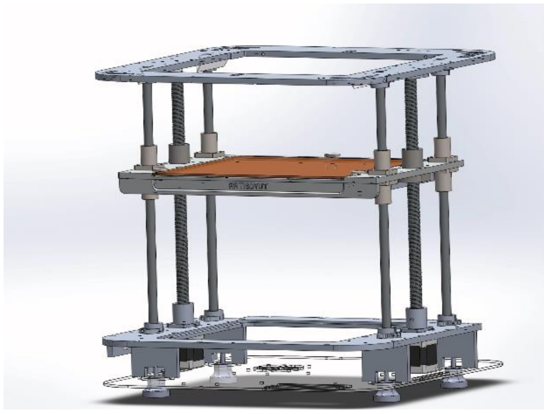

Figure 1: Inner structure of the printer (ArtiBoyut A1 Pro) that the project will be applied on

Objective of this project is to design a solution that implements an encoder that can detect 1/400 of a complete turn ($<0.7^\circ$) and a brake system that can lock the threaded rods in place so when the load on the tray is applied it does not disrupt the position and meddle with the calibration of the tray.

Design

For the project ArtıBoyut requested that the solution should not disrupt current dimensions of the design or interfere with other components of the printer. Company allocated specific positions and dimension limits for our design. The constraints of the project are as follows:

1. Adjustable Shaft Size
2. Size Constraints
3. Encoder Resolution Constraint
4. Braking Capacity
5. Cost
6. Power Draw Constraint
7. Durability
8. Synchronization of threaded rods

Considering the size of the brakes, selection for electromagnetic actuation for the braking force was a sensible choice. And since when the power was turned off on the printer, having a power-off engagement, passively with spring force would preserve the calibration of the printer. Coupling this with an encoder with sufficient layers was the ideal solution.

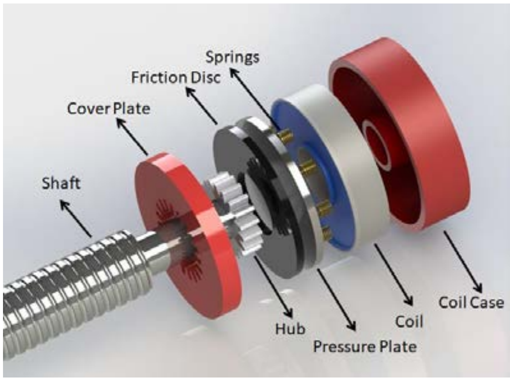

Figure 2: Initial design for the spring applied power-off engagement electromagnetic brake

To preserve the calibration within the acceptable boundaries set by the company, the absolute encoder had to have 9 layers so that $2^n > 400$ ($n=9$, $2^n=512$) and this ment, 9 seperate sensors had to extract binary values from the encoder. This resulted in an increased cost of the end product.

Figure 3: The brake fitted on the threaded cylindrical shaft along with the encoder.

It was decided that to make this solution feasible it was essential to remove the necessity to use 9 optical sensors to acquire position data. Instead of the absolute encoder a rotary position sensor was to be implemented. This is to preserve the reading sensitivity while reducing the cost significantly. During operation the brakes would consume considerable energy 6W per brake, 12W in total would be dissipated during operation of the printer. This reduction in efficiency and disruption of the thermal properties of the printing chamber is something that is not desired, so the final design had to address these problems. Final design has two stable positions in which it engages and disengages the brake passively, the transition in between these stages is the energy consuming process, actuator is activated once to switch from one state to another and until the actuator is engaged to do the opposite, the brake will stay locked in that position.

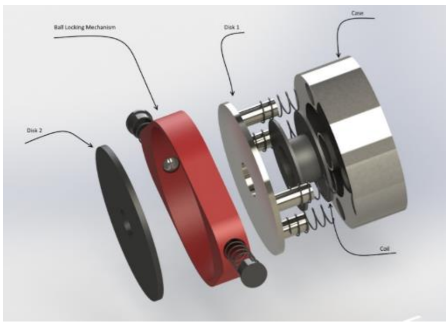

Figure 4: Final design

Outputs

Results:

- ✓ Required braking force is achieved
- ✓ Rotary position sensor can read position data while meeting the precision constraints with low error
- ✓ End product is within the acceptable cost range
- ✓ End product is applicable with the 3D printer
- ✓ Brake engagement and disengagement is fast, does not interfere with the printing process duration
- ✓ All materials used except for the sensor are available domestically and is able to be acquired cheaply from local vendors
- ✓ Machining processes are required only for the external casing of the brake

Outcomes:

- ✓ Usage of this brake enables to use ball-socket (low friction) joints for the 3D printers tray mounts, this drastically reduces energy consumption of the 3D printer
- ✓ Having bistable lock positions for the brake results in no energy consumption during operation, actuators of the brakes only consume energy during state change between braking and releasing states
- ✓ Usage of rotary position sensors in these applications will enable the printer to be calibrated at all times
- ✓ Reliable data from the rotary position sensor enables the printer to operate at higher precision manufacturing processes

The project requires two seperate components to work coherently: the brakes and the encoders, this dual nature of the project required us to coordinatedly work on our design. Both major branches of the project had to accomodate for other side of the system. The innovative design of the brake required many iterations of design. Since there is not any market solutions for this application, all of the design work is done ground up starting from braking force calculations to magnetic force calculations and then required power, heat distrubution, structural stability analysis.

This project is supported by TUBITAK 2209/B program.

SYNDICATE ME (A3)

Vertical Launcher System

Academic Supervisor: Asst. Prof. Onur Özcan

Industrial Supervisor: Gökhan Yazar

- ABSTRACT-

The main objective of this project is to design, develop and manufacture a vertical launcher system prototype. The main inspiration is the Centurion VLS, manufactured in the UK. The system is mounted on a platform which can rotate in azimuth (rotation) direction and is able to use three different types of missiles housed in six elevation-controlled cells. There are six linear actuators and a DC motor to enable required motion in each direction. There are economical, operational, mechanical and manufacturing constraints that shape the final product. The system is more superior than the existing launcher systems in Turkey since it has high coverage area for targeting because of the separate cells, is out of enemy sight because of the casing and able to house different types of missiles. As a result of this project, a vertical launcher system that resolves current negative drawbacks at lowest possible cost is generated for military services.

Syndicate ME

Problem Definition

A vertical launcher system (VLS) is an advanced military system that holds and fires missiles on naval or ground platforms. There are multiple missiles housed in each vertical launcher system. The purpose of the system is to hit a target by accurate and rapid positioning and firing. Multi-functionality of the system is important, which is obtained by hosing different types of missiles for different operations. There is also the issue of being out of enemy sight by covering the missile housings. The current VLS systems have some limits on coverage area for targeting and they can release only one type of ammunition due to their structures. The systems are also incapable of separate movements of missile housings (cells). Moreover, having no cover over the VLS lessens the defensibility and protection of the system.

Figure 1. SAMP/T VLS System **[1]**

The main aim of this project is to design, develop and manufacture a vertical launcher system prototype of a cold launch VLS that can carry at least two different types of missiles. It is mounted on a ground platform and cells are covered by casings. Primary concern is to develop the cold launch systems' chassis mechanically including the actuators for rotation of the main body and elevation of the cells; thereby no firing is expected.

The model that is designed in this project is inspired by Centurion, which is a fully adjustable launcher.

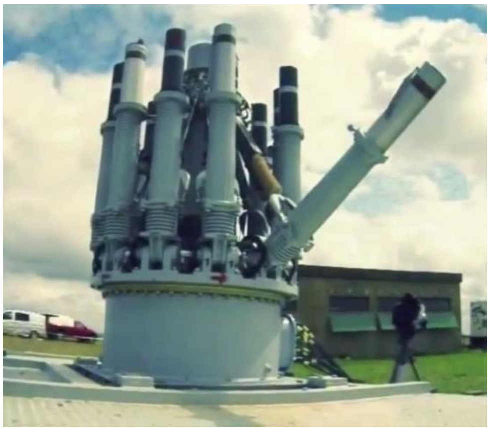

Figure 2. Centurion VLS [2]

The requirements of the project can be listed as the following:

Dimension and weight	At most Φ800 x 2000 mm and 60kg.
Motion in rotation direction	360°+
Motion in elevation direction	Each cell can move separately between 0°-90°
Speed (rotation and elevation)	At least 20°/s
Accuracy (rotation and elevation)	At least 1°

Table 1. Requirements Table

The system is designed in harmony with military standards MIL-STD-2131 and MIL-STD-810G (Env. Testing) Method 501.5, 502.5, 506.5, 507.5, 509.5, and 510.5

[1] "SAMP/T Land Based Air Defense System", Defense Update. Available: http://defense-uptade.com/products/s/sapm-t.htm. 15 Oct. 2017.
[2] Chemring - Centurion Multi-Role Trainable Naval Launcher Technical Firing. Available: https://www.youtube.com/watch?v=ykjen zngX3s. 15 Oct. 2017

Syndicate ME

Design

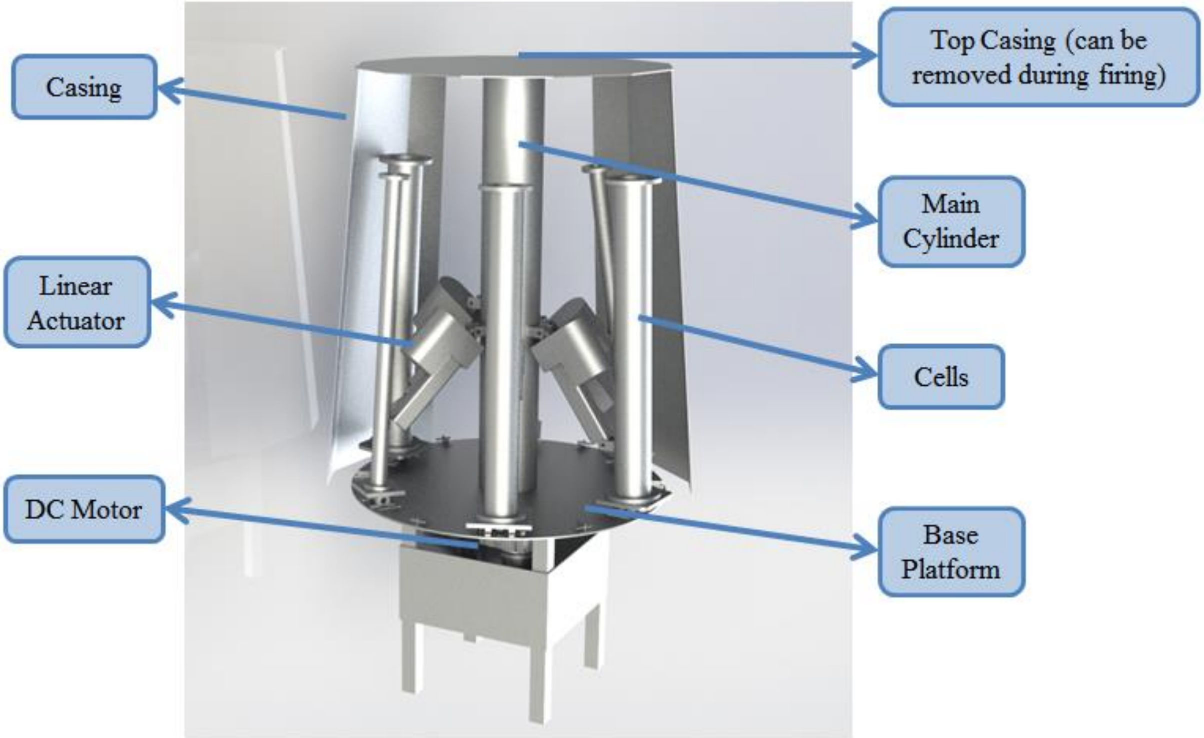

Figure 3. 3D Model of the Design

Mechanical Parts of the System

1. Cells: Cells act as storage units that keep the missiles inside. There are six cells with three different types in the system. So, there are two cells from each type that are designed according to missile specifications. They are mounted on the base platform symmetrically in order to reduce the moment of inertia and off-axis forces of the system.
2. Base Platform: Cells and casings are attached to the base platform that can turn in 360º in rotation (azimuth) direction with the help of a DC motor. Main cylinder is attached to the center of the base platform with a flange. All cells are contained in a single body; but have separate protective caps (casings) that move in parallel with the cells. Cells have the ability of choosing the firing angle from 0º to 90º by making use of their separate linear actuators.

Electronic Parts of the System

There is a vehicle computer through which a user controls the whole system. Both the DC motor and linear actuators have drivers connected to Arduino Mega. Encoder attached to the shaft of DC motor and hall sensors of linear actuators are sufficient to perform the required control action successfully.

Outputs

Results:

When a country purchases a VLS manufactured by another country, the cost extremely increases; so it is important for a country develop its own VLS in harmony with its own tactical needs. Most of the VLSs that are used in military are lacking proper casings and the capability of working with various types of missiles. This project results in a VLS that can move in azimuth and elevation directions with a speed of 20º/s, can release at least two different types of missiles and has a high coverage area for targeting.

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 2017-2018 academic year given as below:

•Literature search that aims to investigate current VLSs under operation and their limits,

•Analytical thinking and determination of sub-systems according to requirements provided by ROKETSAN,

•Engineering analysis including:

-Comsol analysis of joints, cells and determination of cell wall thicknesses accordingly,
-Torque calculations for the rotation of base platform and elevation of cells with linear actuators,
-Kinematic motion analysis in SAM,
-MATLAB codes to obtain required angular velocity for varying positions of cells

•CAD drawings,

•Manufacturing processes and design verification of each subsystem,

•Position control of DC motor and linear actuators & system verification

This project is supported by TÜBİTAK 2209/B program.

Syndicate ME

PERFECTION 102 (B1)

Cooling of a Tractor Engine Using an Axial Fan Driven by Electric Motor

Academic Supervisor: Dr. Barbaros Çetin

Industrial Supervisor: Dr. Hakan Mencek

- ABSTRACT-

The goal of the project was to develop an improved cooling system for a tractor's diesel engine. Currently in Turk Tractor's vehicles, there is a direct connection between the axial fan which cools the engine and the rotor of the engine. This direct connection caused significant power loss and vibrations in the system. To solve this problem, an automated control system was developed which included an axial fan connected to a DC motor with temperature sensitivity. To model the engine, an experimental test setup was developed. The test setup allowed us to run our control system and additionally make a comparison with the results of Computational Fluid Analysis which was conducted in the first phase of the project.

Problem Definition

A vehicle's engine produces a significant amount of heat when it is running, so this heat must be distributed and the engine should be cooled continuously to avoid damage. Therefore, we need a cooling system to control the temperature in the engine. The current tractors of Türk Traktör have a direct connection between the engine and the cooling fan as shown in Figure 1. However, this direct connection and lack of control on the fan causes decrease in power and increase in fuel consumption and vibration. Usually, about 2000 Revolutions Per Minute (RPM) of the fan is sufficient to cool the engine. However, due to the direct connection, when the tractor is used in higher RPM and the rotational speed of the fan increases up to 3000-4000 RPM. This speed is both unnecessary to cool the liquid and also a source of extra vibration in the system.

