BILKENT UNIVERSITY

DEPARTMENT OF MECHANICAL ENGINEERING

INDUSTRIAL DESIGN PROJECTS

2020 – 2021

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Content

PREFACE

University-industry collaborations provide future engineers with a broad understanding of industry and business practices. Such collaborations also provide a platform for students to demonstrate creative design solutions to important problems faced by industry. We provide this learning opportunity during a two-semester design activity for the senior-level students. This year, 13 groups, each consisting of five to six students, were provided with design projects from leading industrial organizations. Projects were selected such that students could leverage their undergraduate studies to design a product needed in today's world. Projects also aimed to bring out the students' creativity in both the design phase, which is completed in the first semester, and the manufacturing phase normally completed in the second semester. At their final presentation sessions, the students are provided with a unique opportunity to present detailed design specifications of their products and the manufactured prototypes.

Because of the exceptional circumstances due to COVID19, our students, instructors and industry advisors had to adapt to the new online communications for meetings, discussions, and delivery of outcomes, and this they have done very well. Our website, online 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 in these trying times.

Adnan Akay
Professor and Chair
Mechanical Engineering Department
Bilkent University

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BILKENT UNIVERSITY

PROJECTS

MECHANICAL ENGINEERING

Mechanical Design of a Roll-Pitch Gimbal and Solving the Zenith-Pass Problem

TracKing (1)

Academic Advisor : Prof. Dr. Sami Turgut Tümer
Industrial Advisor : Anıl Erdem Derinöz
Serter Yılmaz
Teaching Assistant : Damla Leblebicioğlu

ABSTRACT

The aim of this project is to design a roll-pitch gimbal system and to solve the Zenith-Pass Problem which is a problem that interrupts the tracking process of any two-axis gimbal. Gimbal systems are part of stabilizing and target tracking systems called Inertially Stabilized Platforms (ISP) commonly used for military and commercial applications to carry out missile guidance and target-tracking. Although there are various gimbal types available in the market roll-pitch gimbal stands out with characteristics of large field angle together with having a small and compact design. Since missile applications require compactness, the project aims to develop a roll-pitch gimbal design which has weight under 1800 grams and length under 200 mm together with other constraints of interface, functional and performance. To be able to design a roll-pitch gimbal system which works without discontinuity, proposing a solution to the Zenith-Pass problem is crucial. The proposed solution of the project is to find a novel algorithm in the control system which works for both Zenith-Pass cases and normal cases to eliminate any possibility of losing the target when the missile enters the Zenith area.

Problem Definition

Stabilization in target tracking plays a crucial part for military applications since missions generally require clear vision of the sight. Occurrence of external disturbances are primary sources that affect image-stabilization. For this reason, the effect of disturbances should be eliminated to achieve a stabilized system. To carry out this, Inertially Stabilized Platforms (ISP) are used. A significant part of these systems are based on gimbals, a mechanical device that uses various mechanical and electrical components to control the inertial orientation of the payload.

The basic working principle of a roll-pitch gimbal include identification of the applied forces and torques through various sensors and create counter torques to keep the system stabilized. To achieve this, line of sight (LOS) vector is controlled effectively.

Figure 1: Gimbals on missiles [1].

Two or more axis gimbals are commonly used to stabilize the missile structure. While three-axis gimbals are not favoured because of their bulk design and heavy weight, roll-pitch gimbals stand out with features of large field angle and compact design in two-axis gimbals. For the reasons described, using roll-pitch gimbals for missile applications is favorable.

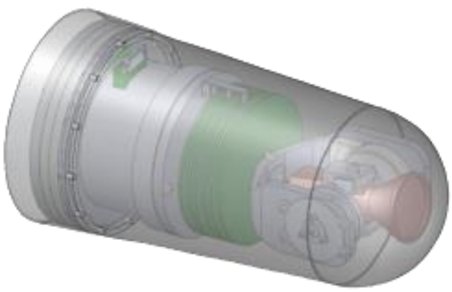


Figure 2: The Roll-Pitch Gimbal

One drawback of this gimbal type is the problem of losing the target when it enters a specific area called the Zenith Area. When the target is aligned with the pitch axis of the gimbal, the roll angular velocity is required to be infinite in order to maintain the tracking of the target which is physically impossible to attain. To solve this mathematical anomality, hardware settings of the gimbal can be adjusted accordingly but this leads to larger area being occupied by the gimbal which exceeds the physical limitations of the system. The other solution is to implement a control algorithm to avoid entering the Zenith area.

In terms of functioning, the system needs to operate with virtual target tracking error of 0.7 ° at most with total angle of view (FOR) being least ± 40 degrees. The system must also have compact design with light weight. The physical and functional constraints of the design are defined by ROKETSAN.

The solution product will be subjected to MIL-STD-810 G standard. This standard is the US Army, Air Force and Navy, and the Institute of Environmental Science and Technology (IEST) which is used to test the durability of the design in the varying environmental conditions.

[1H. Jiang, H. Jia and Q. Wei, "Analysis of zenith pass problem and tracking strategy design for roll–pitch seeker", Aerospace Science and Technology, vol. 23, no. 1, pp. 345-351, 2012. Available: 10.1016/j.ast.2011.08.011 [Accessed 22 October 2020].

Design

Figure 3 : 3D Model of the System

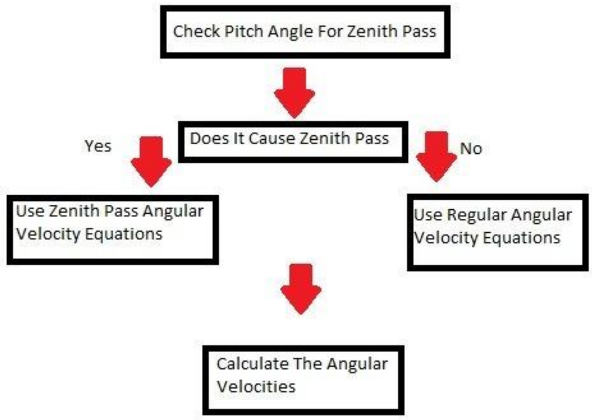


Figure 4 : The Scheme for the Control Structure

The hardware design of the system is composed of roll assembly and pitch assembly. The pitch assembly consists of two large arms with symmetric structure which was intended for the ease of dynamic calculations. Both of the assemblies consists of many sub-components such as optical encoders and gyroscopes. When components are selected, compatibility with the overall structure, satisfaction of the constraints and manufacturability of the overall system was considered.

The control algorithm of the solution is designed such that it will imply different scenarios depending on whether the target is in the Zenith area or not. The novel algorithm works on two levels. The calculated angular velocities, angles, sign of angles, angle changes and tracking errors are sent to the control system in order to simulate our design. When the target is not in the Zenith area, regular equations are used to control the system.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at control systems, dynamics and mechatronics courses. It is done in several steps through the 2020-2021 academic year given as below:

- Literature research
- Determination of the structure of the design considering constraints given by ROKETSAN
- CAD drawings
- Engineering analysis including:
    - -Mathematical modeling
    - -Construction of Zenith-Pass algorithm
    - -Control system construction and analysis
    - -Structural analysis
- Safety Analysis
- Design Verification
- Planning the Manufacturing

Mounting Robot with Height Adjustment

CAGE (2)

Academic Advisor : Asst. Prof. Dr. Onur Özcan
Industrial Advisor : Murat Çetin
Ömer Faruk Yalım
Ebru Bağlan

Teaching Assistant : Ayten Gülce Bayram

ABSTRACT

The aim of this project is to design a system that can reach certain heights on a platform that contains units for the storage of electromechanical parts, disassemble the unit from the platform and parts of the unit from the whole and bring the parts to the ground, and vice versa. The electromechanical part storage as done in ASELSAN is a complex task, since the storage units are heavy, they are contained in cells at different heights, and their configuration demands a certain mounting/ demounting process. The task is time consuming, inefficient, and hazardous when done manually, because the mounting/ demounting process has to be done at the cell height, which can reach 4.5m above the ground. For this reason, a height-adjustable automated system is designed. The design incorporates scissor links for vertical direction and manual stoppers for lateral direction, together with two gripping-screwing subsystems that are connected on a rotating table. The two gripping-screwing subsystems are similar, but specialized for the surface of the part of the storage unit they are designed to carry. The rotating table is incorporated into the design so the whole task of taking (or putting in) a storage unit can be done in only one cycle without collision with the storage platform.

Problem Definition

In industrial usage of machines, the storage of parts of machines is an important issue. Parts that are manufactured need to be stored before their assembly at the field or in case they are needed for replacement and maintenance. For this reason, ASELSAN uses large platforms that can reach 4.5 meters high, and storage units that resemble drawers. Each storage unit weighs around 30 kilograms in total, and is composed of three parts of similar weights that are assembled together. These units are in turn assembled to the platform itself. Inside the units there are important electromechanical parts for radar systems that are used in the defence industry.

The problem associated with this project is that the operation of putting a part in storage or taking a part from a storage unit is complicated, since it requires the completion of a series of subtasks like reaching the height of the cell in the platform where the unit is supposed to be mounted/ dismounted and performing assembly or disassembly procedures on the parts of the unit in the required order.

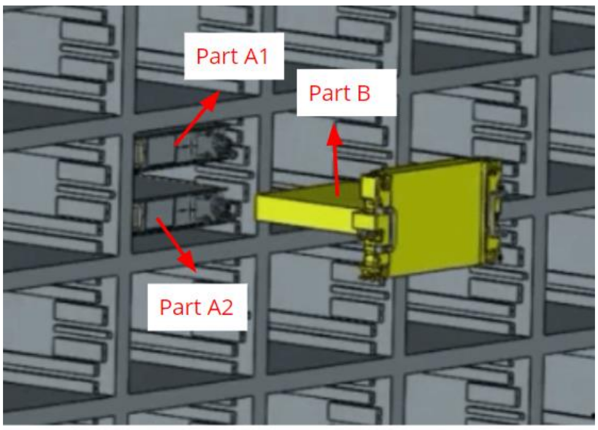


Figure 1: Parts of Storage Unit

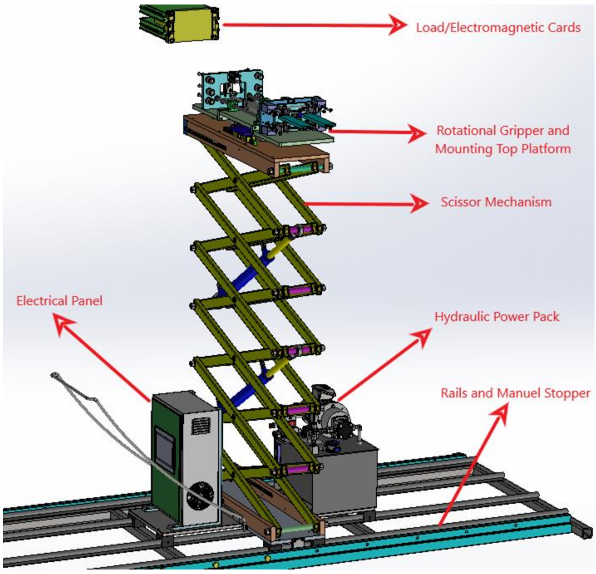


Figure 2: CAD Model of the System

The current solution of ASELSAN is to let two workers use ladders while carrying the units together with equipment for mounting/ demounting. This solution requires a large amount of time and effort, requires more than one personnel in attendance, and is hazardous, since there are large weights combined with dangerous heights and complicated mounting/ demounting procedures. To remove the human personnel from the operation and reduce the time, effort and the risk, this project aimed to design a mounting/ demounting robot with height adjustment.