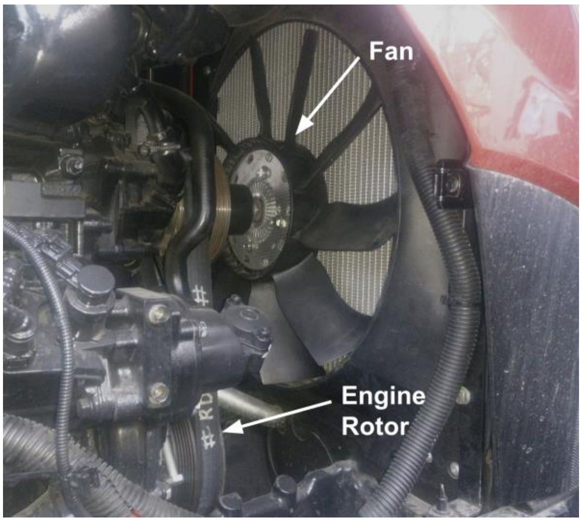

Figure 1. Direct connection of fan with engine in company's tractor

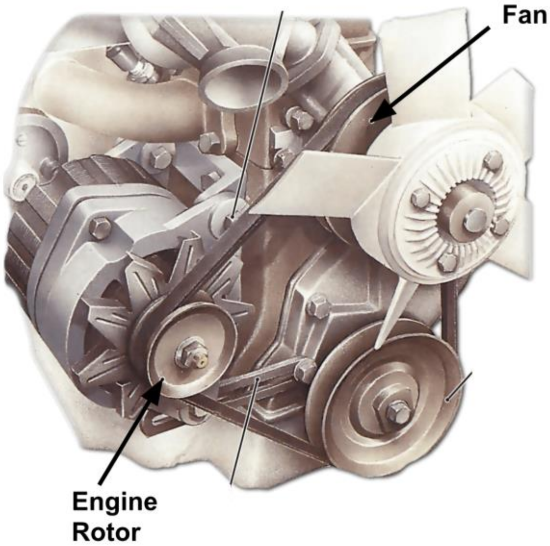

Figure 2. Schematics of direct connection of fan with engine [1]

The aim of the project is two folds mainly:

1. Instead of the engine's rotor, the fan should rotate via an Electric Motor without any direct connection to the Engine.
2. The fan should be temperature sensitive and using a controller, automatically change the RPM based on the coolant temperature.

[1] "How it Works: Engine Cooling Fan"Available: https://www.uniquecarsandparts.com.au/how_it_works_cooling_fan [Accessed 15 October 2017].

Design

A solution to the problem has been designed and produced in accordance to the requirements and constraints of the project. This solution involves the implementation of an automated control system based which has the ability to change the motor speed according to change in temperature of the coolant liquid running through the radiator.

The final design was implemented in Bilkent University's Thermofluids lab so that we can model the heat dissipation of an engine and also compare our results with the analytical calculations conducted in the computational software ANSYS. The final setup consists of following components:

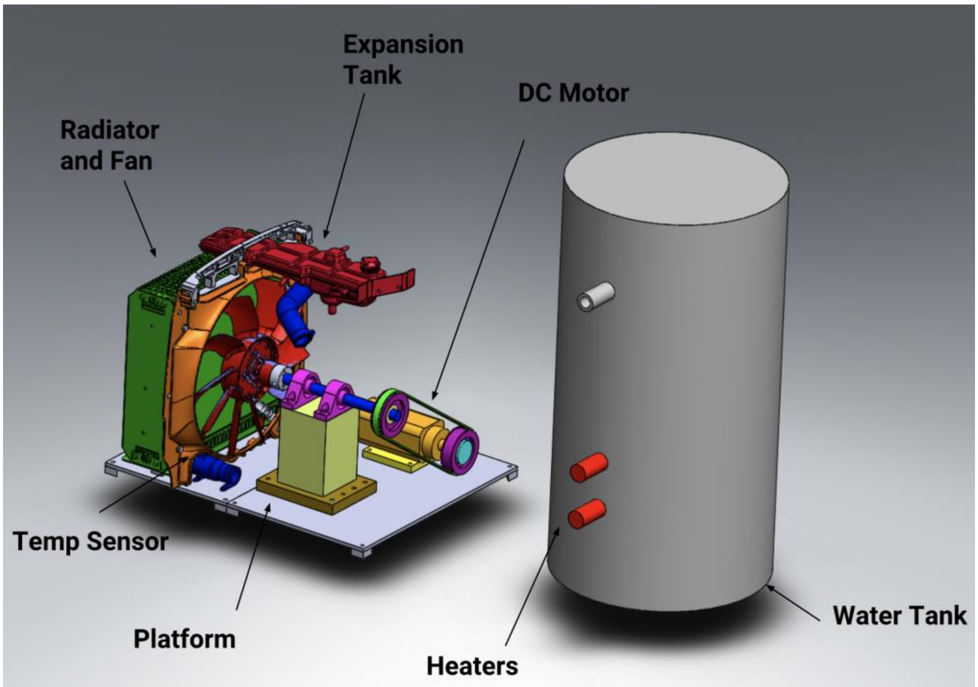

Figure 3. Final design schematics

Experimental setup is very similar to the real tractor's cooling system. Firstly, the fan is the same with the one used in the tractor. Radiator is also the same with the tractor. The working of the system is essentially the same with the tractor except that the electric motor powers the system and open-loop cooling is replaced by closed-loop cooling. The heaters will heat the flowing coolant and the controller algorithm will try to stabilize the temperature around the desired point. Controller commands will be directed to power input of the DC motor and the fan speed will change accordingly. Fan speed will determine dissipated heat. The verification of the system will be done with thermocouples that are positioned at the inlet and outlet of the radiator. Also along the radiator there will be other thermocouples to map the temperature and give a comparison to CFD model.

Outputs

Results:

The CFD calculations carried out in ANSYS gave us a heat rejection of 38 kW with a fan running at 1000 RPM. The coolant temperature was set at 95° C and the aim was to lower this temperature to 85° C after going through the radiator.

For our experimental setup, the most important part was the capacity of our Electric Motor. Usually, Electric Motors are not designed to run mechanical fans, like the one we are using, to such high RPMs. However, after extensive research and help from the company's engineers, we were able to purchase a motor which was powerful enough (4 kW) to drive the fan at speeds higher than 2000 RPM. Additionally, the motor is coupled with an inverter. By changing the frequency of the inverter via a controller, we were able to create a feedback loop system which ensured that speed of the motor is temperature sensitive.

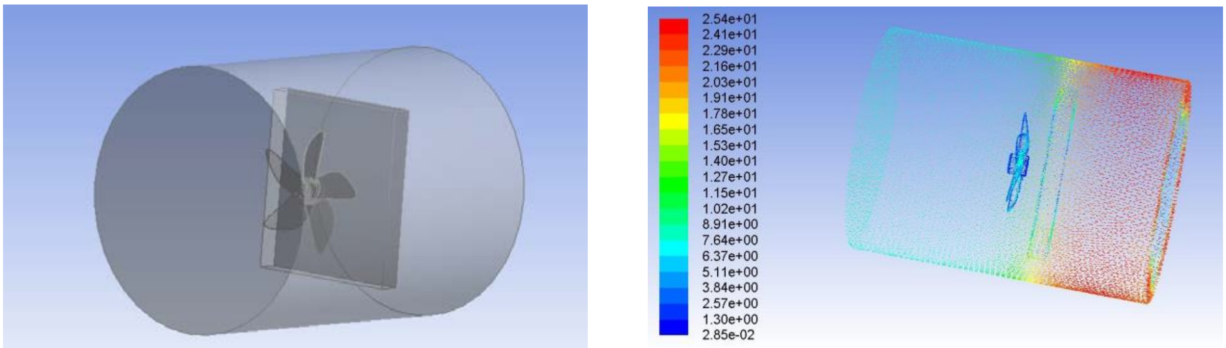

Figure 4. Fan and radiator computational analysis in ANSYS with air velocity magnitude

As it was not feasible to test the system on an actual tractor's engine, we decided to use heaters. In the real test setup, we were able to reach temperature as high as 65° C and using the control system, it was kept constant at 55° C. As this is in agreement with our CFD results (temperature drop of 10° C), we were satisfied with the results of our automated control system.

Outcomes:

The project was a combination of thermo-fluids, mechatronics and mechanical design. Because of this, we had the opportunity to improve our knowledge in each of those critical engineering areas which are essential for any successful engineering system. Due to the success of our project, the company can implement this control system with the same type of motor and fan in their tractors.

We also received a grant from TÜBİTAK and Türk Traktör to fund our project.

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Dilara Uslu

MECHO SAPIENS (B2)

Rough Terrain Advancing Hexapod Surveillance Robot

Academic Supervisor: Dr. Onur Özcan

Industrial Supervisor: Hüseyin Avni Güner

- ABSTRACT-

The aim of this project is to design and manufacture a remotely controlled robot that can move through rough terrains, and that will be used for observation and targeting in risky areas that require remote surveillance. The robot that will be designed and manufactured is obligated to carry the Stewart platform, already manufactured as 2016-2017 Bilkent Mechanical Engineering Industrial Project. This platform will serve to provide stabilization for a pod mounted on it, containing several sensors and a camera. The pod will serve as the targeting/observation system of the remotely controlled robot.

Problem Definition

Military operations in high-risk areas may include surveillance and scouting of hostile targets. Until recently, these types of surveillance operations have been approached with concern, resulting from the underlying risks, such as putting the lives of personnel at stake. Unmanned surveillance vehicles (see Fig. 1) have been proposed as a solution to this problem. The locomotion of the currently available solutions are provided by wheels or pallet systems. These field vehicles are expected to operate on rough and inclined terrains with maximum stability. However, both of these systems lack the ability to successfully traverse obstacles that are of comparable magnitudes to the size of the vehicle, while keeping the surveillance components stable.

Figure 1: Cobham tEODor [1]

Figure 2:iRobot 510 PackBot [2]

The solution to the aforementioned problem should be able to locomote on inclines and traverse obstacles with ease.

To be able to locomote on rough terrains, scientists started to investigate how nature has solved this problem.

The R-Hex [3,4] uses six C shaped legs inspired by the cockroach, providing additional maneuver capabilities to robots like walking, running, pronking, and even jumping.

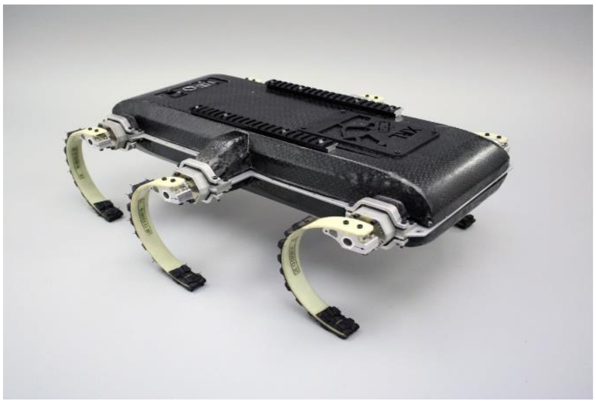


Figure 3: X-Rhex C-Leg Concept [3]

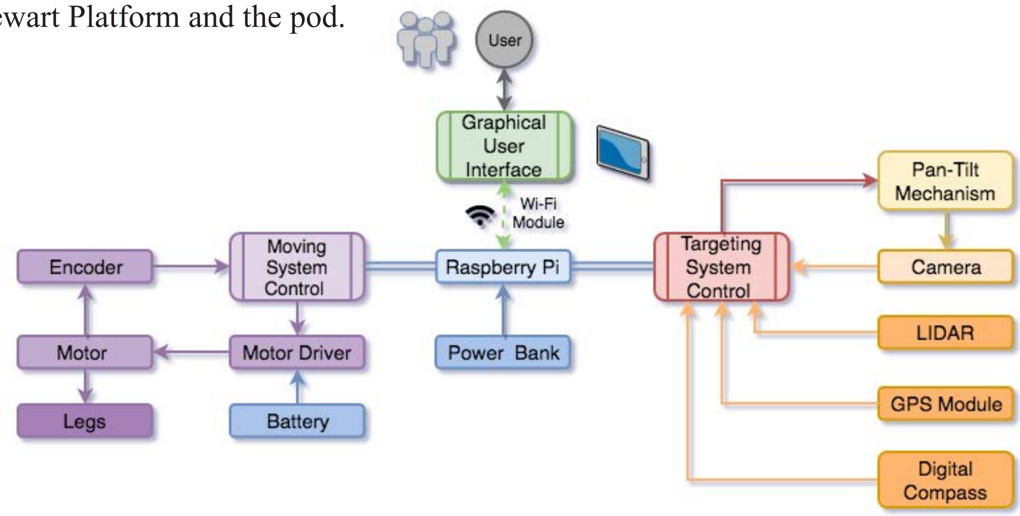
Figure 4: R-Hex [5]

Additionally, the solution should possess a targeting system that should live broadcast a camera feed of the field to its user. In the time of a possible hostile activity, the system should inform the user with exact location of the incident immediately in order to retaliate without losing time.

A robot with observation and targeting capability may work under same conditions without a risk. One person may operate one or more robots from a safe distance. Therefore, the main objective of this project is to design, develop and manufacture a remotely controlled military hexapod robot that will work in dangerous areas.

Design

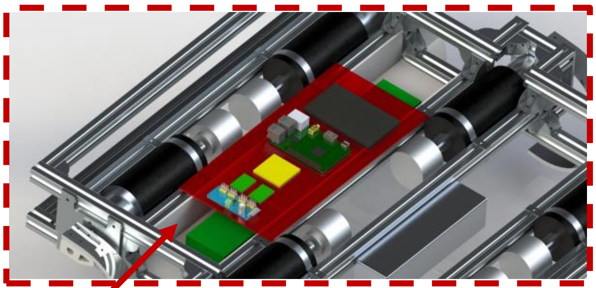
The design requirements of the robot consist of being able to travel on rough terrains, providing real time operation control, and carrying a Stewart platform. Hence, the robot has two subsystems: the moving subsystem, and the targeting subsystem which consists of the Stewart Platform and the pod.

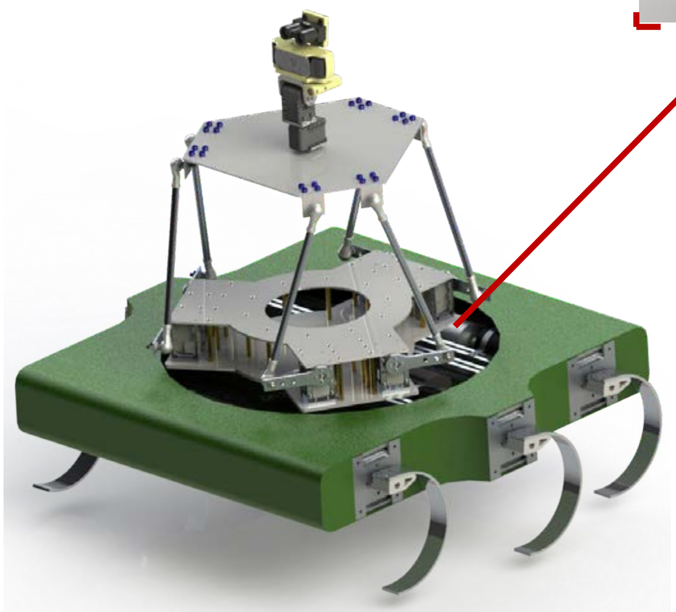


Results of mathematical modeling of the system and analyses based on the requirements and constraints are used to determine components such as motors, encoders, and certain aspects of mechanical design, such as C-leg dimensions.

The robot will be moving on rough and inclined terrains, resulting in undesired fluctuations of the body. The Stewart platform is mounted onto the system in order to stabilize the camera pan-tilt mechanism and allow for an undisturbed camera feed.

The body of the robot is constructed with aluminium sigma profiles to enable a light-weight frame and easy assembly. The C-legs have been manufactured by bending aluminium sheets, and are connected to the motors through designed connector pieces.





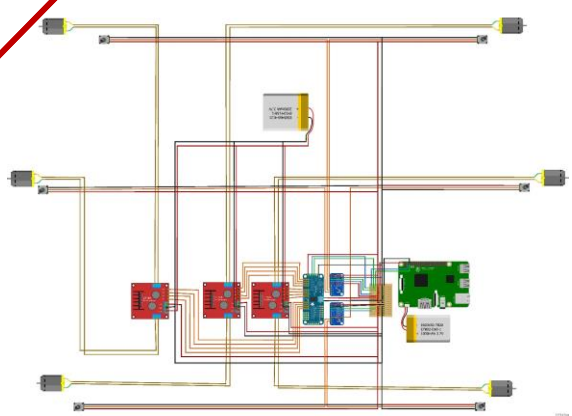


Figure 5: (Left) Full Assembly (Right) Electrical Setup of Components and Schematic

Outputs

Results:

- ✓ The main purpose of the project is to design and manufacture a remotely controlled vehicle which can move through rough and inclined terrains and is also capable of carrying the Stewart platform, which serves to provide stabilization of the pod.
- ✓ The robot satisfies all of the requirements and constraints that were given in the problem statement.
- ✓ In order to increase the movement capability, Stewart platform is combined with the C-shaped legs. This also ensures the originality of the solution.

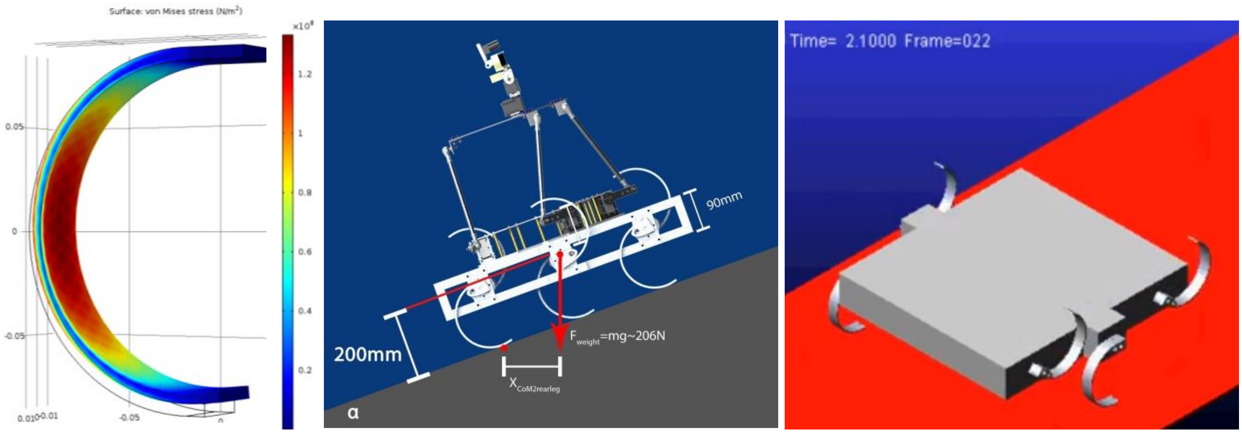
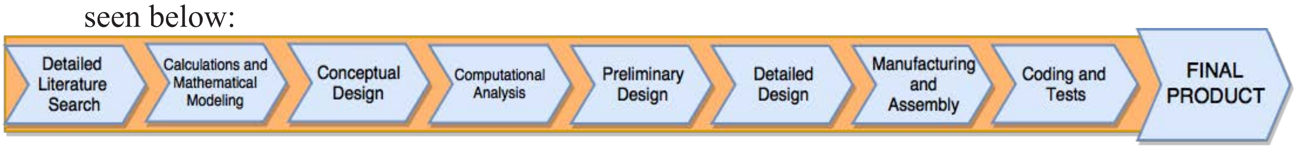


Figure 6 (Left to right): COMSOL C-Leg Analysis, Moment Calculation and Gait Simulation

Outcomes:

- ✓ Conducting this project required an extensive literature research, elaborate engineering analyses, analytical and computational, and lengthy testing.
- ✓ The group has worked on the mechanical, electrical and coding elements of the project, all of significant importance, resulting in an interdisciplinary work.
- ✓ The various engineering procedures which are followed throughout the project can be seen below:



This project is financially supported by
TUBİTAK 2209-B Industrial Senior Year Project Support Program.

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[4]Kevin C. Galloway, Galen Clark Haynes, B. Deniz Ilhan, Aaron M. Johnson, Ryan Knopf, Goran A. Lynch, Benjamin N. Plotnick, Mackenzie White, and Daniel E. Koditschek, "X-RHex: A Highly Mobile Hexapedal Robot for Sensorimotor Tasks".
[5]Boston Dynamics. *"RHex: Devours Rough Terrain."* Retrieved from: https://www.bostondynamics.com/rhex

BIG KING (B3)

Brake Pedal Pushing System with Adjustable Load and Speed Profiles

Academic Supervisor: Asst. Prof. Melih Çakmakcı

Industrial Supervisors: Dr. Hakan Mencek

Ogeday Candaş

- ABSTRACT-

The aim of this project is to design, analyze and manufacture a brake pedal pushing system with adjustable load and speed profiles for tractors. Development procedure consists of literature survey, design process, manufacturing and testing. While developing the brake pedal pushing mechanism, there were several constraints to be satisfied. These were force, speed, safety and economic constraints. By taking into consideration of these constraints, an electro-mechanical mechanism system is designed, analyzed, manufactured and finally tested. This mechanism will be used in research & development and testing phases of tractor brake systems.

Problem Definition

There are governmental regulations that are required to be satisfied for the brake performances of the tractors. In order for a tractor to step into market, it has to meet some strict regulations and standards. These regulations require for a tractor to stop in a desired distance when variable amplitude of forces applied to brakes. In order to meet these regulations, company makes its own tests. However, they do the tests by operators. Since a human is not able to apply a constant force or a variable force profile whose magnitude is known, it causes ambiguities in the results.

There are two graph's given in Figure1. In the first one the force that is applied to the pedal by an operator is given with respect to time. In the second one, is given the company's desired force to be applied to the pedal. Additionally, achieving a test system that gives the desired force is important for company since they will use this system to compare the performances of different tractor models. Therefore, precise results are required to make a reliable comparison.

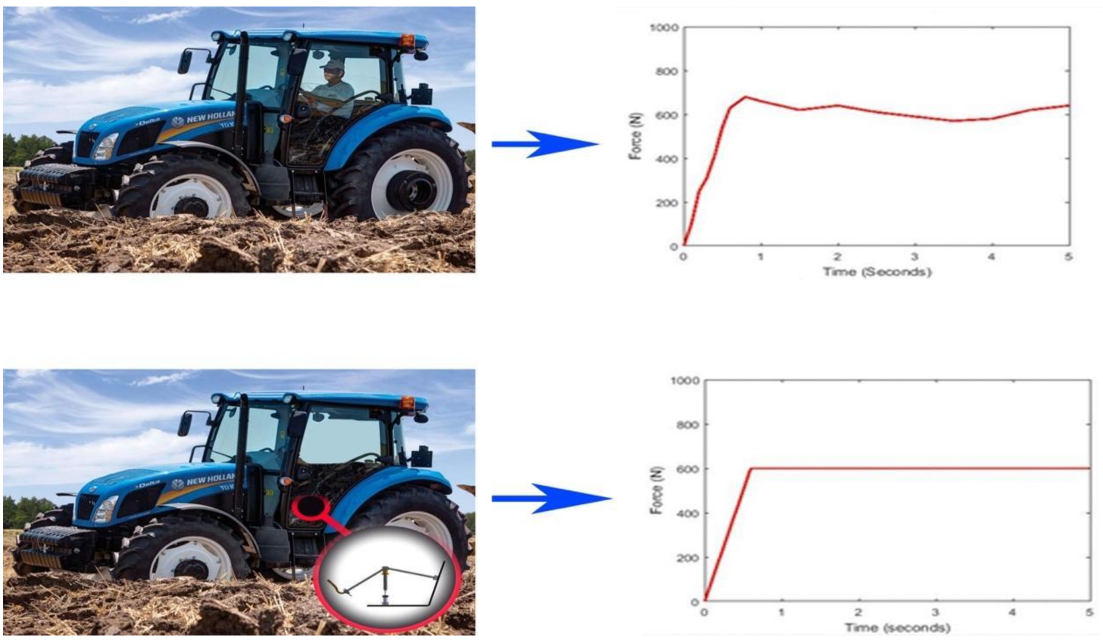
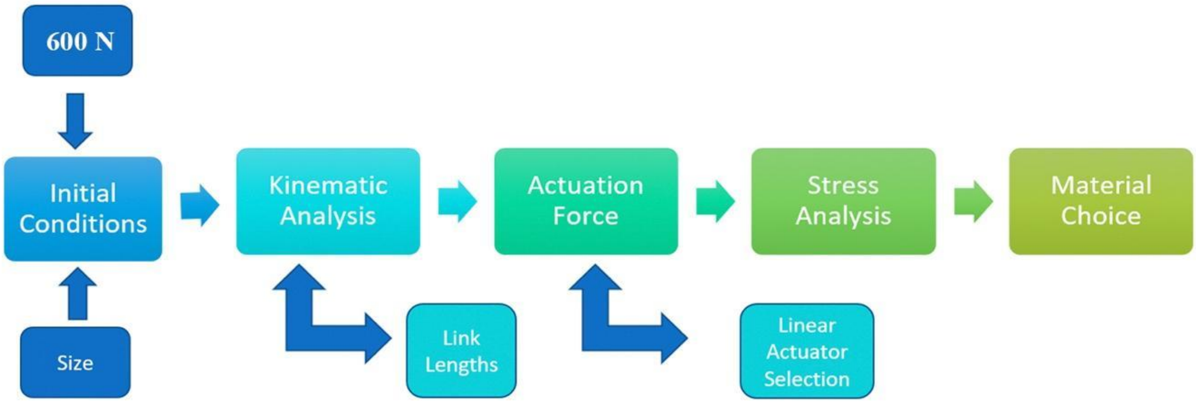


Figure 1: Project Requirement

Design

A solution is produced by considering problem definition, constraints and requirements. Regarding these facts the design procedure can be summarized as follows:



The system is designed as a four-bar mechanism and the fourth bar is modeled as the pedal itself. Linear actuator is used for providing linear motion to the system via its connection to linkage connection point as shown in Figure 2. As the linear actuator moves perpendicularly, the motion, thus the force is transferred to the pedal. By controlling the linear actuator, force to be transferred to the pedal is controlled and thus uniform, comparable brake pushing scenarios are applied. The material chosen for the system components is Aluminum 7075. This material is chosen for its properties of resisting effectively to the applied forces with lightweight and cheap price.

Figure 2: Schematic Representation of Design's Working Principle

Figure 3: Assembly of design that is visually separated into its components

Outputs

Results:

-With the electromechanical brake pedal pushing system, desired constant force is applied to the pedal. This enables standardization of tractor’s brake test.

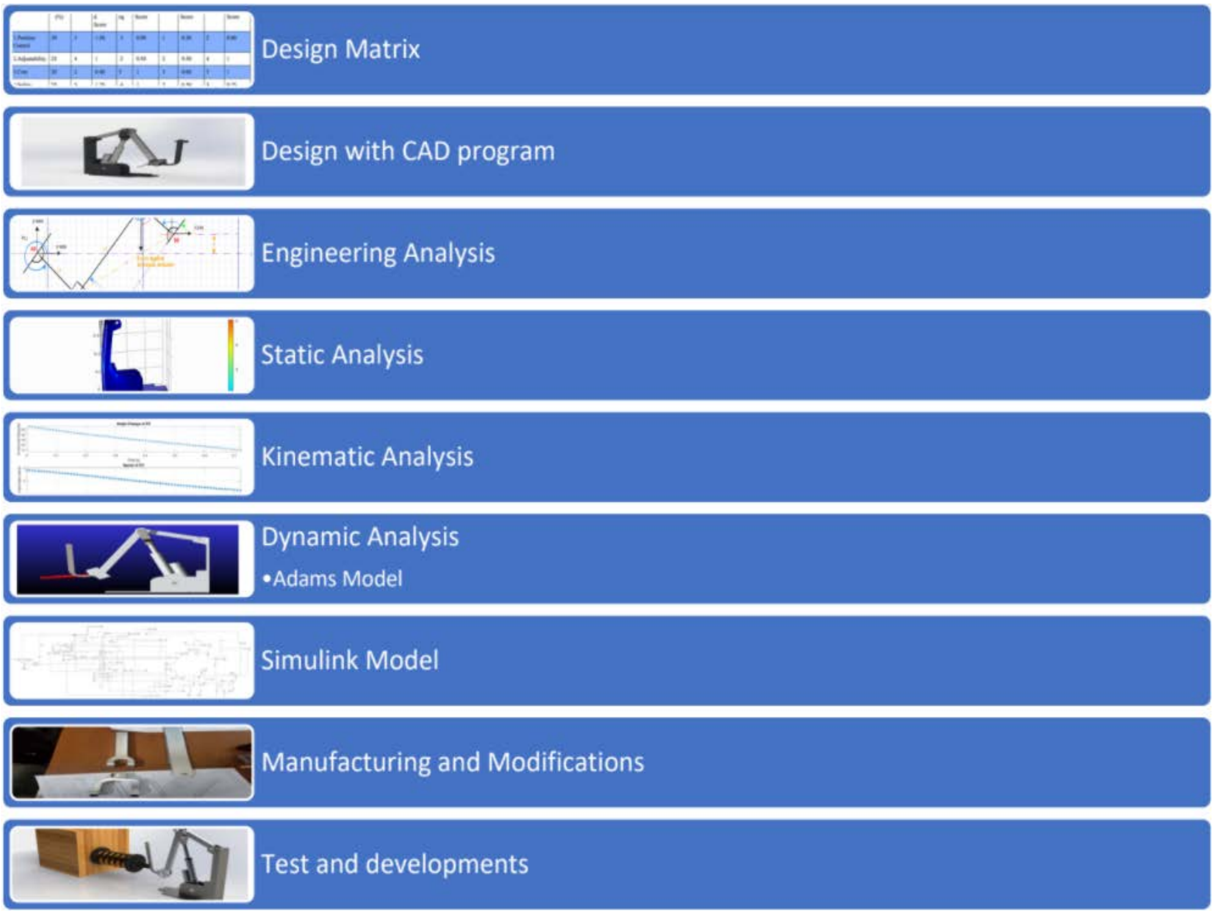
-All of the parts are manufactured and linear actuator is purchased locally.