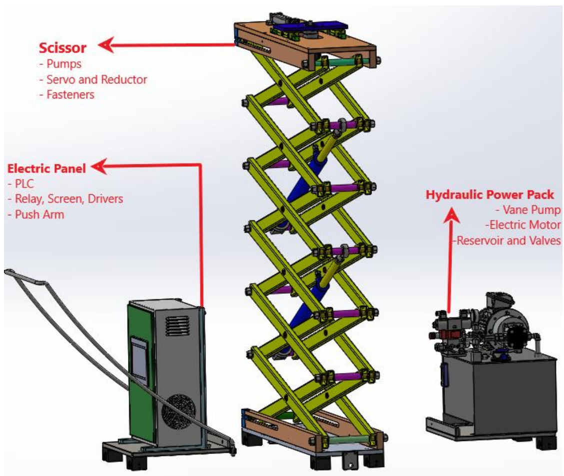


Figure 3 : 3D Model of the Scissor Subsystem

Design

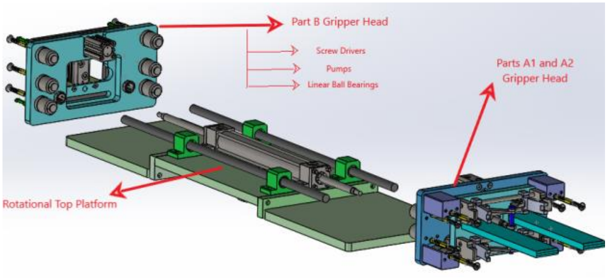


Figure 4 : CAD Model of the Rotating Top Subsystem

The selected design for this project can be described as a scissor-link based height adjustable rotating table combined with gripping-screwing heads. The system has three subsystems: Alignment subsystem concerned with both the lateral movement of the system for aligning with the designated column of the platform and the vertical movement for reaching the designated cell (Fig. 3); rotating top platform concerned with the task of taking all parts of the storage unit in one cycle (Fig. 4); and mounting/ demounting subsystems for gripping and assembly or disassembly tasks for handling parts of the unit.

The lateral alignment is done manually, but the vertical alignment is automated and is done via scissor links. The rotating top platform was incorporated into the system to ensure all parts of the storage unit can be mounted or dismounted at the cell height without going back to the starting position, ie. the task is completed in one cycle; and it rotates the gripping-screwing subsystem so the right head specially designed for the right particular part can work. Since the surfaces and weights of the two kinds of parts of the storage unit are different, the gripping-screwing heads are designed differently. For part B of the storage unit, gripper tips that utilize the holes on the surface of the part is combined with screwing mechanisms that mount or dismount the part form parts A1 and A2. For parts A1 and A2, hard grippers that hold the manual holders on the surfaces, they are mounted/ dismounted from the cell and both parts are taken to the system simultaneously (Fig. 4). The system is powered by an hydraulic power pack and controlled via an electrical panel, both connected to the system to ensure compactness.

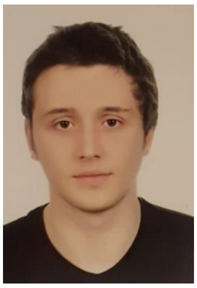
Outcomes

This project is a mechanical design project in which knowledge acquired at dynamics, mechatronics and manufacturing courses are combined and used. The project is done in 2020-2021 academic year by following steps given below:

- Literature Research
- Determination of sub-systems as gripping, screwing and height adjustment.
- Engineering Analysis
  - Mathematical Modeling
  - Hydraulic Pump Selections
  - Kinematic Analysis
- CAD Drawings
- Planning for manufacturing processes, assembly, verification and testing
  - Fastener Analysis
  - Vibration Analysis
  - Kinematic and Static Analysis
  - Vibration Analysis
  - Safety Analysis

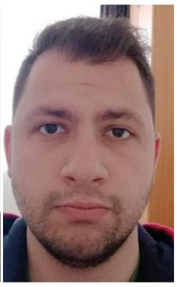
A Creative Design to Discharge the Gas

MEterans (3)



Atakan Karasan

Burak Canyurt



Doğubey Gönül

Hakan Malkoç

Mert Özbayer

Tuğçe Tuğrul

Academic Advisor : Prof. Dr. Ömer Aka Anlağan
Industrial Advisor : Şehmuz Ali Subay
Teaching Assistant : Alper Topuz

ABSTRACT

The aim of this project is to design a creative gas discharge system of a hermetically sealed reciprocating compressor and improving the mechanical and thermo-fluidic properties of the previous design of Arçelik A.Ş. The new design is such a structure where pressure and heat distributions are homogeneous throughout the geometry so that the compressor can withstand at least ten years of operation time because of the warranty regulations and no maintenance nature of the compressor itself. The solution product has been accomplished is capable of enduring the most extreme conditions of 30 bars of pressure, 100°C of temperature and 4500 rpm of piston speed in virtue of detailed engineering analyses in the scope of high performance test, high temperature test, strength and life test, transportation test by using SolidWorks, ANSYS and MATLAB Simulink. All of these tests are highly crucial for the evaluation of the design verification in hand as the last step before the manufacturing phase. In the light of these evaluations, it has been proven and demonstrated how the design is thoroughly qualified and applicable in terms of manufacturing since it was impossible for the ARÇELİK A.Ş. to manufacture the prototype of the new design that has been created due to COVID-19 crisis.

Problem Definition

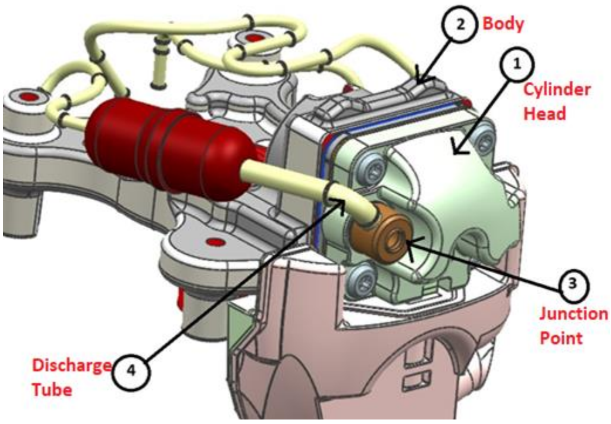


Figure 1: An inside look at components of the previous compressor design

The issue with the compressor's present plan is that the gas chamber (1), compressor body (2) and exhaust terminal (3) are appended to one another by screws that cause outrageous deformations to the compressor body and the gas chamber because of the unbalanced force created by the screws. There are four screws each edge of the chamber head that mount the gas chamber, compressor body and exhaust terminal to one another in the current design of the compressor (see Figure 1). They are fixed by adding 9 [N.m] force at the sides of the chamber head to each screw. The issue with the new design, nonetheless, is that the discharge tube goes through the head of the cylinder to transfer R600 gas into the gas chamber. This association of the discharge tube to the cylinder head is actuated by a fifth unbalanced screw on the chamber head, which is likewise joined to the chamber block. Subsequently, the fifth awry screw that is evenly fixed by 4 bolts on the cylinder head makes uneven force distribution on the head of the cylinder. On the left side of the imaginary y axis, three bolts are tightened, moving from the center of the horizontal length of the cylinder head, while 2 bolts tighten the right side of the imaginary y-axis. Although the torque applied to the fifth asymmetric bolt is decreased by Arçelik engineers up to 7.9 [N.m] to decrease the distribution of asymmetric torque, the issues remain the same. The fifth screw which is pointed as (3) in Figure 1, tightened to the left, induces undistributed deformation, contributing to deformation of the cylinder block where the piston bearings operate.

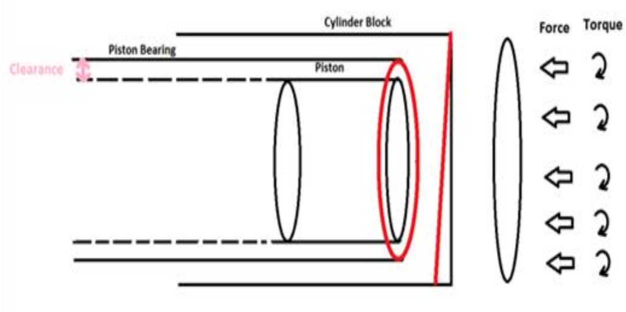


Figure 2: Cross-sectional Representation of Cylinder Body

Torque applied to bolts on the cylinder head acts as a stress on the cylinder body. The right-hand side of the body has two forces, while the left-hand side has three, resulting in an unbalanced force distribution on the cylinder block. Because of the deformation in the cylinder block, piston bearings are subjected to deformation. Despite the fact that micron-scale deformations occur, the components mentioned above are high-precision components that are critical to the safety and sustainability of coolants. Since compressors must be capable of supporting domestic appliances for at least ten years, such deformation negatively impacts the product's warranty [1].

[1]-TR-7293520195-201807201254284-User-Manual---File-Longtr-TR.pdf [Online].Available:http://-TR-7293520195-201807201254284-User-Manual---File-Longtr-TR.pdf. [Accessed:17-Oct-2020].

Design

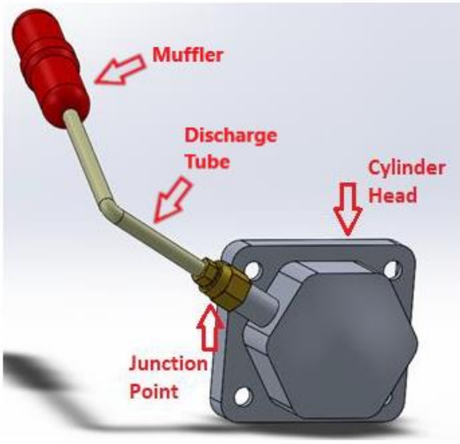


Figure 3 : 3D Inner View Model of the System

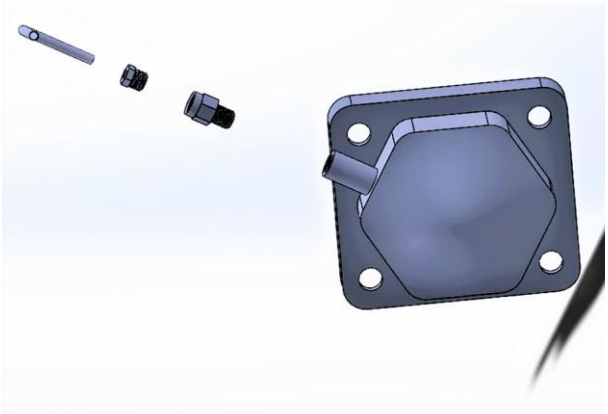


Figure 4 : Components of the Assembly

This design by feature is created to be the most compact and durable among all the concepts that has been suggested for the final solution. Within this design, hexagonal dome-like geometry has been implemented in order to distribute stress accumulation homogeneously originated from working pressure of refrigerant gas. Also an additional tube-like part has been created and at the inside walls where internal threads have been cut so that the discharge tube could be fastened to create a healthy connection point between the cylinder head and discharge tube where minimum leakage is pursued for the safety and efficiency purposes. Gas discharge area should not intersect the screws, so design is made accordingly. For junction point, brass jack screws are used. Jack screws could withstand up to 30 bars pressure and easy to assemble. Internal jack screw has 4 mm inner diameter, 6 mm outer diameter with threading and 11 mm length. For external diameter, in order to assemble with discharge tube, it has 6.8 mm outer diameter with threading and to assemble with internal jack screw, it has 6 mm internal diameter with threading.