- Our system produces required speed and force.

-The prototype and test mechanism give satisfactory results that are already approximated by virtual modelling and analytical calculations of the system.

Outcomes:

In each step of the project, problems are solved with engineering approach. After the design step, an extensive engineering analysis is applied to optimize the design and to get output parameters of the brake pedal pushing system. The engineering analysis does not only contain calculations, but also contain usage of advanced computer programs for modelling and stress analysis, dynamic analysis, kinematic analysis and static analysis. The steps of the project are listed below:



This project is supported by TUBITAK 2209/B program.

BigKing

MAKERS (B4)

Development of Cable Winding Machine

Academic Supervisor: Prof. Dr. Ömer Aka Anlağan

Industrial Supervisor: Erkal Özbayramoğlu

- ABSTRACT-

The objective of this project is to develop a cable winding and laying machine to be used in the mine testing process of armored vehicles. There exists automatic cable winding and laying mechanisms in the market however they only work for one cable at a time and their functions are limited to winding or laying only but not both. Throughout the project, literature search, design processes, manufacturing, structural analysis and testing procedures are conducted. To satisfy the needs of the project, a cable winding-laying machine which will shorten the required time for both cable winding and laying operation during the tests and work with multiple cables at a time is designed and manufactured.

Problem Definition

In the defense industry, various military standard tests are conducted to test equipment, devices, and vehicles. One of these tests is mine testing where the hull of armored combat vehicles is tested in order to determine its durability. Mine tests are challenging tests because it is conducted against time and in field conditions.

For the infrastructure of the test, several cables are used to collect data about the test. These cables are for data acquisition system, trigger system for the igniter, high-speed camera system etc. In FNSS, mine testing area, four cables are used along 300 meters distance from the safe area to vehicle location. The cables are laid down before the mine test and they are wound after the test. Currently, the winding and laying process of the cables are done by technicians who winds and lays cables along 300 meters. This process takes a whole day. Therefore, it causes waste of time and economic loss. The aim of the project is to shorten the duration of the process by designing a cable winding and laying machine that winds and lays at least 4 cables at the same time which automates the testing process.

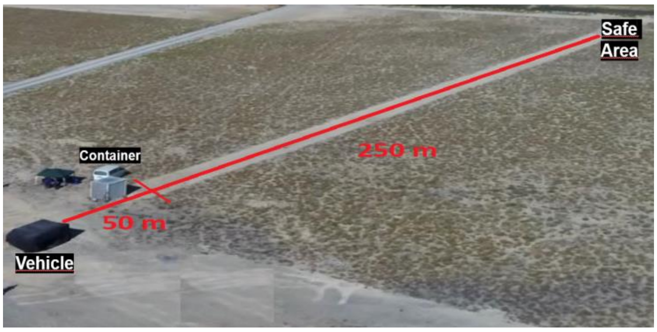


Figure 1. Testing Area of Mine Testing

The designed cable winding and laying machine is located on the cargo area of a pickup truck. While the pickup truck travels from the safe region to the container, a technician starts the motor and laying process initiates. After the first 250 meters of cable is laid down, from safe region to the container, the technician detaches the small reel and lays the last 50 meters of the cable manually.

After mine test is done, the technician winds the cable to the small reel and attaches it to the big reel. Then the motor is started again and the big cable reel winds the 250 meters of cable on the ground between safe region and container. Finally, after the winding process is completed, the pickup truck comes back to the safe region.

Figure 2. Application of Mine Testing [1]

Requirements / Constraints
The weight of a 300 meters long cable of heaviest type is 80 kg.
Total distance that cable should be laid and wound is 300 m.
The flange diameter of the large and small reels should be enough to provide a winding capacity of 250 meters and 50 meters respectively.
The total number of cable winding units should be at least 4.
A maximum of 2.5 kW is available in the work field.
The system should be driven by electrical actuators durable to environmental conditions.

[1] "Protection and Survivability." FNSS Savunma Sistemleri A.Ş., www.fnss.com.tr/en/services/test-analysis/protection-and-survivability.

Design

The design was done by considering the problem to be solved, requirements and constraints. The order of design process is as in Figure 3 below.

Figure 3: Design Process Scheme

Designed components are shown in Figure 3. Torque obtained from the motor is directly transmitted to the shaft by using a gearbox to obtain a fixed rpm. At the right part of the side support a bearing is used. Cable Reels are fixed on the shaft by the weld neck flange.

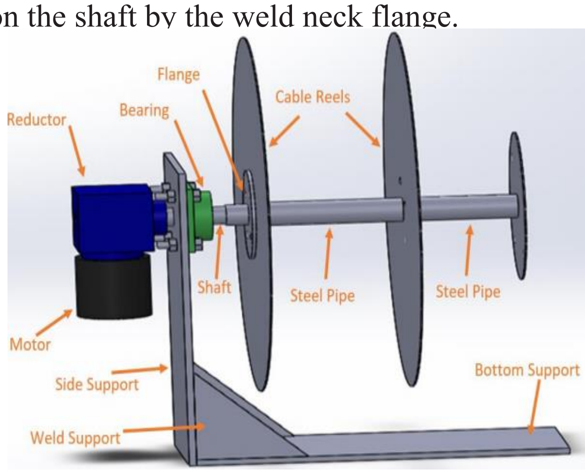


Figure 4. Components of the Final Design for sngle unit

Attaching / Detaching Mechanism of Small Cable Reel from Big Cable Reel

This is provided with bolts and nuts. Bolts are welded on the inner surface of the large cable reel. These bolts are tightened from the inner surface of the small cable reel.

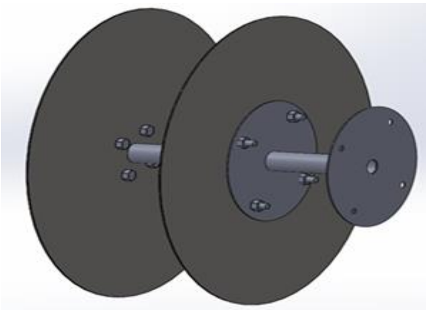


Figure 5. Representation of Attaching/Detaching Mechanism

Manufacturing process began with CNC Machining of Cable Reels and Supports. Then welding process was applied.

- Two flanges of the cable reels are welded together with a steel pipe.
- Side supports, bottom supports, and weld supports are welded together.
- Bolts and nuts are welded on the side surfaces of the reels.

Figure 6. CNC Machining of Components

After welding process, motor-gearbox, bearing and shaft mounted on side support as shown in Figure 7.

Figure 7: Assembly process of Motor-Gearbox-Bearing-Shaft-Weld Neck Flange on the side support

Outputs

Results:

✓ A cable laying-winding machine which works successfully with multiple cables at the same time is developed.

✓ Operation of the machine from the container to the vehicle (see Figure 1) is provided by detaching and attaching mechanism with bolts (see Figure 5).

✓ Controlling of the dc motor is accomplished by a remote control unit which prevents usage of extra connections with cables for motor system.

✓ Operation capability of the machine developed is from safe region to vehicle (see Figure 1) which is 300 meters length.

✓ The total time estimated for cable laying and winding process in mine testing is reduced to 3 hours.

✓ Developed machine can work in field conditions against rain and snow and is durable against impact damages.

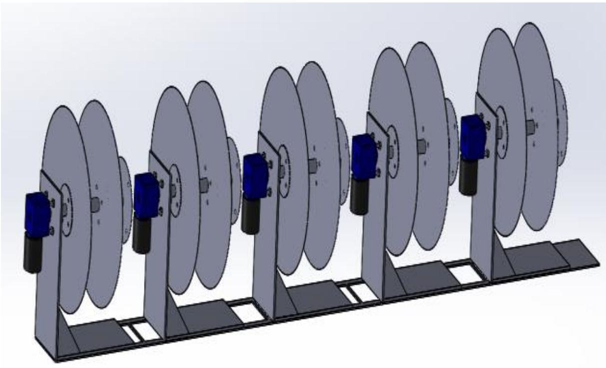


Figure 8. Final Assembly of 5 Units in a Line

Outcomes:

Development of cable winding and laying machine includes many design phases, engineering analysis and testing procedures to be achieved step by step. Throughout this project, all of the learned engineering procedures and practices are used.

- Project requires literature search about manufacturing techniques.
- In project development phase, many CAD drawings are made to illustrate different design ideas.
- Structural Analysis is made in COMSOL Multiphysics.

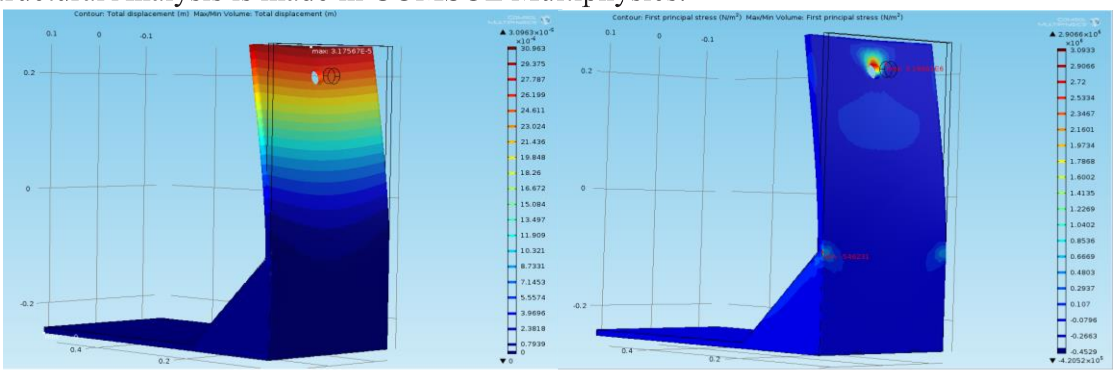


Figure 9. COMSOL Analysis of Structure

- Motor unit for cable reels is controlled by a controller.
- Manufacturing techniques are used.
    - CNC Machining
    - Welding
    - Turning / Milling

This project is supported by TÜBİTAK 2209-B Industrial Senior Year Project Support Program.

FROSTBITE (C1)

Design and Production of Position Controlled Stirling Cooler

Academic Supervisor: Dr. Barbaros Çetin

Industrial Supervisor: Dr. Besim Baranoğlu

Teaching Assistant: Dilara Uslu

-ABSTRACT-

The purpose of this study is to design and produce a refrigerator based on Stirling Cycle for small volume cooling applications. Due to various advantages such as high efficiency in small volumes, silent operation and environmentally friendly working principle, the Stirling Cycle is preferred for the study instead of other cycles. Throughout the project, it is aimed to cool down a small volume requiring a lesser amount of energy compared to the conventional Stirling refrigeration cycles; therefore, the use of independent position controllers is proposed to increase the over-all thermodynamic efficiency of the system. Firstly, a mathematical model was developed to calculate the best possible displacement. Then, after the manufacturing of the system, the model developed by Frostbite was implemented.

Problem Definition

Stirling cryocooler is a refrigeration system that uses mechanical energy to transport heat energy utilizing Stirling cycle. In this cycle, fluid in the cylinders are periodically compressed and expanded to transfer heat according to the first law of thermodynamics, energy conservation.

Although there are various refrigeration cycles available for use such as Gifford, McMahon and Brayton coolers; Stirling cryocoolers are used in a range of applications varying from systems in space to cellular cryogenics. They are preferred due to their [1, 2, 3];

- Silent operation
- Wide input range
- Scalability
- Higher efficiency in low temperatures.

Current applications of Stirling engines and refrigerators rely on a crank-shaft mechanism in which two pistons are connected to each other as in Figure 1.

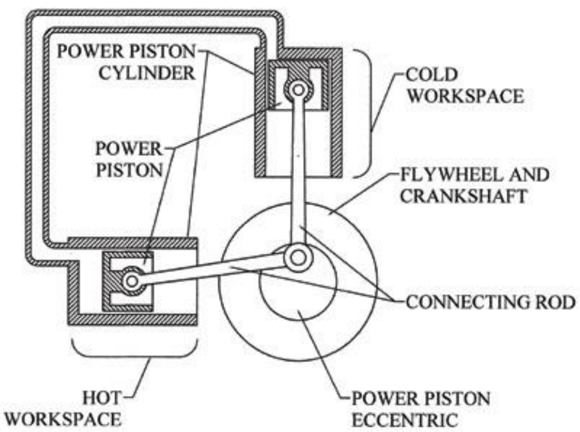


Figure 1: Conventional alpha type Stirling Engine [4].

Since the mechanical power is related with the area under pressure – volume diagram, efficiency of practical systems can be visualized as in Figure 2.

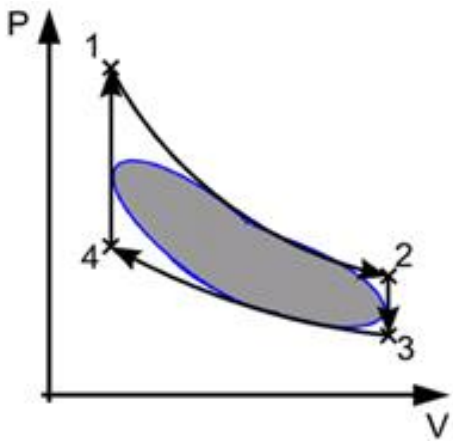


Figure 2: Ideal cycle vs. conventional applications [5].

In Figure 2, black lines indicate the theoretical limit of the pressure - volume in a cylinder. The blue line is the data obtained from an actual Stirling engine. Since the area under the graph is related with the efficiency, it is seen that the current mechanisms are unable to reach the maximum efficiency.

Therefore, this project aims to replace the crank-shaft mechanism with two independently controlled pistons to solve the problem, as in Figure 3.

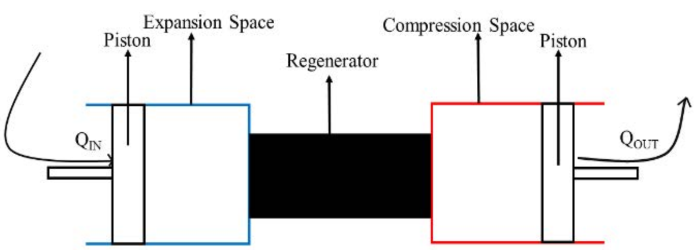


Figure 3: Independently controlled pistons.

Design

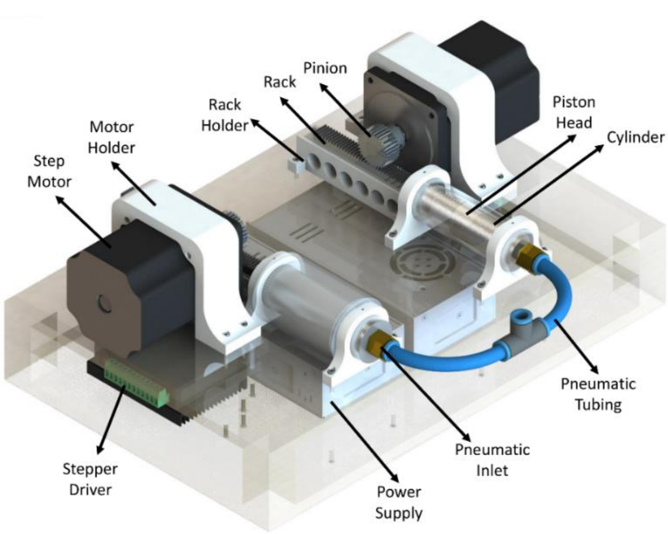


Figure 4: Frostbite design.

A novel design, shown in Figure 4, in accordance with the industrial requirements and constraints is proposed to solve the problem. This solution consists of two piston-cylinder assemblies connected by a piping. Pistons are driven by two step motors as shown in Figure 4. Positions of each piston is controlled by step motors which enable user to implement different kinds of displacements. Power is transmitted to the pistons by a rack and pinion mechanism.

Fluid cools down when expanded and warms up when compressed. In Stirling Cycle, this expansion and compression occur in different cylinders. Since expansion and compression processes are separated through the process, one cylinder cools down and one cylinder warms up. The regenerator inside the piping ensures an efficient heat exchange. In this design, it is also possible to change the displacement of pistons according to a different working condition.

In Figure 6, the basic working principle of the Stirling refrigerator is shown as a schematic. Controller gives the position information to the step motors. Step motors then move the pistons via rack and pinion mechanism. This movement initiates the Stirling Cycle and according to this cycle, fluid inside the cylinders is expanded and compressed. As a result, temperatures of each cylinder change.

Cooling Temperature	Cooling Volume	Cylinder Pressure
up to -40 °C	< 100 cm^3	< 3 bar (absolute)

Mass	Dimensions	Cycle Frequency
< 20 kg	30 cm x 40 cm	1 – 10 Hz

Figure 5: Requirements and constraints.

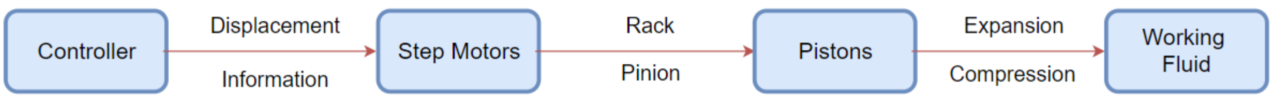


Figure 6: The schematic working principle.

Outcome

To realize the project, the overall progress was planned beforehand. First, a literature search and a feasabilty study were done. Then, a mathematical model was developed. At the same time, an experimental setup was constructed. Using both, data is gathered, and model is improved accordingly.

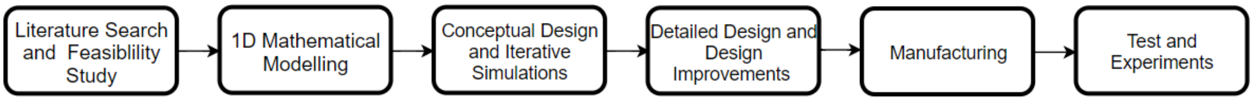


Figure 7: Progress plan.

Extensive knowledge on the following subjects is required;

- Fluid dynamics,
- Heating systems,
- Sealing systems,
- Thin-walled vessels,
- Design parameter optimization,
- Coupled system simulations,
- Dynamics and control,

So, the main purpose of this project is to introduce a national refrigerating system. Completing the steps shown above, the following outcomes are obtained at the end of the process:

- A national refrigerator unit allowing us to set any displacement possible enables flexibility for the user to test out novel and unique cooling patterns,
- Novel thermal model was developed,
- Requirements regarding size and the temperature were met.

*This project is financially supported by TÜBİTAK 2209-B Industrial Senior Year Project Support Program.

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ANONYM (C2)

Designing a Compact Drying System for a Dishwasher

Academic Supervisor: Dr. Şakir Baytaroğlu

Industrial Supervisor: Batuhan Akbaş

Teaching Assistant: Cem Aygül

- ABSTRACT-

Aim of this project is to redesign the existing drying system for dishwashers in order to put new functions.This mechanism should satisfy constraints of the company. In order to do that, a comprehensive literature search is done to see current applications in industry. Then, different mechanism solutions are designed to choose the proper one with our mentors. Chosen design were improved by engineering approaches. Prototypes of the design were manufactured. Test and evaluation were done on the prototypes. As a result of these stages, final product was created.

Problem Definition

In the current drying systems, there are a lot of unused spaces in the“condensation rooms” which is the place where condensation occurs. These spaces inhibit to put new functions and components.The goal in the new project is to make a compact design of the existing design to create extra space for new components and new functions. This problem is solved by using a smaller fan and decreasing the volume of condensing unit.

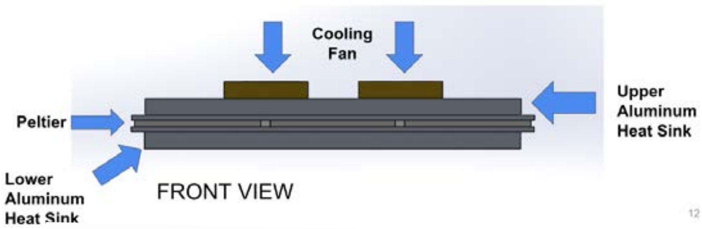
Old Fan

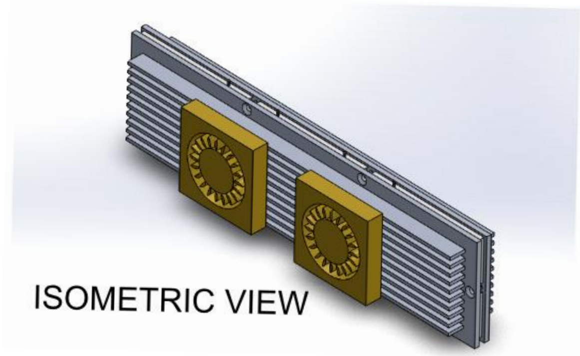
Figure 1

New Fan

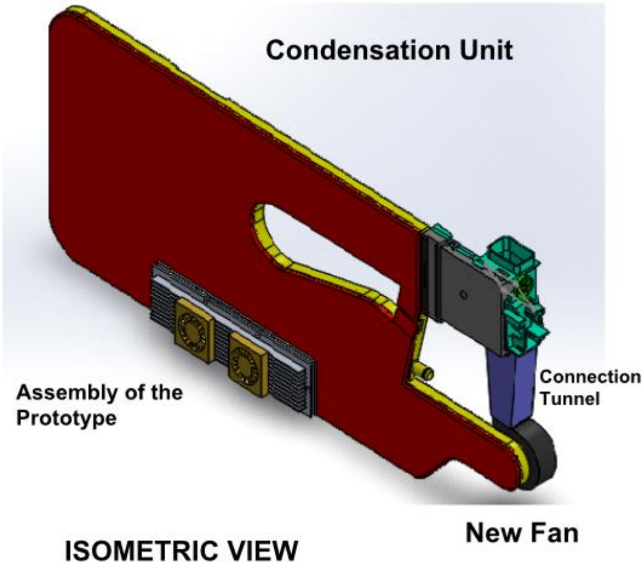
Figure 2

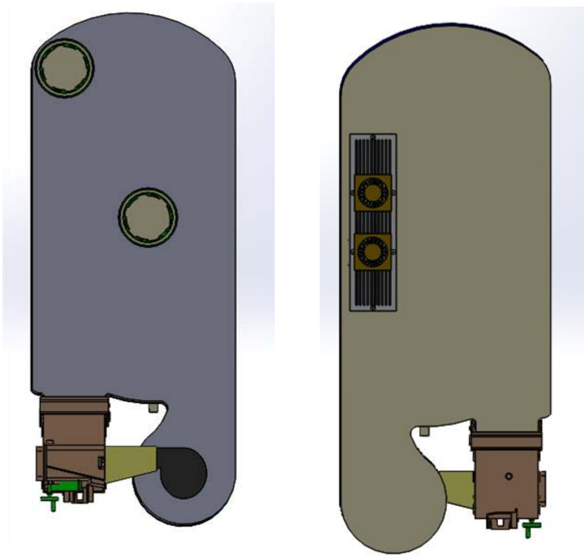
Also, to decrease the time of drying and to increase the efficiency of electricity usage, an assembly of aluminum heat sinks, peltiers and cooling fans are used which is shown below.





In addition to the current system, we used a new DC fan which is very small in comparison with the current fan which increases the space at the fan area which is shown in the following figure:

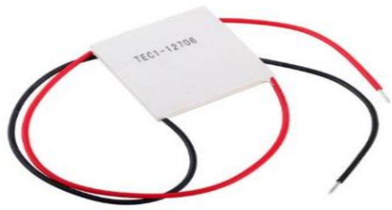




- The current fan is changed with a smaller DC fan
- Aluminum heat sinks, peltier and cooling fans were attached in condensing unit
- A connection tunnel is manufactured between DC fan and the shutter.
- Condensing unit is redesigned and the volume is decreased.

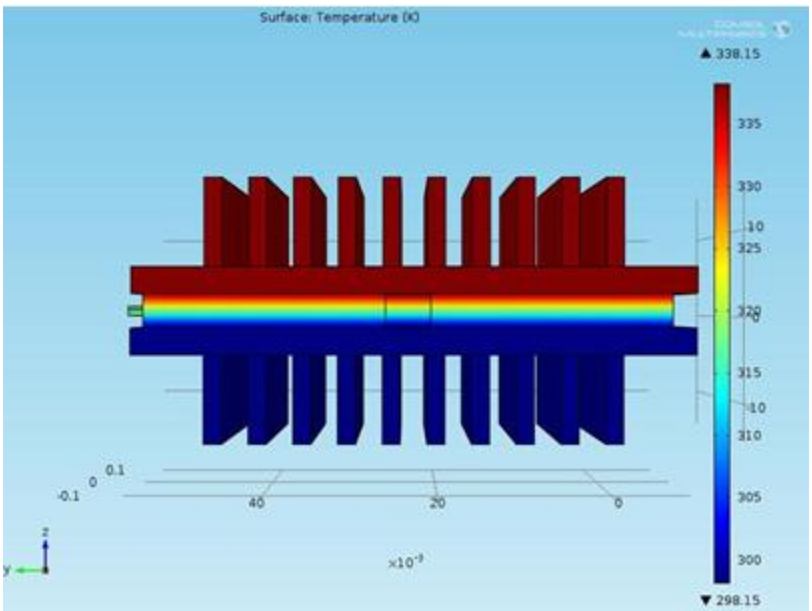
Design

This project is an application of four year engineering education. We used not only knowledge from the lectures but also gained information from the literature state of the senior project. During this design and manufacturing process:



- CAD drawing tools
- Technical drawing rules
- Engineering calculations
- Program based engineering analysis (COMSOL analysis)
- Test and manufacturing techniques (including 3D printing) were used.

Literature survey → Virtual system → Prototype and tests → Final design



Outputs

Results:

✓ Main purpose of the design other than its technical aspects is producing an expensive technology coming from abroad with more reachable sources. This project proved that a technology can be developed mainly by using sources without needing any exports. This point reduced the cost and in additional to that, technology became more improved with localized sources.

✓ All virtually fictionalized systems proved to be working even the prototypes and test mechanism.

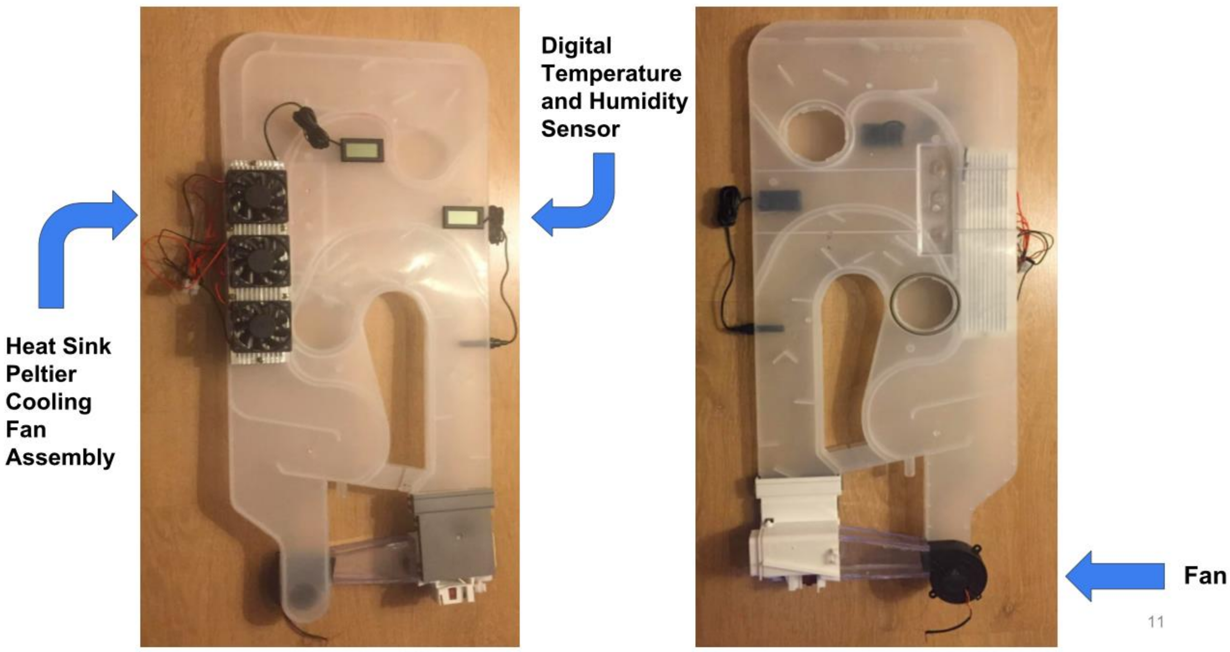
✓ System satisfied all of the requirements defined in the problem statement and can be usable in military conditions.

✓ Condensed water was increased by it's two or three times, which means a reduct,on in time and an increment in condensation.

✓An additional cooling fan and peltier were added according to test results that have been done with the first prototype.

Outcomes:

This project procedure consisted of several steps. In each step lots of engineering calculations are procedeed. Yet calculations are not the only engineering approach that is followed, analysis and simulations are also used such as the condensation analysis and the heat calculations. Throughout this project all of the pre-learned engineering procedures are used.



PYRO (C3)

Automatic Rollover Protection Structure (ROPS) Development

Academic Supervisor: Asst. Prof. Melih Çakmakcı

Industrial Supervisor: Volkan ARI

Teaching Assistant: Tamer TAŞKIRAN

- ABSTRACT-

Aim of the project is to design and manufacture a mechanism that automatically activates from standby status to operational status in case of a rollover incident. The operational problems that manual ROPS creates is solved by designing an automatic ROPS. Four alternative triggering systems are evaluated by taking into consideration functional, safety, manufacturing, economic, aesthetic, ergonomic, life cycle constraints. Consequently, Mechanical Spring Triggered Automatic ROPS has been designed, manufactured and tested.