Outcomes

The system in hand is a mechanical design project which requires the mechanical engineering expertise attained via thermo-fluids, design & manufacturing, mechanics of materials and dynamics & control theory courses. It is completed in several stages through the 2020-2021 academic year as mentioned below:

- Literature research
- CAD drawings
- Engineering analysis including:
  - Detailed Steady-State Static Structural Analysis
  - Turbulent Fluid Flow Analysis
  - Detailed Steady-State Thermal Analysis
  - Modal & Harmonic Response Analysis
  - Random Vibration Analysis (3 DOF System Modelling)
  - Thread Engagement Length Calculation & Pressure Vessel Thickness Calculation for Screws
- Devising the manufacturing process, assembly and design verification in terms of High Performance Test, Strength and Life Test, High Temperature Test and Transportation Test.

Mechanical and Controller Design of a Drone for Missing Children

sQUADs (4)

Academic Advisor : Asst. Prof. Dr. Onur Özcan
Industrial Advisor : Burçak Özonuk
Teaching Assistant : Mustafa Uğur

ABSTRACT

The aim of this project is to design a drone that is able to locate a missing children during field trips. Children tend to be easily distracted and may wander away from their group. In such cases they may go unnoticed and end up somewhere that is out of the vision of their teachers and classmates. In such cases the first 30 minutes of the search and rescue operation is crucial since the required search area increases in a polynomial manner. These operations are conducted via manpower and sometimes fail due to insufficient manpower. The proposed solution is to design a drone with autonomous flight option, that can scan a designated search area while avoiding any obstacles it might come across to eliminate the need of manpower and increase the effectiveness of search and rescue operations.

Problem Definition

In the US 460.000 and in the United Kingdom 112.000 missing children's cases are reported almost every year in the last decade. In Turkey, this number is almost 120.000 for 2017 [1]. As seen from the statistics was and is a common problem (see figure 1). Since, attention span expectation for children that are under 6 years old is short, they are the first social group that comes to mind when the case is missing. Those children can only focus for 24 minutes at most and when they go missing, they will panic, and their walking profile will become unpredictable as time passes by after the first missing incident happens.

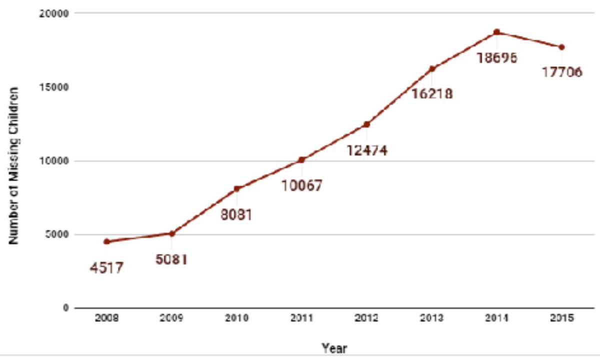


Figure 1:Number of missing children by year in Turkey

Therefore, the National Center for Missing Children suggests that the first 30 minutes are crucial to track the children and rescue them without any unfortunate events occurr. Especially for cases that involve larger areas such as forest etc., SAR operations become almost impossible to achieve with only manpower. In June of 2020 in Giresun, for a

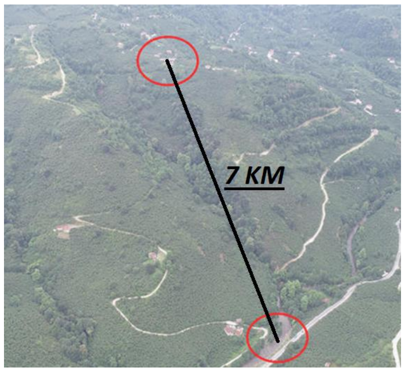


Figure 2: Child's distance from their last seen location in Giresun case

child that went missing; 50 law enforcement personals, 3 tracking dogs worked for 4 days and nights and were not successful on their mission and the kid’s dead body was found 7 km away (see Figure 2) from the last point she had seen [2]. In such cases it is obvious that a device that can scan large areas from the sky and move fast will ease the missing cases and will increase the ratio of success in SAR operations for law enforcement units. This project aims to develop a quadcopter in order to find missing children in rural environments half-autonomously at a user defined altitude and avoid obstacles autonomously when encountered. The operation of the product, as expected, needs some constraints due to technical and environmental factors. The drone, mass between 0.5-4 kg, should fly up to 15 minutes while covering 125 metered radius area with 7-8 m/s. Continuous data transmission must be obtained with a telemetry system having atleast 5 Mbps. An object avoidance system is integrated in case of any possible obstacles during flight period.

[1] Biruni.tuik.gov.tr, 2020. [Online].Available: https://biruni.tuik.gov.tr/medas/?kn=98&locale=tr
[2] "Kayıp İkranur her yerde aranıyor; JÖH'ler devreye girdi", Hurriyet.com.tr, 2020. [Online]. Available: https://www.hurriyet.com.tr/video/kayip-ikranur-her-yerde-araniyor-johler-devreye-girdi-41553806.

Design

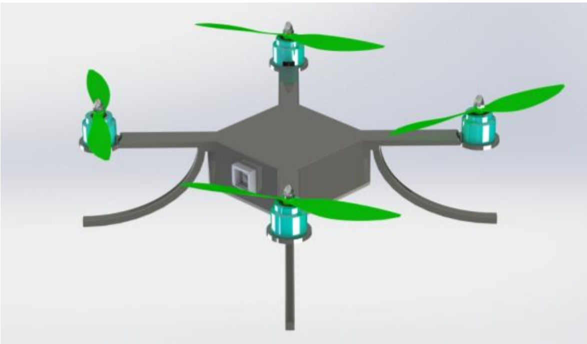


Figure 3 : 3D Model of the System

The quadcopter is designed according to rules and standards are determined by the Directorate General of Civil Aviation (DGCA) of Turkey. Weight of the quadcopter kept between 500 grams and 4 kg. Quadcopter frame that is the main body of the drone is made out of acrylonitrile butadiene styrene (ABS) that has the adequate toughness and strength. GARTT ML2212 920KV Brushless DC Motor is used to rotate the propellers at high speed which supplies 860 grams of thrust per motor with 10 inch 4.5 degrees angle of attack propellers.

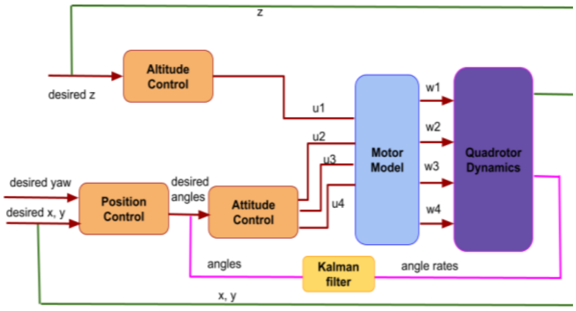


Figure 4 : Simplified Version of Quadrotor Control Algorithm

The other part of the quadcopter design, is the flight controller. Quadcopter is an underactuated system. 6 degree of system system is controlled by 4 actuators and flight controller designed to stabilize each of the degrees of freedom so that drone can hover and move in each axis autonomously while being robust to disturbances. To stabilize the quadcopter and feedback loops that are designed for flight controller, an IMU (Inertial Measurement Unit) is used to measure the tilt angles and height difference with the earth frame.

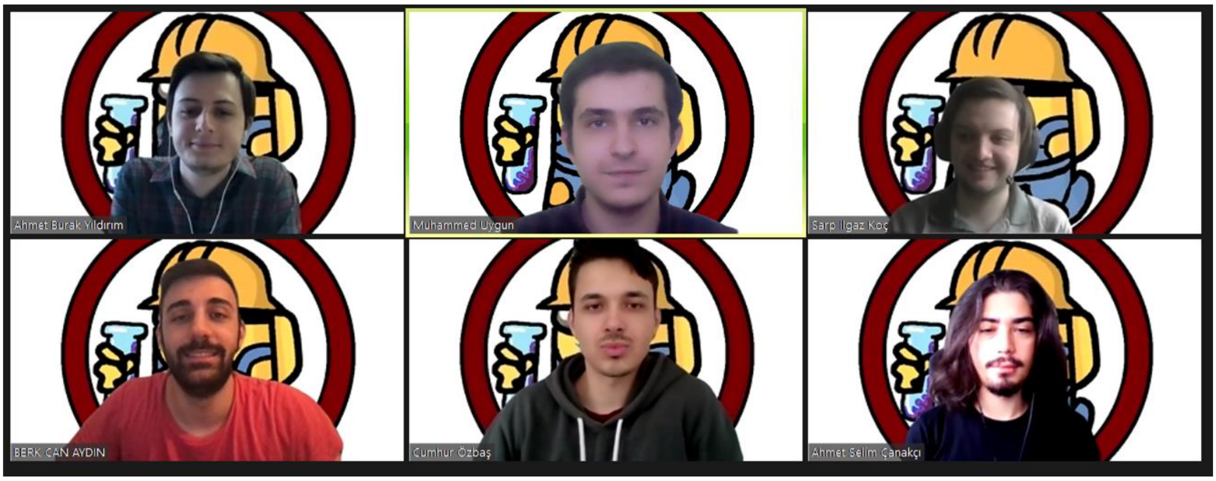
Outcomes

This project is a mechanical design and simulation project which combine knowledge acquired at the material, dynamics, control and mechatronics courses. This project is completed by following the steps below;

•Literature research for requirements to find a missing child
•Design of sub-systems of the quadrotor
  - Quadrotor dynamics
  - CAD design with the required quadrotor equipments
  - Flight control
  - Path following algorithm
  - Object avoidance algorithm
•Engineering analysis and simulation including:
  - 6 DOF System dynamic modeling
  - Flight control system structure analysis
  - Path following simulation
  - Object avoidance simulation
•Safety Analysis
•Planning of design verification and testing of the system

Design of Magneto-Rheological (MR) Suspension Systems

MR SUS (5)



Academic Advisor : Asst. Prof. Yegan Erdem
Industrial Advisor : Şamil Akaslan
Teaching Assistant : Emre Eraslan

ABSTRACT

The aim of this project is to design an MR suspension system suitable for military ground vehicles which had been investigated rigorously while providing an insight to FNSS in case they need to implement a suspension system with varying damping coefficient in the future. Effect of additional decrease in vibration due to varying damping coefficient becomes significant when the military vehicles operate in road profiles with non-uniform road disturbances considering that the vehicles are to carry sophisticated military equipments. The investigations include comprehensive analyses including: The control system involving the usage of continuous and discrete methods; fluid dynamics including the examination of the molecular formations under external magnetic field and computational magnetohydrodynamics analysis; and mechanical system considering static and dynamic stability of the design while satisfying the requirements for the military vehicle operating conditions provided by FNSS. These concepts are described using the available engineering knowledge and patents on these topics with theoretical and numerical explanations alongside them. The completed project ensures that the design goals are achieved, as the MR suspension reduces the vertical displacement comparatively higher than the suspension systems with static damping coefficient, provided that the prescribed design conditions and corresponding standards defined during development are followed.

Problem Definition

Passive suspension systems do find value in luxury cars due to the highly increased passenger comfort they provide alongside the overall better handling of the changing road conditions. To be complementary to the project at hand, focus should be given to why such a system should or can be important for a military vehicle. Although the conventional suspension systems are generally more than enough for the general applications regarding the mission the military vehicles serve, passive suspension systems can become prominent when it comes to ensuring the stability of devices which can be found in military vehicles.

Under normal circumstances, stability for such essential devices is provided via additional means that are not related to the suspension systems used such as stabilizer components attached to the weapon systems to ensure accuracy and safety.