Problem Definition

Rollover Protection Structure (ROPS) is mounted on the front or the rear section of a tractor to prevent accidents during rollover condition. When an accident happens, the structure creates a safety area between ground and its own body so that the driver does not suffer from exterior damage.

Figure 1: Illustration of Manual ROPS [1]

As manual ROPS is attached to tractor, the vertical height of vehicle increases. Drivers usually detach the structure since their angle of vision is diminished because of the system. This issue can be addressed with the replacement of conventional manual ROPS with an automated one, which opens up only in rollover accidents. Once the Automatic ROPS is mounted to tractor, it cannot be detached by the driver's will.
As manual ROPS increase the vertical length of tractor, it also restricts the motion in zones where low height is required, such as orchards and animal shelters. Because of that, drivers prefer to detach the ROPS or fold it for operational ease. This leads to unsafe working conditions and hazardous scenarios. This issue is prevented by Automatic ROPS in which, increase in vertical height is conducted as deployment of tubes once the rollover condition is sensed.
Since tractors are mostly used in farms in where there are harsh conditions, the careless act of the driver could cause an accident which may end up with severe damage. This issue can be addressed with the replacement of conventional manual ROPS with an automated one, which opens up only in rollover accidents, before the rollover condition occurs.

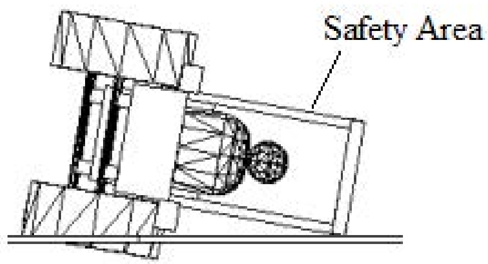


Figure 2: Manual ROPS Safety Area Formation [2]

There are currently existing solutions for Automatic ROPS such as Anchor Mechanism Attached Manual ROPS, AutoROPS and Air-ROPS. However, these solutions come up with drawbacks such as single deployment, lack of information regarding maintenance, durability and sustainability and risk of ROPS sinking into the ground.

[1]:"Erkunt Servet" Tractor, [Online].Available: http://www.erkunttraktor.com.tr. [Accessed 15 October 2017].
[2]:Silleli, Hasan H. "The Development of a System Increasing the Driver Safety and Driving Performance in Front Mounted Roll-Over Protective Structures" Tarım Makinaları Bilim Dergisi, 2006, pp. 41–48.

Design

Automatic ROPS is composed of two vertical rods. Each is structured by two telescoping tubes. These rods are mounted to tractor. Mechanical Spring Triggered System is going to be used to trigger Automatic ROPS system. Two mechanical springs are going to be placed on bottom of each rod. Also, there is the top section of the ROPS that elongates horizontally once the operational status occurs. Standby status of Automatic ROPS refers to the scenario in which two mechanical springs are compressed and telescoping tubes are not operated. The operational status of Automatic ROPS refers to deployed position of telescoping tubes with vertical force provided by springs. This retracted position of springs is achieved by two dc motors integrated with rack and pinion mechanisms.

When the rollover condition is sensed by the sensor system, signal is sent from sensor system to pins. After that, pins are releasing the compressed springs and it is going to provide the force to operate the tubes in vertical direction. Once the deployment is achieved, two latching components, which are placed on the interconnected region of two telescoping tubes, lock the deployed structure.

In some scenarios, false deployment of telescoping tubes may occur once the rollover condition is sensed but rollover does not exist. At that condition, deployed system must be brought to standby position. By that, reusability of the ROPS system is achieved.

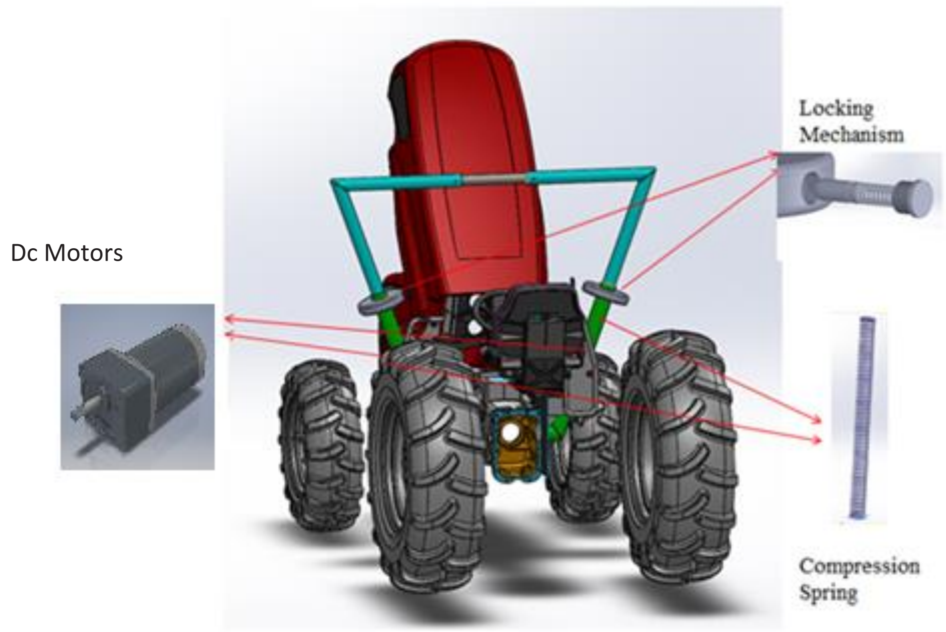


Figure 3: Illustration of Automatic ROPS Components

Outputs

Results:

✓Common materials are used in the design so that it can be produced in local industrial zone with basic manufacturing techniques at low cost.
✓The structure is mounted on tractor body in lowered position. With this approach, manoeuvre capability is increased.
✓When the rollover is detected with the sensor system, deployment of the structure is accomplished in time before tractor hits to the ground.
✓Clearance region, that is the virtual living space for the driver, is satisfied according to OECD CODE 6.

Figure 4: Proposed Final Design

Outcomes:

From the beginning of this project, there are several processes that have been carried out. For the drawings, SolidWorks is used. In analysis process, ANSYS is used. Engineering calculations and design improvements are contained in each process.

- Literature Research for Currently Existing Solutions
- Technical Drawings
- Engineering Analysis
- Manufacturing Processes
- Sensor Unit Integration
- Test Setup and Testing Procedure
- Installation of Automatic ROPS on Tractor Body
- Cost Analysis

The project is funded by TUBITAK 2209-B Industrial Senior Year Project Support Program.

DISCOVERY (D1)

Deployment and Retrieval Mechanism for Towed Decoy

Academic Supervisor: Prof. Ömer Anlağan

Industrial Supervisors: Okan Çınar
Hünkâr Kemal Yurt

Teaching Assistant: Levent Dilaveroğlu

- ABSTRACT-

The objective of this project is to design, analyze and manufacture a deployment and retrieval mechanism for towed decoy which is going to be used in national jet fighter project of Turkey. Decoys, deployed electronic devices from plane for distracting air missiles targeted to host aircraft, are one of the most essential defense mechanisms for aircrafts in air threatening situations. Most of the existing decoy deployment mechanisms do not allow reuse of deployed decoy twice. This project provides opportunity of reusing decoy more than one time in same flight.

Problem Definition

A towed decoy system is an anti-missile countermeasure. Decoy system used on multiple U.S. Air Force, Navy, and Marine Corps aircraft, and by certain non-United States air forces. These types of decoys contain various types of electronic circuits to create an apparent target to a weapon which attracts the weapon to the decoy rather than aircraft.

It would be desirable to deploy decoy when a threat has been sensed and retrieving it when threat is gotten over in order to use that system more than once during one combat mission as additional threats may be detected. Since the timing is important in advanced air fights, deployment of the decoy should be carried out quickly. Decoys have different working range limitations for actualizing several duties like jamming signal for radars or becoming a desired target for enemy missiles. These limitations show up requirement to locate decoy in a predetermined distance from the aircraft. Furthermore, it is important to recover towed decoy as long as it remains functional, mainly because of high cost and complex electronic construction of it. Also when the decoy is deployed, it restricts the maneuver ability of aircraft.

Figure 1. Currently existing mechanism for U.S. Air Force

In order to use the retrievable towed decoy mechanism more than one time in the same mission it must be ensured that decoy resume it is original pre-deployed state within its housing. Designed project should also include a cutting mechanism which performs in an emergency situation.

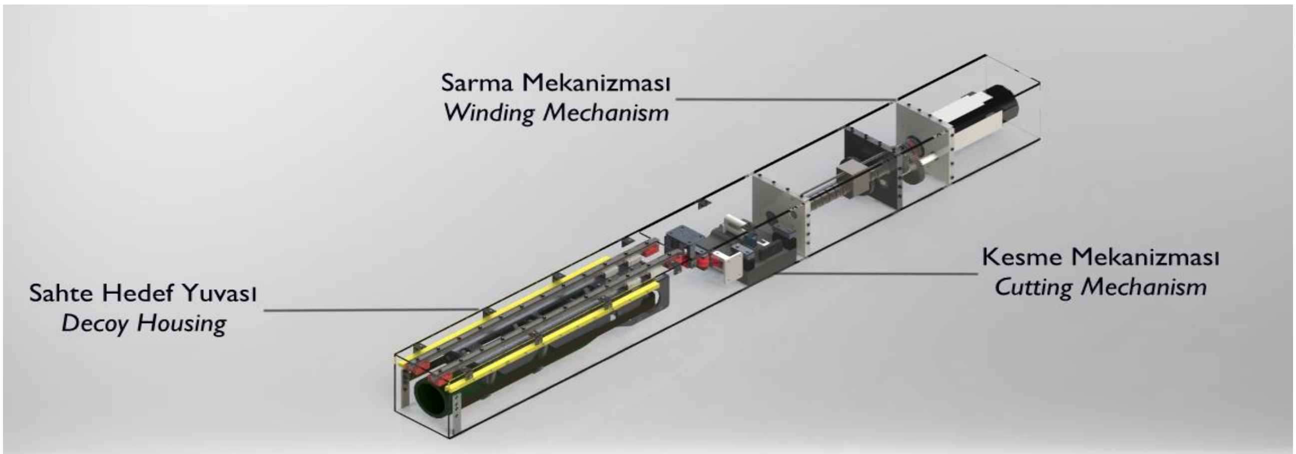
It is known that the currently available products are not purchasable seperately from an aircraft. Therefore, national decoy deployment and retrieval mechanism is needed. Besides, design of these systems are protected as military secret, so they are not eligable. That's why, researching, designing and manufacturing the deployment and retrieval system for towed decoy in the same country where it will be used is crucially important.

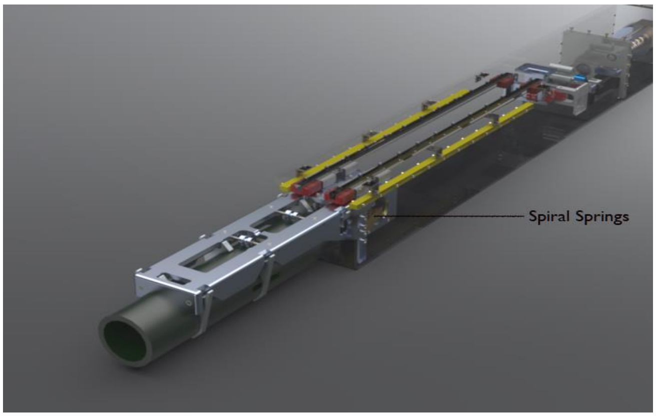
Constraints	Value
Cruise Speed of Air Vehicle	0.8 Mach
Operation Distance from Aircraft	60 m – 180 m
Deployment Velocity	5 m/s
Deployment Time (Max)	10 sec
Cable Diameter	4 mm
Outer Dimension of Mechanism	150 x 150 x 1700 mm
Dimensions of Decoy	100 x 500 mm

Thus, the main purpose of this project is to design, analyze and manufacture a deployment and retrieval mechanism, which can meet the desired requirements along with the maintenance and reliability requirements also adaptable to the working conditions and standards of the military systems.

Design

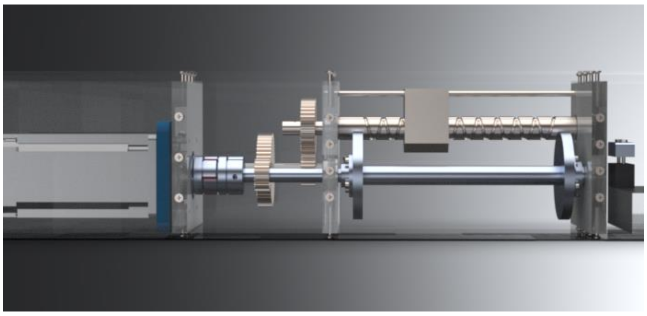
In order to solve the problem that is defined in previous section, following system is designed. Whole system consists of three sub-mechanisms which are deployment and retrieval mechanism, winding mechanism and cutting mechanism.

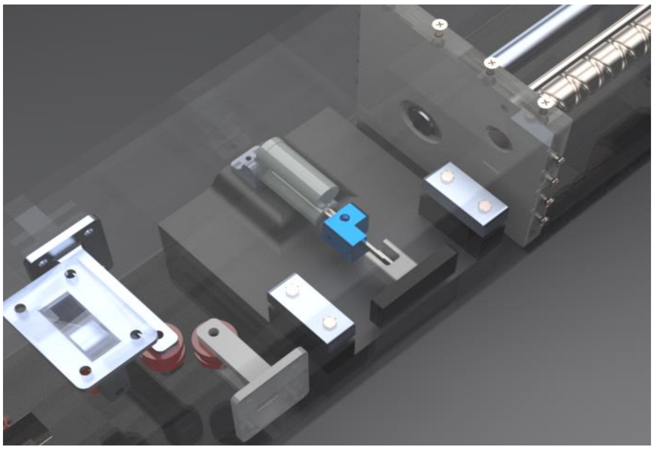




Deployment phase will be executed by the energy stored in stiff spiral springs. When springs are released, decoy will be thrown from the mechanism and located in the predetermined distance from the aircraft. During deployment phase, main motor of the system will release 180 meter of cable in 10 seconds with 2500 rpm speed.

Winding mechanism (a router shuttles along a self-reversing screw) is necessary for both successful deployment and successful retrieval. It basically provides uniform wrapping of cable around spool to use decoy attached to cable again.