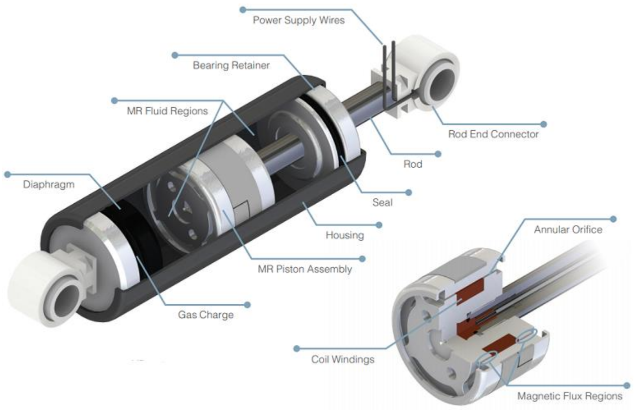


Figure 1: An exemplary MR suspension [1]

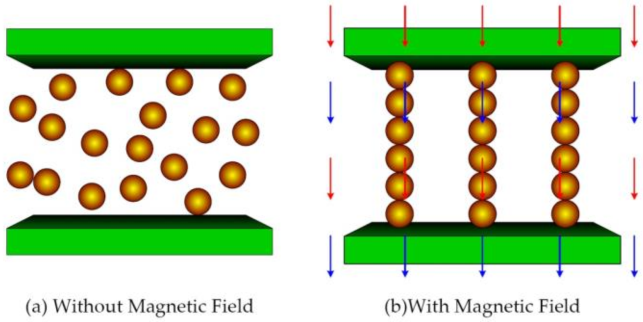


Figure 2: Orientation of particles due to application of magnetic field [2].

In theory, the advantage provided by passive suspension systems regarding the road conditions can negate the necessity of using additional systems to ensure the stability of these crucial devices, such as weapon systems, provided the design is done correctly. Regardless of whether such an advantage can be realized without an issue, the purpose of this project was to develop an MR suspension system model with all necessary steps excluding the production of a prototype, which includes complete mechanical design, numerical analysis and computer simulations, together with the background information given on the practical constraints.

The expectation was to achieve this goal by utilizing and developing necessary control systems, solid mechanics, and fluid dynamics knowledge correlated to the design of an MR damper and come up with an initial mechanical design, which can be utilized by FNSS as a resource in any potential project or development in this field.

[1]"Adhesives, Coatings, Vibration and Motion Control, Sensing, and Magnetically Responsive Technologies," *LORD Corp*. https://www.lord.com/ [Accessed: 04-Apr-2021].
[2] D. Q. Truong and K. K. Ahn, "MR Fluid Damper and Its Application to Force Sensorless Damping Control System," *IntechOpen*, 17-Oct-2012. [Online]. Available: https://www.intechopen.com/books/smart-actuation-and-sensing-systems-recent-advances-and-future-challenges/mr-fluid-damper-and-its-application-to-force-sensorless-damping-control-system. [Accessed: 04-Apr-2021].

Design

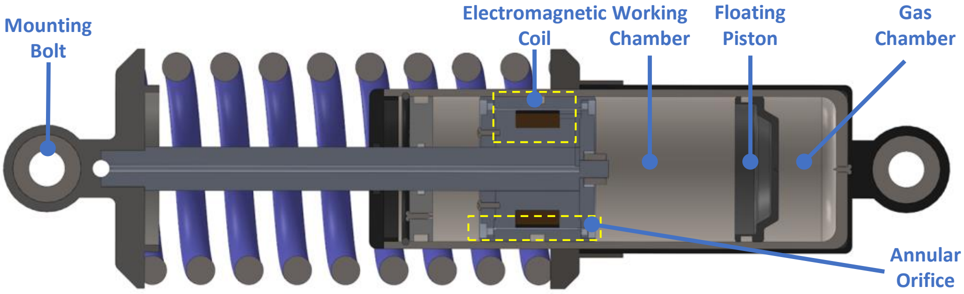


Figure 3: CAD model of the designed MR suspension system

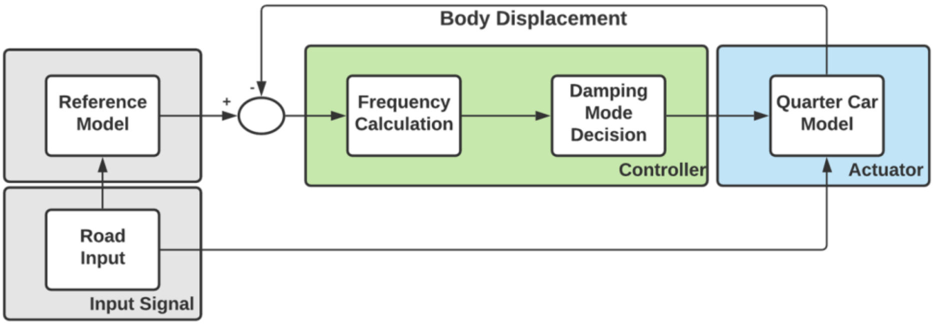


Figure 4: Schematic of the designed control system

The coilover was finalized as a monotube shock absorber designed to be assembled with a commercial spring that fulfills the design constraints. Key dimensions of the piston valve such as annular orifice gap, length and diameter alongside the size of the electromagnetic coil are determined based on the range of damping coefficient values that system requires for optimal operation.

The controller is designed based on CFD analysis of the MR fluid to obtain viscosity versus magnetic field data, and its relation to the geometry. Discrete modes are set to maximize the effect of damping coefficient and control model was constructed. Varying damping coefficient yielded 10% reduction in the vertical movement, in addition to 50% reduction from the static suspension design.

Outcomes

The system is a mechanical design project that may be considered a combination of various mechanical engineering disciplines involving statics, solid and fluid dynamics, control systems and mechatronics to come up with a magnetorheological damper satisfying constraints provided by FNSS. The goals have been achieved in several prescribed steps during the 2020-2021 academic year as follows:

- Literature research on theory and practical considerations regarding MR Damper and involved disciplines
- Mathematical modelling and construction of a control system architecture
- Fluid and molecular analysis of magnetorheological fluids to determine design limits and create a mathematical model suitable for the control system
- CAD drawings to visualize the system and FEM analysis to determine durability of the system using stress and fatigue models

Mechanical Design and Dynamic Control of Active Suspension for PARS 4x4

2Infinity&Beyond (6)

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Ali Özer

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Industrial Advisor : Dr. Şakir Baytaroğlu
Alpay Sancar
Teaching Assistant : Emre Eraslan

ABSTRACT

Concrete goals of the project are to reduce car body displacement and to enhance both ride comfort of crew and road handling performance simultaneously by designing an active suspension system on heavy duty military vehicle of FNSS's wheeled armored vehicle PARS 4x4. In PARS 4x4 vehicle, conventional double wishbone passive suspension system is used to achieve road handling and ride comfort. Passive suspension has set values for damping and stiffness which makes the suspension system less useful in case of a terrain change and undesirable vibrations which can reduce the crew comfort and create an unsafe atmosphere. The goal of this project is to reduce the car body displacement by 10% and improve the road handling and ride comfort. The solution applied is implementing a hydraulic actuator controlled by LQR controller. Since the hydraulic actuator can apply required force which is provided by LQR controller with the analysis of the road profile, pre-determined hydraulic actuator is selected. The proposed solution for this project is to design a double wishbone active suspension system to eliminate road disturbances with a hydraulic actuator controlled by LQR controller and road profile analysis.

Problem Definition

In many military applications, safety and the crew comfort are excessively essential. In military vehicles, the crew, the transported ammunitions and the equipment are exposed to unwanted disturbances from various road terrains. Constant exposure to disturbances such as vibrations, can create discomforts in terms of health problems and unsafe environment for the crew as there might be explosives inside of the vehicle.

The PARS 4x4 vehicle consists of independent passive double wishbone suspension system. Basic passive suspension systems for quarter car modulization resemble two degrees of freedom (DOF) mass-damper-spring system as shown in Fig.1.

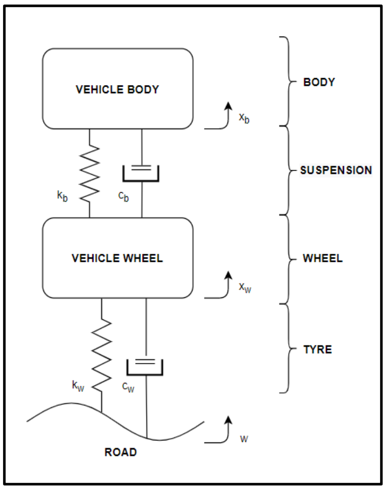

Fig. 1: Passive Suspension System for Quarter Car Model.

It is important to mention that the parameters listed above are for quarter car models and to be altered and modified for the full car model.

Fig. 2: 4x4 PARS Military Vehicle [1]

By designing an active suspension system, the goal is to reduce the undesired reactions of the system to mere minimum. This goal is achieved by importing a hydraulic actuator into the system. The actuator will be controlled in order to get the desired system response. Also, the road can be different for each tire which means that the system will give the desired output if and only if all the four tires are controlled properly. Both the mechanical design of the suspension and the control of the system are crucial for assuring a stabilized drive for the vehicle. The mechanical design is responsible for the transfer function of the system whereas the control design is responsible for getting the desired output. The operational, dimensional and control requirements are provided by FNSS Savunma Sistemleri A.Ş..

The design of the active suspension is subjected to ISO standards in terms of material, safety and transportation. The standard for the military applications are based on MIL-STD-810-G, used as a guideline.

[1] FNSS Savunma Sistemleri A.Ş., "PARS 4x4 STA," *FNSS Savunma Sistemleri A.Ş.* [Online]. Available: https://www.fnss.com.tr/urun/pars-4x4. [Accessed: 20-Mar-2021].

Design

Fig. 3 : CAD Drawing of Full Car

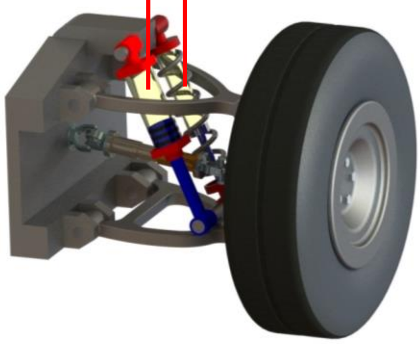

Fig. 4 : CAD Model of Quarter Car

The design of the system was finalized as a 7-DOF system that consists of spring, dashpot and hydraulic subparts. First, body of the vehicle is initiated and both powertrain and suspension system are placed onto the designated compartments. Dimensions of the parts are supplied by FNSS Savunma Sistemleri A.Ş.. After fatigue and static analyses are conducted, the reference geometry is modified to sustain safety factors of corresponding parts. Thus, mathematical model of the system is altered accordingly.

Hydraulic actuator, streamline and hydraulic sub-elements are placed into the system. After the vehicle faces external road obstacles, hydraulic fluid is pumped from the reservoir to the hydraulic actuator through the initiated streamline. Feedback-control system responses to the external obstacles by measuring the body acceleration via the accelerometer. Ultimately, it is aimed that external road disorientation is automatically smoothened in a way that specified constraints are satisfied simultaneously.

Outcomes

The ultimate goal of the project is to accomplish both mechanical and control designs of active suspension system, which integrates the principles of mechanical engineering subjects about dynamics, control systems, manufacturing, machine elements and mechatronics. The stages of the project are listed as follows:

- Literature research
- Determination of constraints and requirements with FNSS Savunma Sistemleri A.Ş.
- CAD drawings
- Engineering analysis:
  - Mathematical modeling of 2-DOF/7-DOF active suspension systems
  - Control system modelling and tuning for PID and LQR controllers
  - Static & fatigue analyses of quarter car model
  - Reliability analysis
- Planning Design Verification Schedule
- Executing Design Verifications

Design of an EV Battery Protective Carrier to Meet Specific Safety Requirements

CARRY4DV (7)

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Industrial Advisor : Burak Yazıcı
Ayşe Merve Çetiner
Teaching Assistant : Osman Berkay Şahinoğlu

ABSTRACT

The objective of this project is to design an EV battery carrier integrated to the main chassis of Ford Transit Chassis Cab (CCAB) to absorb and direct the resulting crash energy, by satisfying the specific safety standards provided by Ford-Otosan Company. Battery failure due to the deformation after a high impact during a crash instant poses a serious safety problem for the electric vehicles. Therefore, a battery protection system which can keep the electric vehicle's battery safe from external damages caused by particularly the side impacts and also carry the battery is required. The proposed solution is a design consisting of a sandwich structure with an aluminum honeycomb core to absorb or dissipate a certain amount of crash impact energy, an aluminum inner layer for battery protection against sudden intrusions and a polymer outer layer for durability against in plane loads at the crash instant. The protective carrier also consists of joining elements as well as outriggers for connecting the battery to the vehicle chassis. The structure has been designed in SolidWorks and all necessary analyses have been conducted in Altair. Manufacturing and the cost analyses were made on estimation considering the manufacturability and availability of the system components. The conclusion has been made according to the analyses results with their justification by the provided constraints and requirements.

Problem Definition

Battery failure resulting from side impacts poses a serious safety problem for EVs. A battery protection and carrier system which can maintain the integrity of the electric vehicle's battery in the case of external damages is necessary in order to avoid battery failures.

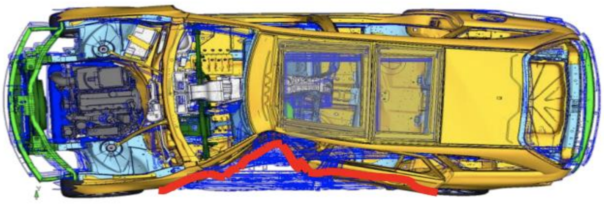


Figure 1: Battery Intrusion at a Side Impact on a Vehicle [1].

The solution must separately fulfill the main objectives of the mentioned problem, namely, absorbing and dissipating the impact energy before reaching to the battery module, minimizing the deformation at the battery during a crash. It must be applicable for Ford Transit CCAB, which has a wider battery pack than its main chassis (Figure 2). Battery is also located on the exterior of the vehicle, which makes the connection and protection of the battery even more challenging. Therefore, a design with superior energy absorbing characteristics to manage the crash energy, and an optimized geometry to connect the battery to the rear floor of the vehicle, specifically design for Ford Transit CCAB is required.

Project requirements are based on the safety requirements that are determined by the FMVSS 305, Laboratory Test Procedure For Electric Powered Vehicles: Electrolyte Spillage And Electrical Shock Protection and

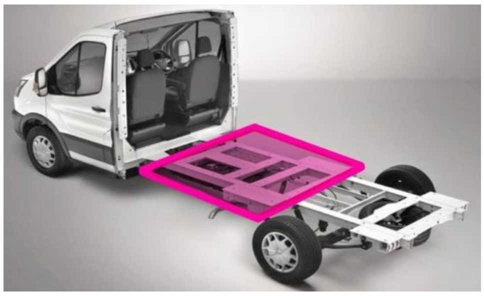


Figure 2: Position of the Battery Pack in Accordance With the Vehicle's Main Chassis [2].

FMVSS 214 Laboratory Test Procedure for Side Impact Protection which specifies the performance criteria of the battery pack when it is subjected to side moving barrier and side pole tests. Company specific requirements are also utilized.

Design

The design consist of two main parts: (1) sandwich structure with an honeycomb core to absorb the crush energy, and (2) the joining geometry to carry the battery, as well as connecting it to the chassis of the vehicle (Figure 3).

Sandwich structure consist of an Al-5052-H38 honeycomb core, enclosed by an Aluminum inner and a polymer outer layer. It is placed to the outer sides of the battery in order to protect the battery from any side impacts, (Figure 4). The connection of the battery, main chassis and the honeycomb is provided by six connecting elements, namely, outriggers. In the case of a side impact, the major part of the energy absorption is taking place in the honeycomb core, thanks to its constant load carrying characteristic, providing an accordion-like deformation resulting in gradual energy absorption.

[1] P. Sun and R. Bisschop, "(PDF) A Review of Battery Fires in Electric Vehicles," *ResearchGate*, Jan-2020. [Online]. Available: https://www.researchgate.net/publication/338542510_A_Review_of_Battery_Fires_in_Electric_Vehicles. [Accessed: 19-Mar-2021].
[2] "Ford Transit Chassis Cab MWB," *Ford Transit CCAB*, 22-Jul-2020. [Online]. Available: https://www.leasenotbuy.com/car-leasing-deals/ford-transit-chassis-cab-mwb/.

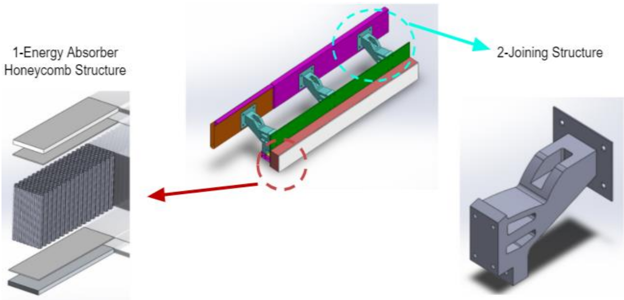


Figure 3 : 3D Model of the Proposed Design with its Components

Remaining deformation crush energy is directed to the rear floor of the vehicle instead of the battery itself, via outriggers. The outrigger design is topologically optimized in order to direct and withstand the crash energy.

The length, cell size and the volume of the honeycomb core is calculated considering the energy absorption need set by the requirements. The material of the honeycomb core, the inner plate and the outriggers is selected as Al-5052-H38 because of its formability, fast prototyping for testing purposes, availability and accessibility.

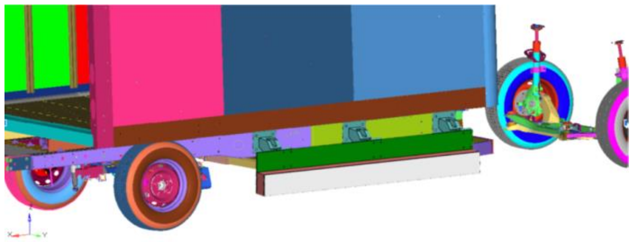


Figure 4 : The Design Location on the Ford Transit Chassis Cab (One other on the other side)

The material of outer plate of the sandwich structure is selected as a PPS Polymer in terms of its cost-effectiveness and high tensile strength characteristics. Adhesive bonding has been chosen to be applied between the inner and outer plates and the honeycomb core for the assembly purposes of the sandwich structure. The adhesive bonding type used for this purpose will be an epoxy layer which will stick the layers effectively.

Also, steel M10 bolts with hexagonal heads will be bought according to the bolted-joining locations of the design.

The design has been verified in each design stage using impact simulations modeling the side pole impact test, and FEM static load analyses.

Outcomes

System is a mechanical design project that combines the mechanical engineering knowledge acquired at statics, dynamics and mechanics of materials courses. It is done in several steps through the 2020-2021 academic years given as below:

•Literature research

•Determination of the design geometry, component material selection and joining technologies according to the requirements and constraints provided by Ford-Otosan

•Engineering analysis including:

- The honeycomb structure’s dimensional calculation
- Static load analysis by FEM in Altair/Hypermesh
- Impact simulation analysis in Altair/Hypercrash

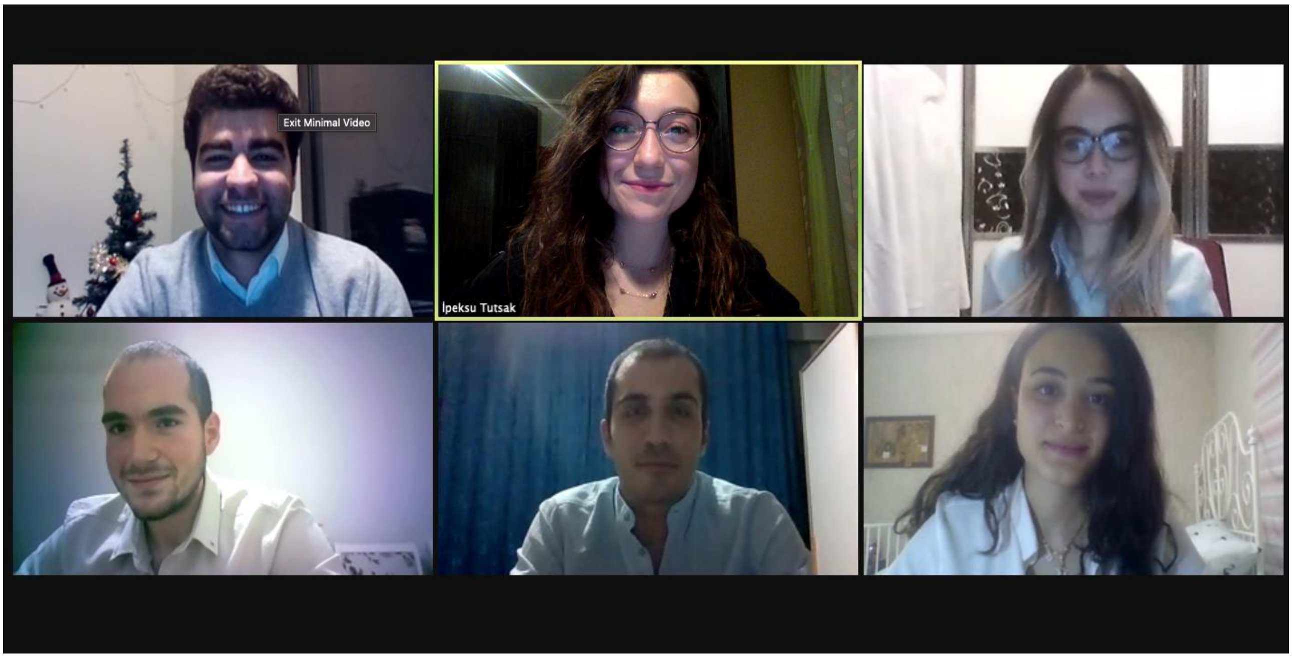
•CAD drawings

•Safety Analysis

•Planning of manufacturing processes, assembly, design verification and testing of the system

Design of a Thermoacoustic Refrigerator

Group 8



Academic Advisor : Assoc. Prof. Barbaros Çetin
Teaching Assistant : Alper Topuz
Group 8 Members : Abdullah Fırat Uyar
Ali Yücel
Aysel Güleç
Görkem Balyalıgil
İpeksu Tutsak
Simay Cankurtaran

ABSTRACT

Many developments experienced today increase the need for cooling systems. Although cooling needs can be met by conventional methods, today's conditions require more environmentally friendly and reliable systems for cooling. Thermoacoustic refrigerators are systems that can be an alternative to conventional systems. These systems do not contain gases that are harmful to the environment, and they are long-lasting and reliable systems that do not require maintenance since no moving parts are used for system operation. Within the scope of this project, it is aimed to design a thermoacoustic refrigerator in accordance with the efficiency and design parameters determined by using numerical and analytical models.

Problem Definition

The need for cooling systems is constantly increasing due to many reasons: new technological systems require heat removal, weather temperature increases due to climate change, etc. The most common systems are operate with refrigerant fluid. Even though these systems work efficiently, they are harmful to nature because of the refrigerants they contain. Therefore, new environmentally friendly cooling systems should be developed or existing but inefficient environmentally friendly systems need to be enhanced. Thermoacoustic cooling systems are good candidates in this regard. Furthermore, the thermoacoustic cooling devices generally do not contain any moving parts, so the system does not need lubrication, sealing or regular maintenance. The cost of the system can be regarded as relatively cheap compared to the other refrigeration systems as the system consists of few and simple components.