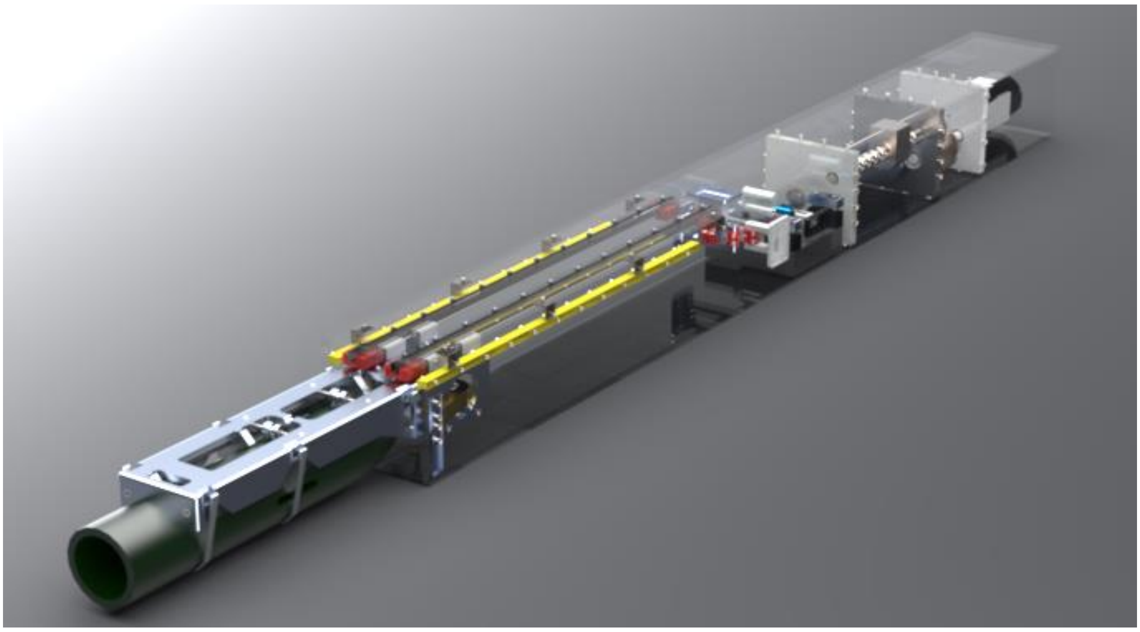
Cutting mechanism is required to be used in case of emergency such as decoy is hit by missile. Motion of this mechanism is actualized by linear actuator and its controller Arduino.

DISCOVERY

Outputs

Results:

- Winding mechanism winds the cable firmly and several usage of the sysytem in one flight is possible due to that.
- All virtually fictionalized systems proved to be working even the prototypes and test mechanism.
- Cutting mechanism cuts the cable in one attempt without any complications.
- Constant force springs' set up is done by tension of the cable
- Clamps can catch the decoy smoothly and preserve its position during denployment and retrieval
- For the control of the mechanism sensors are placed according to the needs and safety of the system is increased



Outcomes:

This project has been done in several steps stated as follows:

- Literature search for the similar system and sub-mechanisms.
- Analytical thinking
- Engineering analysis
- Calculations of necessary deployment motor speed and required initial force to apply decoy.
- Kinematic and dynamic analysis of system in ADAMS simulation program.
- CAD drawings in Solidworks
- COMSOL and ADAMS analysis
- Manufacturing processes
- Test and improvements on mechanism

This Project is Supported by Tübitak 2209-B Industrial Senior Year Project Support Program

PRENCH (D2)

Design of a Door Assistance System for Armored Vehicles

Academic Supervisors: Asst. Prof. Yegân Erdem

Dr. Şakir Baytaroğlu

Industrial Supervisor: Yasin Kabasakaloğlu

- ABSTRACT-

The aim of the project is to design, analyze and manufacture a door assistance system to ease the difficulty of operating an armored vehicle door under varying conditions. A controlled pneumatic system is designed and implemented which provides necessary force to assist the vehicle personnel. Depending upon the maximum force needed, the pneumatic system responds with the sufficient force output. The system is manufactured and tested in Nurol Makina's facilities. During the final design stage, several constraints were taken into account such as the cost, manufacturability, safety and reliability of the system.

Problem Definition

Due to the nature of the armored military vehicles, the raw material (armored steel) used to make the door, has a weight of approximately 110-120 kg. The basic concern is according to military standards and company requirements, designing opening and closing system for armored doors. Heavy doors because of the safety reasons cannot be controlled solely by human strength, for this reason a system is required that makes it easier to open and close.

Figure 1. Armored vehicle door

In hard terrain conditions such as inclined paths, rugged terrain opening and closing doors becomes harder as compared to normal conditions. Armored doors are already too heavy, when it is used in inclination; the door needs to be opened against gravity, which means more force is required in this case to open the door as compared to no inclination at all.

In our designs, weight of the doors is estimated to be around 120 kg each and required force to open these doors are determined at least 400 N at previous process.

According to our mathematical model and calculations, required force can go up to 600 N of force is required to open doors with door assisting system. However, the maximum horizontal force that one can exert to push or pull while in seating position is limited. Alongside with this, armored vehicle's doors are planned to be opened on inclinations up to 30°, in such cases the force to be applied will decrease because of the ergonomic limitations.

Nurol Makina's expectations are listed as following:

- Height of the door: 1120 mm, width: 800 mm, thickness: 10 mm
- In order to provide assistance for opening the door, necessary force should be provided.
- Safety is the most important requirement for military vehicles. In order to avoid injuries, the system should be resistant to failure.
- Production of the project is provided by Nurol Makina with local facilities.
- Maximum weight of the door should be 120 kg

Figure 2. Armored vehicle on an inclined path

Design

Considering the defined problem and given requirements above, a solution is produced. Design consists of one pneumatic actuator to provide linear force to the door, compressor to gather pressurized air, one tank to provide the air to the compressor, button to control the system and pipes and wires to connect components to each other. Pneumatic actuator is fixed to both the hinge which is a part of the vehicle, and to the door as seen in figure 2. Design process can be summarized as the following:

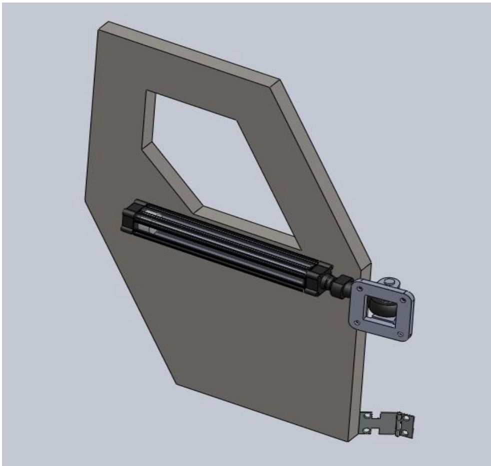


Figure 3. SOLIDWORKS drawing of the door and the actuator

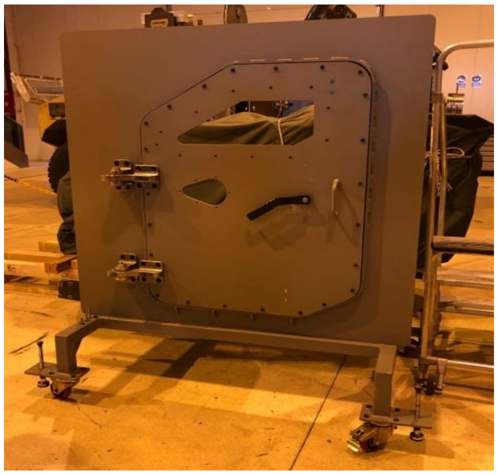


Figure 4. Manufactured door

An example case explaining how the system works is described: Personnel inside the vehicle decide to open the door. He pushes the assigned button to activate the assistance system. With the signal coming from the microcontroller, electronic valves between the tank and the piston opens letting air fill the desired segment of the piston. At this moment, personnel may push the door by applying the average force that he can apply under the given conditions, although the system can operate without the need of an additional force. Rod inside the cylinder extends towards the door. Since the door and the end of the rod are connected, rod starts to rotate the door around the hinges. A similar path is followed when the user tries to close the door by pushing a different button.

Figure 5. Parker pneumatic actuator

Figure 6. ARB compressor

Outputs

Results:

- ✓ Door assistance system for an armored vehicle is manufactured locally.
- ✓ All components, connectors and electronic controller are checked and proved to be working under desired working conditions.
- ✓ System satisfied defined constraints and given requirements.
- ✓ Door can be operated without the support of a human however, user can apply additional force to shorten the time that the door takes to open or close.

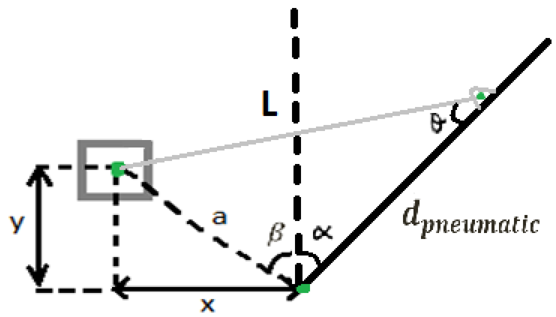


Figure 7. Top view when the door is open by **α** °

Design limitations allow the maximum amount that the door can be opened to be 80°. By using geometric equations, stroke length (L), distance between the hinge and the fixed end of the pneumatic actuator (x,y) are determined.

Outcomes:

This project procedure consisted of several steps. Each step required engineering calculations. Mathematical calculations are used to determine reqired paramteres to choose the appropriate pneumatic actuator. Simulation and analysis of the hinges and connectors were carried to prove our reliable design.

Alternative designs are made and the optimum one is selected as the final design
Tests on the prototype and the final product are conducted and by using the results, design is iteratively upgraded.

This project is supported by TUBITAK 2209-B Industrial Senior Year Project Support Program

LAST ROMANCE (D3)

Design and Manufacturing of an Adaptive Tesla Turbine

Academic Supervisor: Asst. Prof. Barbaros Çetin

Industrial Supervisor: Nebahat Karasu Atabey

- ABSTRACT-

The purpose of this project is to create, analyze and manufacture a mechanism to increase the efficiency of a Tesla turbine to get the desired work output for different inlet conditions. The selected solution for that problem is the adaptive plate spacing design concept which aims change in inter disk spacing of a Tesla turbine according to the inlet fluid properties and obtain higher efficiency. Engineering analysis, literature survey, design activities, manufacturing and testing was made in the progress. According to the requirements, results of simulation and experimental results, a Tesla turbine having a new feature, adaptiveness, was designed and produced.

Problem Definition

Tesla turbine is a design which consists of parallel discs attached to a shaft and located inside a casing as can be seen in the figures 1-2 below.

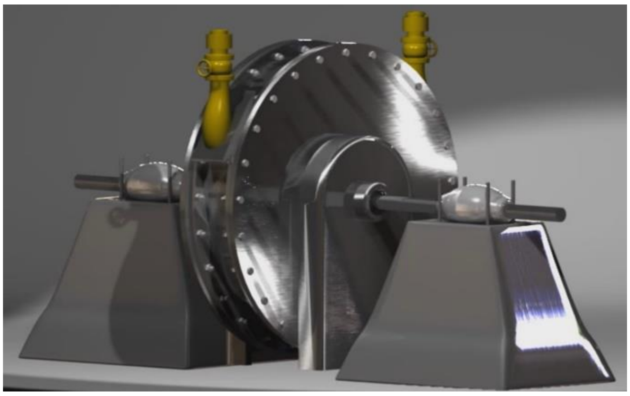


Figure 1. Tesla Turbine

When a pressurized fluid is given into the system, the discs starts to rotate making the shaft rotate and enables it to produce electricity with this rotational motion.

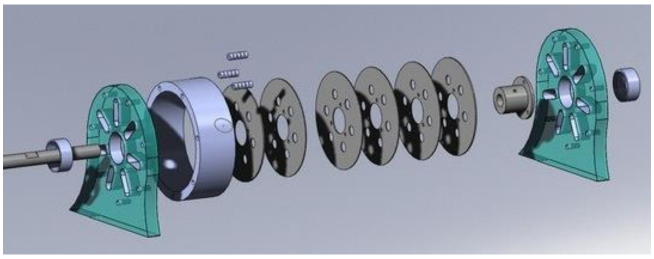


Figure 2. Disassemblied view of the Tesla Turbine

Tesla turbine is an alternative to existing turbo machineries used for power production with lower cost, higher safety and ability to work with wide range of fluids (both with gases and liquids). Despite these advantages, Tesla turbine is not widely used in the industry for electricity production because of its low efficiency.

The objective of this project is to increase its efficiency and make it find itself a place in the industry by manufacturing a Tesla Turbine whose spaces between disks can be arranged to the desired value via using an actuator. Tesla Turbine can be utilized in order to produce electricity from various working fluids. The working fluids include steam, air, 2-phase mixtures and so on. Although turbines are being used in industry widely for the purpose of producing power, Tesla Turbine is not reached an enclosure in industry. However, if the efficiency of Tesla turbine is enhanced, due to various advantages of it such as low cost, low maintenance, and simplicity in terms of production, it can be replaced with steam/gas turbines in industry. Tesla Turbine does not contain blades unlike axial/centrifugal turbines. Instead, in Tesla turbine there exists a series of closely packed connected to a shaft that are arranged within a sealed chamber. As the fluid enters the chamber of Tesla turbine and travels between disks, the fluid motion provides rotation to disks due to exchange of momentum between working fluid and disks. The output rotation performance is directly related to the inlet fluid properties and the layers created by the fluid between the discs. So, a solution including the control of these layers were considered.

Last Romance

Design

For the desired aim given in the previous page, some solutions were proposed and an adaptive disk spacing idea was selected as the concept. The power output and efficiency of a Tesla turbine depends on the properties of fluid coming inside the turbine. As viscous and frictional forces provide the discs to rotate, the area between the discs which air is flowing should consist the layer which the effect of these forces are higher. For each different characteristic (like pressure, flow rate, viscosity) of the inlet fluid, this layer thickness is different. So, it is decided to arrange the spacing between discs according to the properties of the given fluid. With such a solution, the turbine will give the highest efficiency results for each different inlet fluid properties.