Applying acoustic waves through a driver, the gas resonates. As the gas oscillates inside the tube, the gas particles are exposed to expansion and compression because of the acoustic waves. As a result of expansion and compression, a temperature gradient occurs along the length of the stack, and heat is transferred between the oscillating gas and the stack. One heat exchanger removes heat from the cold environment, and produces a refrigeration effect, while the other heat exchanger pumps the heat to the hot environment [1].

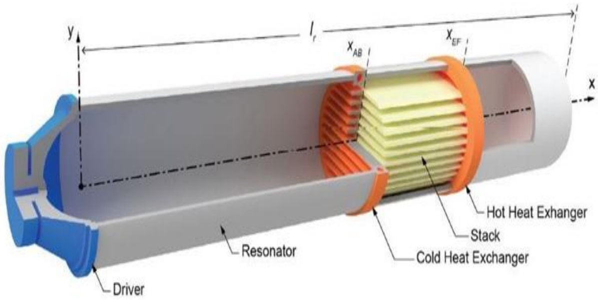


Figure 1. General Standing-Wave Thermoacoustic Refrigerator Model [1]

Although these devices are environmentally friendly and long life systems, they have always been disadvantageous in terms of efficiency, so they could not be turned into commercial products. Within the scope of this project, it is aimed to develop and produce a thermoacoustic cooler with reasonable efficiency values.

In term of operation, 10 W of cooling load should be provided on the cold environment. The system must also be reach a temperature difference of of 0°C from ambient temperature. The design should fit into a 60 cm ╳ 30 cm ╳ 30 cm box.

The solution product is planned to follow ISO-TC 86 for refrigeration and air conditioning standard [2]. TAR systems have been evaluated in terms of terminology, mechanical safety, method of testing, measurement of sound level, refrigerant and refrigeration lubricant chemistry according to this standard.

[1] A. Raut and U. Wankhede, “Review of investigations in eco-friendly thermoacoustic refrigeration system,” *Thermal Science*, vol. 21, no. 3, pp. 1335–1347, 2017.
[2] “ISO/TC 86 - Refrigeration and air-conditioning,” ISO, 30-Oct-2020. [Online]. Available: https://www.iso.org/committee/50356.html. [Accessed: 10-Nov-2020].

Design

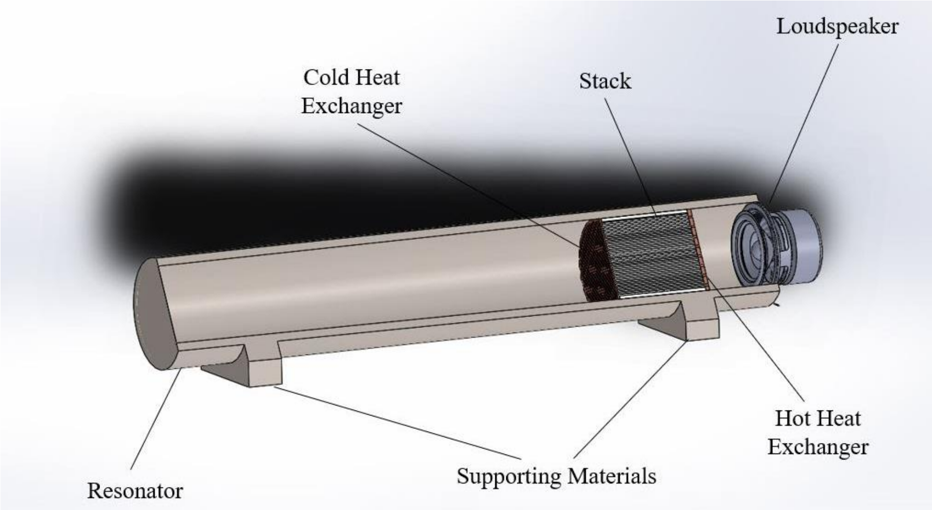


Figure 2 : 3D Model of the System

The system consists of five main elements. These are respectively sound source, resonator, stack, hot and cold heat exchangers. Resonator acts as a capsule covering the system. The loudspeaker is used as a sound source and produces sound waves at the frequencies needed for the system to operate. The stack section is the most important part for the designed product. Heat transfer occurs in the stack during compression and expansion.

Hot and cold heat exchangers are located on both sides of the stack section. These heat exchangers support the heat transfer occurring in the stack section. Analytical and numerical models were developed in order for the system to work in the most efficient way and to reach working conditions, and the system design was carried out in this direction. Thanks to these models, many parameters such as the sizes, positions and materials of the system elements were determined.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at thermodynamics, mechanics and acoustic courses. It is done in several steps through the 2020-2021 academic year given as below:

- Literature research
- Determination of system elements according to the design constraints
- Engineering analysis including:
  - Analytical Analysis
  - Numerical Analysis
  - Static Analysis
- CAD drawings
- Safety Analysis
- Planning of design verification of the system

Fire Control System for Non-Visible Targets

WallHack (9)

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Arda Sönmez

Altay Türkmen

Osman Afandiyev

Yiğit Erdost

Fırat Deniz Müftüoğlu

Academic Advisor **:** Prof. Dr. S. Turgut Tümer
Industrial Advisor : Reha İnal
Teaching Assistant : Mert Yusuf Çam

ABSTRACT

The aim of the project is to design of the Fire Control System for Non-Visible Targets and to develop a fire control system that can assist the turret in hitting targets without visual contact with the help of an external observer. Operation, dimension, safety, material, and cost requirements and constraints are determined. The general working principle of the system is explained using a visual schematic. Observer (military personnel) uses gyro and laser distance measurement device to calculate relative position of the target. Positions of observer and the turret are determined using RTK-capable GPS modules. Using vector addition, the position of the target relative to the turret is calculated. Servo and stepper motors are used to move the turret in the direction of the target. RF transmission is used to communicate information between the observer and the turret. Safety measures needed to protect vital components of the system are described. The project aims to minimize uncertainty and detect objects with the radius of 0.10 m at the distance of 100 m. All these values make certain that selected components are capable of satisfying the requirements and constraints of the project. Additionally, reliability analysis was performed for every component of the system. The aim of reliability analysis is to either maximize the reliability of electronic or mechanical components to determine and maximize their life cycle. As a result, designed system meets all requirements.

Problem Definition

A fire control system is an integration of components such as radars, sensors, computers, servo systems, and calibrators, designed to assist a ranged weapon in targeting, tracking, and hitting its target [1]. Its objective is the same as a human gunner firing a weapon, however, the fire control system tries to do this faster and more precisely.

One of the important features of contemporary fire control systems is that they require a clear vision of the target in order to perform effectively. However, this condition may not be satisfied when combat operations are performed in compelling zones, like residential or woodland areas. Areas like this abound potential hiding and ambushing spots, which may put the weapon system in a vulnerable position. Conveniently, most of these hiding spots are made of relatively soft materials, which makes it possible to pierce them by gunfire of high caliber machine guns (12.7-14.5 mm). Therefore, once the target's position is known, it can be liquidated by gunfire.

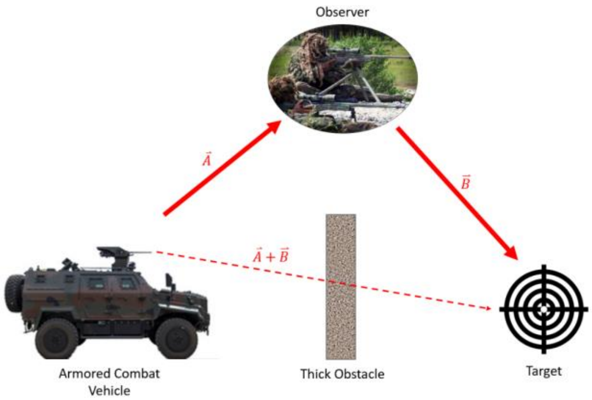

Figure 1: Relative Positions of Target, Observer and the Turret [2]

The goal of this project is to design a fire control system that can help a turret to accurately aim at a non-visible target behind an obstacle. To do this, the fire control system will use the position data provided by a third-party observer that has a clear vision of the target. First, the observer's position relative to the turret will be determined. Next, the target's position relative to the observer will be found. Finally, the position of the target relative to the turret will be calculated using vector addition (see Figure 1). Once the location of the target is known, the fire control system should aid the turret to accurately aim at it.

In terms of requirements, the system should be able to accurately aim at a human-sized target over the ranges of 3-100 meters. The turret is expected to follow a target moving at the speed of 1.6 m/s (average human walking speed). The solution product will be subjected to MIL-STD-202 G standard. This standard is the Department of Defense Test Method Standard which is used for general electronic components in military products.

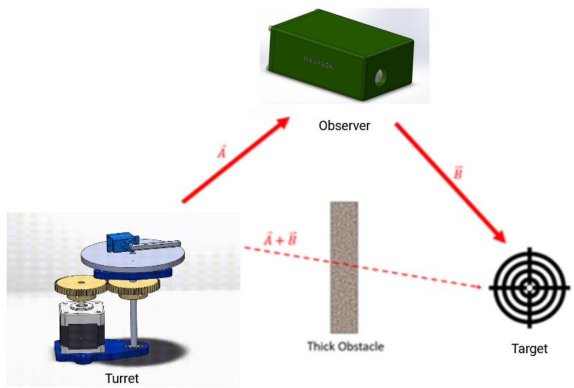

Figure 2: Visualized representation of the whole system.

[1] "Fire-control system," Wikipedia, [Online]. Available: https://en.wikipedia.org/wiki/Fire-control_system
[2] Nurol Makine. Fire Control System for Non-Visible Targets. 2020.

Design

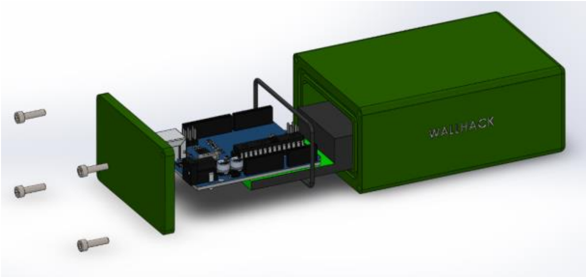

Figure 3 : Target Designation System inside housing

The design of the system consists of two different main parts: the target designation system (TDS) and the turret aiming system (TAS). The aim of this project is that these two systems work in correlation and successfully hit a non-visible target via armored vehicle. The system was designed based on a number of concepts and parts, measurements and calculations such as control system of the mechanism. For these stages, the TDS system will measure the position and distance of the target and transfer the position vector of the target to the TAS system with the radio frequency module. The TAS system then takes aim and fires at the non-visible target, using the target's location and its own position information. To examine the parts in detail,

Figure 4 : Turret aiming system with its electronic components

TDS system consists of eight main components. These are observer, laser rangefinder, GPS, Gyro, RF module transmission, Arduino, battery and housing. Except for the observer, all components are together in the housing. Observer enables the system to be mobile by carrying the TDS housing. In TAS system, there are four main components: Stepper motor, servo motor, gear drive mechanism and key joint. The stepper motor enables the turret to rotate according to the movement of the target, while the servo motor provides aiming with the up-down movement of the barrel. The key joint provides the connection between gear and shaft. In the gear drive mechanism, power transmission is provided to the plate rotating from the motor.

Outcomes

The system that has been designed has electronic and mechanical subsystems. Through 2020-2021 academic year design plan was executed by the use of the knowledge from mechatronics, dynamics and fundamental design principles acquired from ME courses.

Significant steps of the design project include :

- Literature and component research
- Research on different design options based on requirements and constraints given by Nurol Makina
- Determining a viable design plan and executing it step by step.
- Engineering analysis including:
    - Mathematical modelling of the system through MATLAB.
    - Result oriented graphical illustration and testing of the system through MATLAB mathematical model.
    - Uncertainty and reliability analysis of the subsystems.
- CAD drawings and animations
- Manufacturing details of the mechanical design.
- Safety analysis for the system components and their housing.

Optimal design for mounting of compressor on refrigerator in terms of mechanical stability and vibro-acoustic performance

Group (10)


Hammad Ullah


Hasan Onur Yurtkulu


Hassaan Ahmed Chaudhry


Gokberk Kurt


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ABSTRACT

The aim of this project is to design a refrigerator compressor mounting in terms of suppressing mechanical vibrations, especially, at low speeds i.e. 800 - 1000rpm. The criteria for the material concept are cost and material strength whereas the criteria for the design concept are assembly, compactness, adaptability, frequency damping and deformation. Comparisons with the current mounting structure that Arçelik is using are done. Analysis was done using ANSYS for both static and dynamic responses while the design modeling was done using SolidWorks. The analysis showed commendably lower deformation in the rubber grommets and lower stress concentration in the foot plate in the new design as compared to the old design. Moreover, the modal analysis proved the new design to be a winner. The final price for a single part of mounting structure for the compressor becomes as 8TL

Problem Definition

The project can be summarized as "optimization of the compressor mounting design in terms of mechanical vibration and acoustics, especially, at low speeds (20 Hz and below)".

Arçelik is one of the only two companies on the globe that manufacture compressors that can work at rpms as low as 1000. This helps save energy when the ambient temperature is low and heavy working by the compressor is not required [1].

The compressor, itself, is very stable and has no vibration issues but the problem arises when the compressor is attached to the mounting, which is then attached to the main body of the refrigerator [1].

Figure 1: Hermetic Compressor[2].

Cabin interaction related problems consist of physical interaction between cabin and pipes, condenser vibration noise and compressor resonance noise. Noise related with physical interaction in the evaporation chamber is also a problem [1].

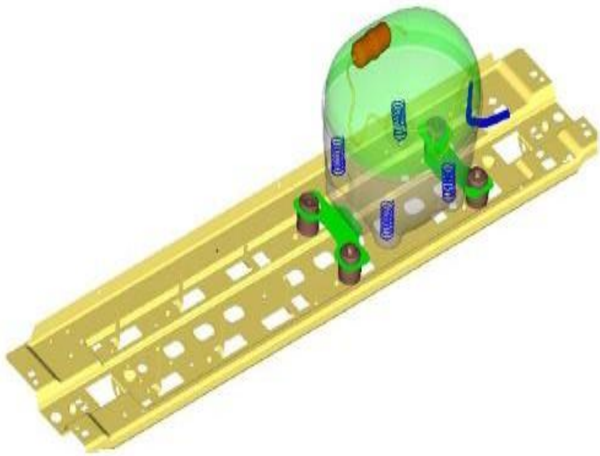

Figure 2: Arçelik Current Design [1].

Compressor and cabin interaction related noise problems would be tackled using a mounting that is able to observe majority of the excess vibrations. Resonance problems in the system will also be considered which occur after connecting the compressor with refrigerator via mounting [2].

Compressor related noise problems consist of valve noise, oil noise and resonance in different components. Valves present inside the compressor are the cause valve noise at low frequencies. In inverter compressors, there is continuous oil dripping, and it tends to cause noise at higher frequencies, while working over 2500 rpm [1].

However, our primary focus is the external (compressor cabin interaction) vibration as it is the main issue that Arçelik is facing right now.

[1] "ArçelikKompresör – KabinDibiÇalıştayı, Arçelik EKİ – EBİ – Merkez ARGE, Prof. Dr.Çetin YILMAZ (BoğaziçiÜniversitesi)
[2] "Hermetic Refrigeration Compressors | Secop", Secop.com, 2020. [Online]. Available: https://www.secop.com/solutions/compressor-ga-tools/hermetic-compressors.

Design

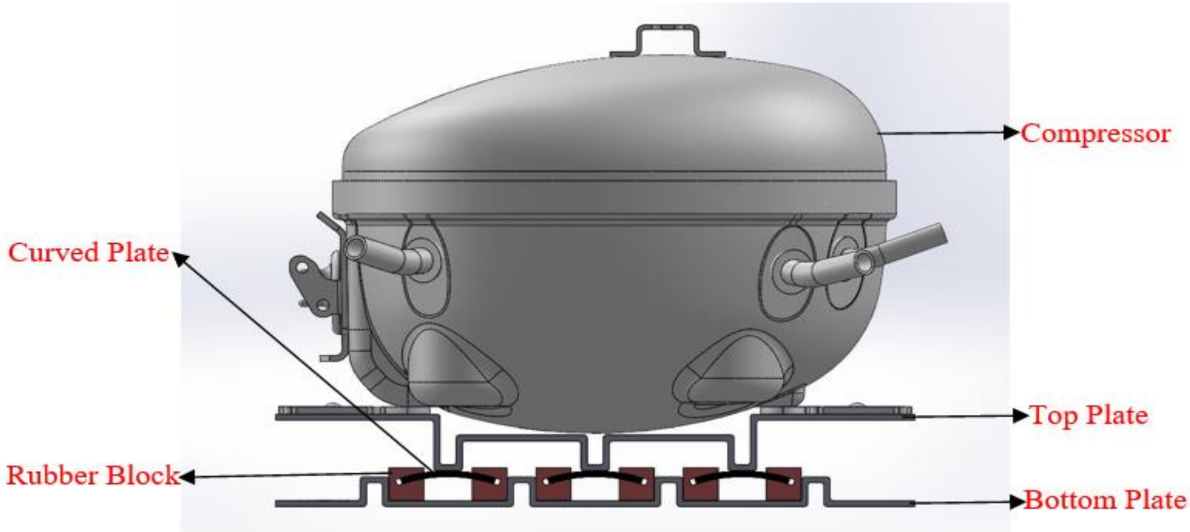

Figure 3 : Compressor and Mounting Assembly

The design of the system was finalized as a 5 DOF system. The top and bottom plates of this design are made of galvanized steel and they both are in single sheet form. Since it has a relatively low thickness value, which is 2mm, it can be shaped by roll-forming machines. Under the top plate, there are three curved plates that are basically connecting the top plate with the bottom plate. Curved plates are connected to the bottom of the top plate by screws.

Over the bottom plate, there are rubbers, which are made of HDPE to reduce the vibration in the system caused by the compressor. These rubbers offer protection against wear and ensure a dramatic decrease in vibration, according to the analysis. These rubbers are glued onto the bottom plate. The curved plates are put inside the grommets. The four rubber grommets are the same as Arçelik's previous design, to put the mounting over the footplate.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at noise and acoustic, mechanics and dynamics courses. It is done in several steps through the 2020-2021 academic year given as below:

- Literature research
- Engineering analysis including:
  - 5 DOF System modeling
  - Mathematical modeling
  - Frequency response analysis
  - Static Structural analysis
- CAD drawings
- Safety Analysis
- Planning of manufacturing processes, assembly, design verification, cost reduction and testing of the system

Engine / Ambient Temperature and Speed Sensitive Adaptive Vehicle Front Grills

Grup Mejur(11)

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Industrial Advisor : Batuhan Serel
Teaching Assistant : Mert Çam

ABSTRACT

Combat vehicles need an armored structure for ballistic protection. The front grille of the vehicles is of critical importance in order to deliver the required airflow for cooling to the engine and to protect the engine from bullets and shrapnel fragments. In the currently used land combat vehicles, the grids are protected by plate armor steel at an angle of 45 degrees. While the vehicle is in motion, the need for ballistic protection of the vehicle will be less and the need for cooling the engine will be more, so having the grilles completely open will provide the most airflow to the engine vice versa when the vehicle is slow and in the conflict. For these reasons, an adaptive vehicle front grille that is sensitive to vehicle speed and ambient temperature is designed in this project. In the project, our team designed a mechanical system for changing grid angles. It consists of spur gears, linear bearings. These moving parts are protected from dust, particles by a plastic covering. The actuator is selected as a step motor. The step motor is controlled by a microcontroller. The grid angles are measured by an angle sensor and give negative feedback to our system. The grid angle is determined after flow analysis. The necessary air inflow is calculated for the corresponding engine load. According to the relationship between airflow and angle degrees, the control system is embedded into the microcontroller.

Problem Definition

Combat vehicles need armor for ballistic protection. One weakness to any armor system is the air passages needed for running engines. For example, armored vehicles often have intake and exhaust vents for supplying air to engine components and other systems. However, if a projectile enters the vent, it can damage the engine or other components. Projectiles are considered missiles, artillery rounds, bullets, shrapnel, spall or other debris created by an explosive event. Therefore, while a need exists to supply air for operation and cooling, there is also a need to protect the occupants of the vehicle as well as allow the vehicle to perform a given mission. A balance must be reached between protection and functionality. Ballistic grilles are thus used to provide protection as well as airflow. The required openings for air flow make grilles inherently difficult to protect.

Figure 1: Fixed Grilles [1]

The grilles are fixed at 45 degrees currently. Although 45-degree flaps try to balance the conditions in terms of ballistic protection and engine cooling, they are not desired equally in most scenarios. There can be situations that require different flap angles.

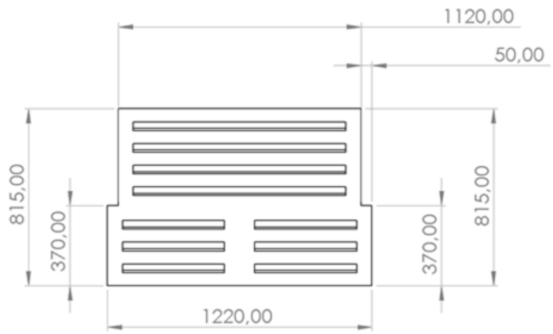

Figure 2: Dimensions of the Grill

For example, in the combat zone where the vehicle is vulnerable to any kind of damage, the flaps must be fully closed to not let any particle pass through the engine. In this situation, ballistic protection is way more important than engine cooling. On the contrary, when the vehicle is being transported to the combat zone for the mission and moves fast, the engine works overwhelmingly. In this situation, the grill must be opened more than 45 degrees and even fully for proper airflow through the engine. Therefore, the problem described above can be solved by an electro-mechanical system which can adaptively set the angle of the flaps depending on these situations. By this design, grill openings can be adjusted to the desired value between 0 and 90 degrees, which is dependent on situations.

The solution product will be subjected to MIL-STD-662F and MIL-STD-3038 standards. Those standard is the Department of Defense Test Method Standard which is used to test the armor and ballistic protection of the product.

[1] Nurolmakina, “Savunma Sanayi, Zırhlı Araç,” *Nurol Makina*. [Online]. Available: http://www.nurolmakina.com.tr/. [Accessed: 03-Nov-2020].