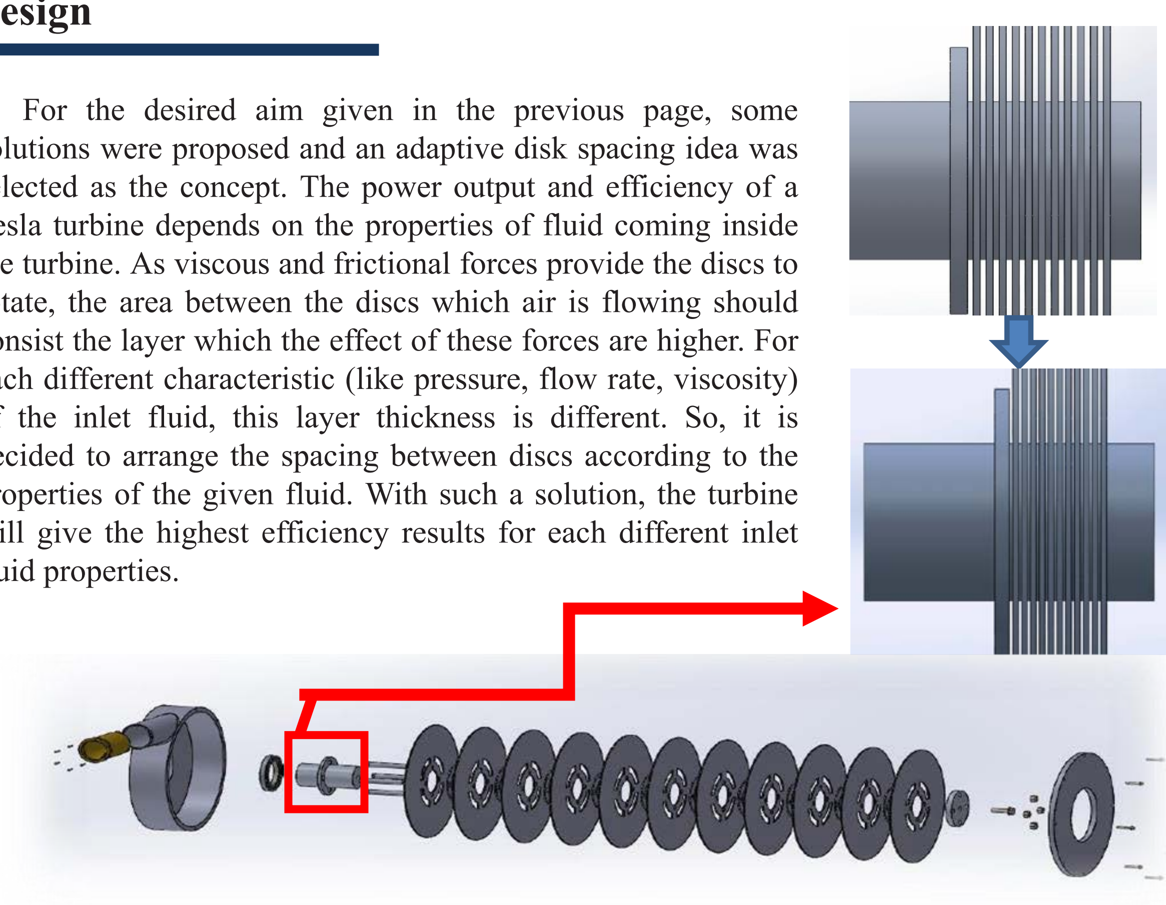


Figure 3. Adaptivity of the Inter Disc Spacings

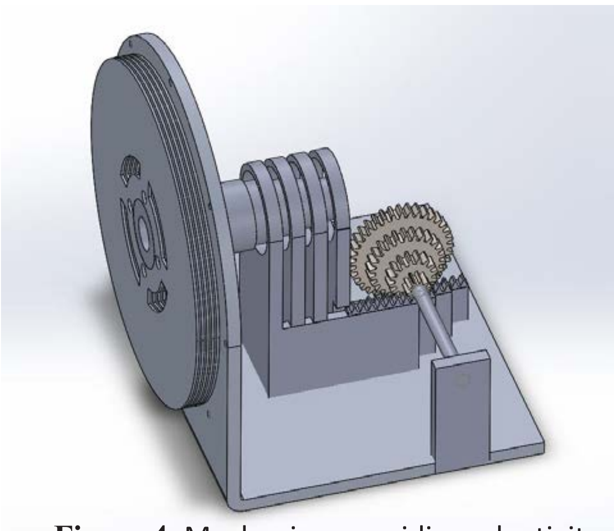
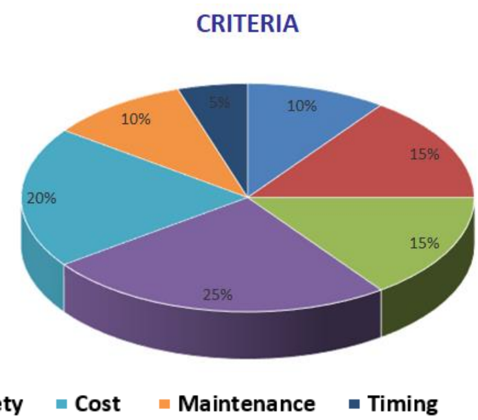


Figure 4. Mechanism providing adaptivity

This solution leaded us to another decision process: the shaft mechanism providing this adaptiveness. The mechanism should be able to move the discs axially and change the spacing between discs in a way that each spacing will be equal. For that purpose, a mechanism which works with rack and pinion systems was designed. The mechanism is given in figure 4. There exists a gear for each disc and these gears holds the cylinders of each disc.

The cylinders form a telescopic shaft which makes the discs able to move axially when the rotor of the gear system is turned with a servo motor. The criteria considered for the design process is given below.



Last Romance

Outputs

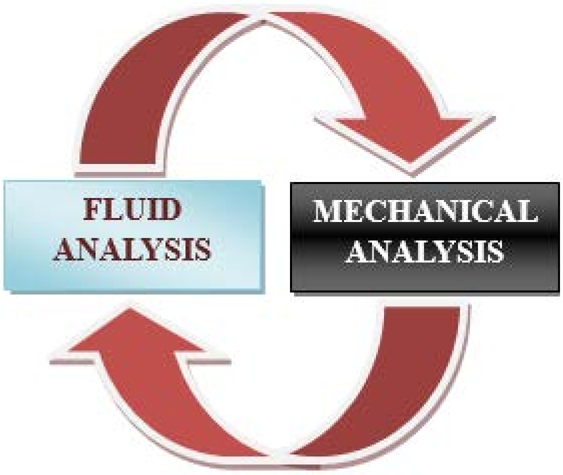
Results:

- ✓ This project shows that any fluid having more pressure than the atmospheric pressure enables us to produce power, adding an alternative of gaining electricity to the areas where there exist nothing but a pressurized fluid. Therefore, it can be considered as an emergency power source to be used in military vehicles.
- ✓ The output rotational speed values are around 8000 rpm which is suitable for the applications where high rotational speed is needed.
- ✓ By adapting the disc spacing according to the inlet fluid enables this design to work efficiently in many different conditions which makes the design compatible and preferable by a wide range of applications.

Outcomes:

The project procedure was held in many different sides along its process. The steps and development required fluid dynamics knowledge and analyses besides mechanical knowledge and calculations. These steps are:

- Literature Search
- Analytical Thinking
- Building CFD (Computational Fluid Dynamics) Models on ANSYS and COMSOL
- Controlling the Reliability of the CFD Models with Analytical Fluid Dynamics Calculations
- Making CFD Analysis for the Design Process
- Designing the Mechanism
- Technical Drawings with CAD Program
- COMSOL Analysis on the Design
- Mechatronic Systems and Control Setup
- Manufacturing
- Test Mechanisms



This project was financially supported by TUBITAK 2209-B Support Program.

Academic Advisor: Ömer Anlağan
Industrial Supervisor: Oğuzhan Ergün
Teaching Assistant: Tamer Taşkıran

ABSTRACT

TBM (Tunnel Boring Machine) Cutter Disc replacement operation is one of the basic elements of TBM maintenance. Current solutions do not offer high time efficiency and also involves dangers for human health. The aim of our project is to design a semi-automatic system, situated outside the excavation chamber of the TBM which can change the twin disc cutter with a much better time. Different mechanisms were considered when implementing our final design, with reiterations taking place at each step of the project phase, as testing was performed on the prototype.

Problem Definition

One of the main activities concerning the maintenance of TBM'S is related to the wear of the tools on the cutter head. Like the cutter of a turning machine, the wear life of these cutter discs depends on the material that is being excavated. However, replacing worn cutter discs is a difficult task as the replacement is performed in the muddy and confined excavation chamber. An example of a Tunnel Boring Machine (TBM)

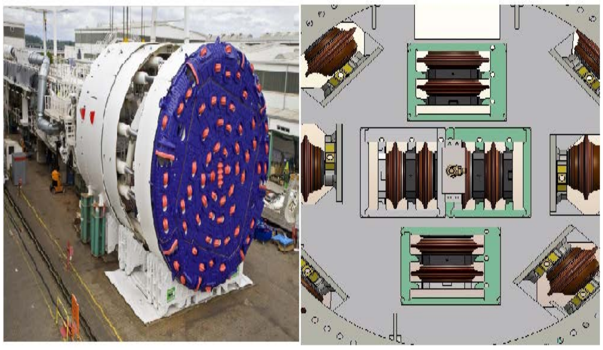


Figure 1 Tunnel Boring Machine

is shown in **Figure 1**.

Moreover, the disc cutters are heavy and take between 45 to 60 minutes to change. Operations concerning the changing of disc cutters include using pneumatic screw drivers to unscrew the cutters, cleaning the region of the disc cutter holder and putting in a new cutter disk. This procedure takes too much time and leads to increase in the cost of tunneling. Hence, the aim of this project is to design a semi-automatic system in order to change the twin disc cutters within 30 minutes. In this project, we will mainly focus on carrying out our idea on TBMs produced by E-Berk. It is important to note that our sole focus will be on changing twin disc cutters which are placed near the center of the cutter head.

Table.1 shows the requirements and constraint that would be imposed on our final design choice. These requirements are as per E-Berk's standards in an actual TBM but have been scaled down to work for a miniature prototype which will be built in this project.

Operational Constraints	Lifting twin disc cutters: 50 Kg Opening Bolts: 10 Nm Torque Time < 30 min Size Constraints: Length < 40 cm Width < 30 cm
Material Constraints	Localization
Safety	Retractable System Control System
Manufacturability	Use of E-BERK'S or local facilities
Economic Constraints	₺10.000,00
Ergonomic and Aesthetic Constraints	User-Friendly Controller

Table 1 Requirements and Constraints

Design

For the aforementioned problem, a final design was made to solve the problems, within the constraints given. The design consists of a I-Beam profile retractable rail with an attached crane system, along which a linear rail is attached, linking to a linear positioner. The linear rail is attached to a car part which will be responsible in changing the twin-disc cutter in the TBM.The retractable I-Beam rail system is used to propel the system in the y-direction whereas the linear rails help in stabilizing the motion in the z-direction via the crane. Linear positioner is attached to the end of the linear rail which helps in determining in x-direction of the system with respect to the position of the twin disc-cutters. The final design is displayed in **Figure 2**. The car part is attached to the linear positioner via a shaft in shaft mechanism for stability. Motors are attached in the car part which are attached to both the drills, as well as a four-bar gripper mechanism which will help in removing and applying a new twin-disc cutter to the housing of the TBM during maintenance. Car part components are shown in **Figure 3** with each labelled equipment used.

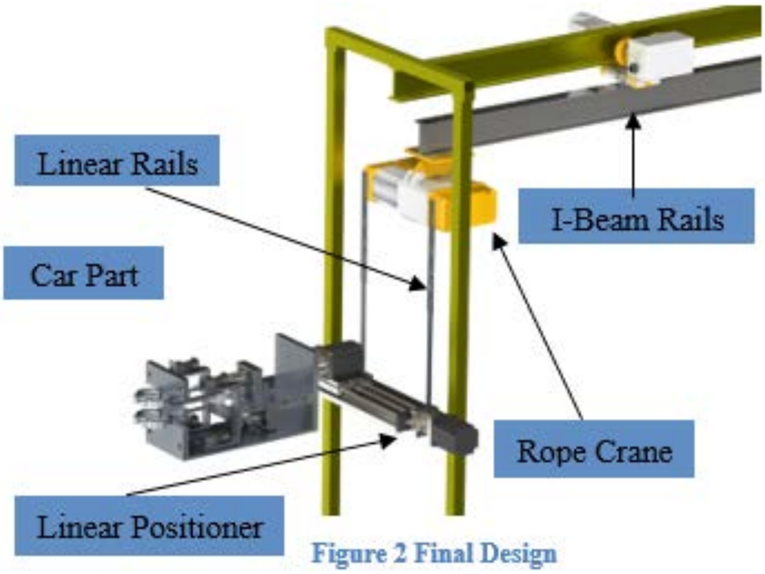


Figure 2 Final Design

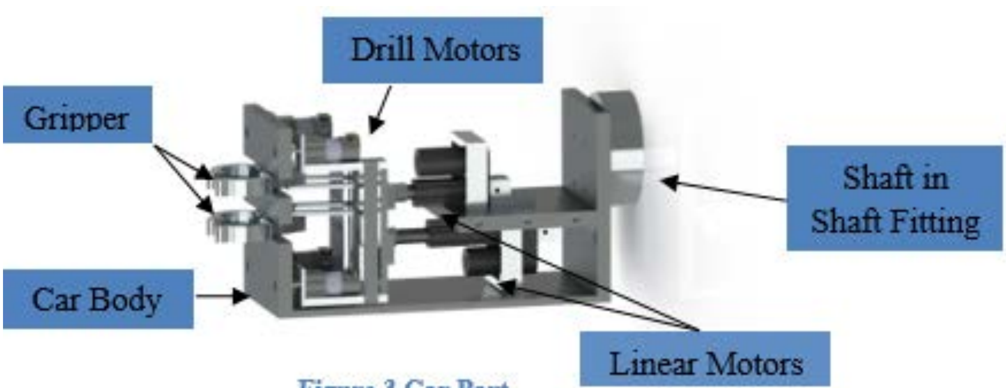


Figure 3 Car Part

Outputs

Results

- Main purpose of this project is to reduce the time required to change the twin disc cutters that were previously being changed manually in E-Berk. This project proved to reduce the amount of time used.
- Furthermore, it also reduced the safety hazard to which the labor, changing the twin disc cutter, was exposed to since now it's a semi-automated system which is controlled by a person from outside of the excavation chamber. The whole system is produced using local resources without any parts being imported which means it can easily be produced.
- Changing the twin disc cutters manually took 45 minutes to an hour which is reduced to approximately 30 minutes.
- All the tests performed on the system passed and theoretical analysis proved to be correct.
- All the constraints and requirements were satisfied by the system.

Outcomes

This project was completed in several steps which are listed in figure 4:

- Literature search regarding all the possible solutions that exist.
- Analytical thinking about the solution.
- Engineering analysis
- Calculating the weight that the system needs to support.
- Determining the force required to tighten the screws in the housing of the twin disc cutters.
- Determining the limited space available for the system to function.
- Coming up with possible solutions to choose the best one from.
- Designing the system on SolidWorks.
- Analysis on ANSYS
- Checking if the components like shaft can tolerate the weight being supported by it.
- Manufacturing process and ordering components.
- Test mechanisms and procedures
- Verifying if the speed of the system satisfies our needs.
- Improving the design based on the results of the tests.

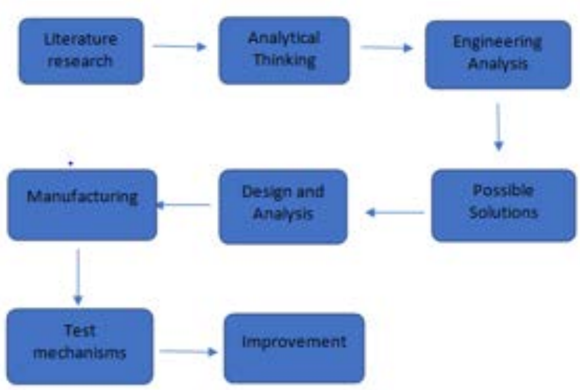


Figure 4 Outcomes