Design

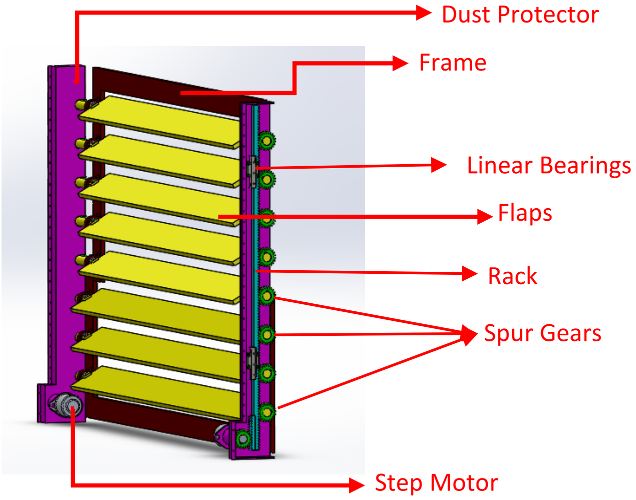

Figure 3 : 3D Model of the System

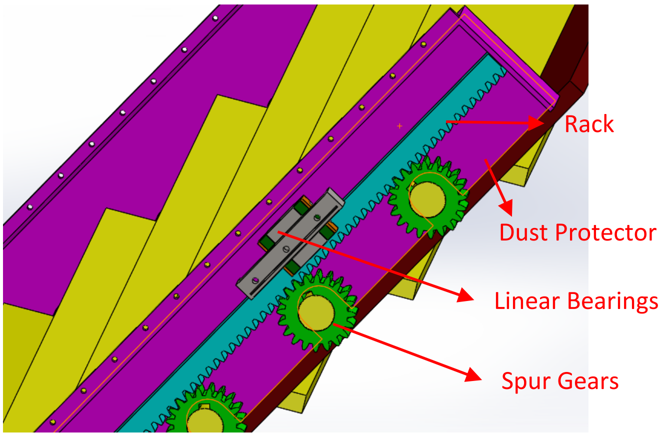

Figure 4 : Right View - 3D Model of the System

The design of the system was finalized as two sided rack and gear assembly to rotate the flaps by using the step motors. Working principle is as follows: Step motors move the racks up and down. As a result of that, gears which are mounted to flap pins are rotated. Step motor’s rotating speed and working time are arranged in a way that flap angles is adjusted to desired value depending on enviromental and duty conditions. Control system sends relevant values to the step motors and gets feedback from the flaps.

In the system, ball bearings are used between flap pins and frame mounting unit to minimize friction. Linear bearings are used to keep the racks on its fixed path. As the front grille is aimed to work at hard terrains, a dust protector is added to the system to protect mechanical parts which are racks and spur gears against the extra friction due to dust and other land pieces. Some security precautions like system failure angle stabilizer are also added to the design against any situation.

Outcomes

This project is designed according to mechanical engineering branches such as mechanics and material, mechatronics, control, CFD and heat transfer courses. Through the 2020-2021 academic year, there are some stages which are considered and these are given below:

- Literature research
- Determination of sub-systems according to requirements provided by NUROL MAKİNE
- Engineering analysis including:
  - Mechanical design
  - Electrical system construction and analysis
  - Control system construction and analysis
  - Mathematical modelling and analysis
  - Dust consideration and Vibration Analysis
- CAD drawings
- Safety Analysis
- Design Verification

Cold Launch of Low Orbital Missile

G (12)

Jankat Kozok - Mehmet Arı - Mert Alagözlü

Anıl Hancılar - Barlas Tarık Arslan - Enise Kartal

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ABSTRACT

This project aims to come up with a solution to the next-generation air threads by implementing a cold launch system for low-orbital missiles of ROKETSAN. Low-orbital missiles are widely used in the small area battlefields. However, the issue of these missiles is achieving the short range targets. When the main engine of the missiles is engaged at the beginning of the launch, i.e. hot launch, it is hard to rotate the missile after launch due to its high velocity. This weakness in nose-pointing ability of the hot launch missiles make it harder to cope with low-altitude and short-range threads. One of the solutions for this is rotating the missile before the main engine is started. In order to do that, the missile is launched by using compressed gas power. This solution introduces the chosen cold launch type and the appropriate sub components to operate.

Problem Definition

Military technologies have gained importance as the technology developed rapidly. Defensive systems that previously focused on the front missions, now face a 360-degree threat. Therefore; identification of threats, accuracy, and adaptivity are now the core concepts to design next-gen air defense systems to deal with the recent air-threats. So far in military technologies, missile systems are mainly used as air-defense systems. To define our main problem in more detail, the launching mechanisms of the missile systems should be clarified. There are two types of launching style in missile technology; hot launch and cold launch.

Briefly, hot launch can be defined as: missile uses its own engine to ignite, before leaving the tube, get enough power from this chemical reaction and leave the tube without any external force. In cold launch systems, missile launching by an ejection mechanism such as the working mechanism of SMA actuators or compressed gas, and when it reaches the desired altitude and angle, the main engine ignites. One of the advantages of cold launch systems is nose-pointing ability. Nose pointing is very crucial with dealing low altitude enemy targets, missiles should be aligned rapidly to the target. Since many air threats use low-altitude flights because of stealth, cold launch systems are very important.

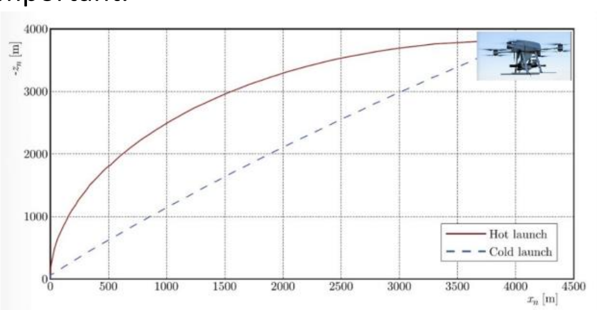
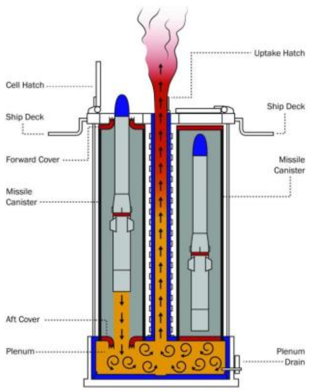


Figure 1: Trajectory motions of hot launch vs. cold launch [1]

Here is the visual demonstration of the distinction between cold launch and hot launch of missiles.



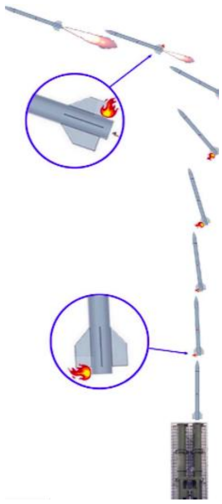


Figure 2: Hot launch of missiles [2]

Figure 3: Cold launch of missiles [3]

Dimensional constraints of the missile were provided by ROKETSAN, missile's length is 3 meters with 230mm diameter. This dimensions are used in order to design a suitable pod for the missile to achieve the desired ignition. After the ignition, the missile's tail will reach a minimum height of 20 meters and its velocity will be around 25 m/s then the side thrusters will be activated in order to rotate the missile upto 70 degrees without losing any critical altitude.

Design includes gas ejection mechanisms, therefore the final system will be suitable with MIL-STD-2131, and MIL-STD-810G standards.

Design

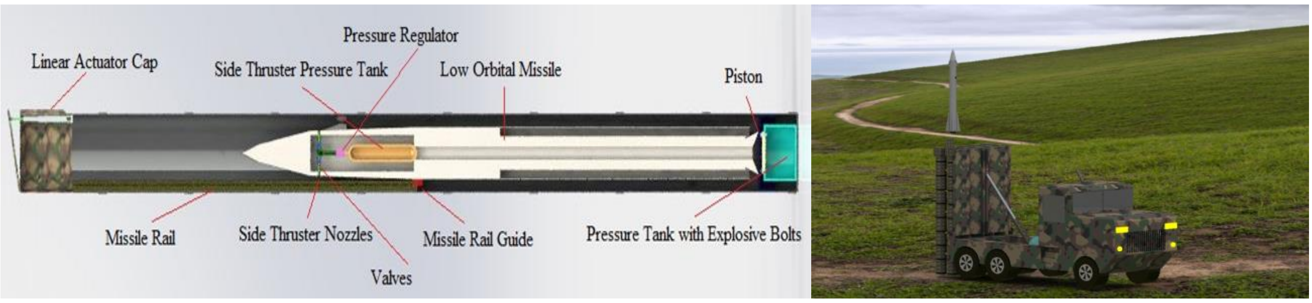


Figure 4 : 3D model Low orbital missile cold launch system

The design of the system was finalized as a 6 DOF system that relies on the 4 side-thrusters that are planned to place within the upper side of the low orbital missile. The system is composed of a cylinder, linear actuator cylinder cap, missile guide rail, piston, explosive bolt pressure tank and a low orbital missile which dimensions are provided by ROKETSAN. Internal parts of the low orbital missile are placed while assuming there iş enough space in it. Missiles head will be turned via side thrusters which are powered by pressure tank inside the missile. Side thrusters will apply force via releasing the gas.

The system was designed based on number of concepts, cold launch of the missile was considered as a piston and cylinder system. Movement of the low orbital missile after the cold launch is based on lateral thruster systems. Low orbital missile does not perfect fit to the cylinder but piston is. Within the release of the gas inside the pressure tank via the explosive bolts, piston will push the low orbital missile to the air within the required speed and rotated to a certain angle by side thrusters which are provided by ROKETSAN

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at thermodynamics, dynamics, control system and mechatronic courses. It is done in several steps through the 2020-2021 academic year given as below:

- Literature research
- Determination of sub-systems in order to meet the requirements provided by ROKETSAN
- Engineering analysis including
  - 6 DOF System modeling
  - Thermodynamic analyze of cold launch and side thrusters
  - Kinematic analysis of missile
- CAD drawings
- Simulation
- Verification

[1] R. Głębocki and M. Jacewicz, “Simulation study of a missile cold launch system”, *Journal of Theoretical and Applied Mechanics*, p. 901, 2018.

[2] White. R, “Cold Launch vs. Hot Launch”, [Online]. Available: https://navalnews.net/cold-launch-vs-hot-launch/. [Accessed: Oct. 22, 2020]

[3] R. Głębocki and M. Jacewicz, “Simulation study of a missile cold launch system”, *Journal of Theoretical and Applied Mechanics*, p. 901, 2018.

Design and Analysis of Sliding Door Mechanism on Light and Medium Commercial Vehicles

Puzzle (13)

Kerim Kutluhan Tunalioglu

Shahan Khan

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Asadullah Farooqi

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Teaching Assistant : Berkay Şahinoğlu

ABSTRACT

The objective of this project is the dynamic analysis of door closure systems on light and medium commercial vehicles. The main focus will be on the simulation and analysis parts of the forces involved in the sliding doors; friction, drag and impact, and their effect on the energy requirement for the proper functioning of the system. The aim is to optimize the design of the door, decrease the amount of force required to operate the door by hand and minimize any noise and vibrations. The parameters that affect the performance of the motion of the sliding doors are the attachment of sliding doors, the track that sliding door rollers move along, inclination of the road, friction coefficient of the materials used, minimum force required to overcome opposing forces to the motion, and spring-mass model of the area where sliding door hits the body of the vehicle. Each parameter is assessed according to different criteria and a design matrix is formed for all of the parameters and final selections are concluded.

Problem Definition

The parameters that affect the performance of the motion of the a sliding door are: the weight of the sliding door, attachment of sliding doors, the linear track that sliding door rollers move along, friction coefficient of the materials used, impact when the rollers reach the end of the guide track when the door fully opens or closes, the minimum force required to open/close the door at different levels of incline/decline

By taking Ford's model Tourneo as an example, the weight of the car door should be approximately 35 kg. The team will be working to minimize the energy required for closing and opening the sliding door mechanism with an upper limit of 14 J. The length and angles of the rail will be varied find the optimal properties that give a minimum force required.

By defining a coordinate system where the z-axis is along the height of the car, x-axis is along the front-back line of the car and the y-axis is along side-to-side of the car), the rails can have varying angles from 0°-90° on the x-y plane with respect to y axis, and 0°-3° on x-z plane with respect to ground i.e. x-axis.

The sliding door should be immobile under the friction effect that is created solely by its own inertial properties to eliminate any possible injuries to user.

Among many other standards that the final design will be subjected to, IATF 16949 will be used to ensure that the provided solution falls under the limitations set by Automotive Quality Management.

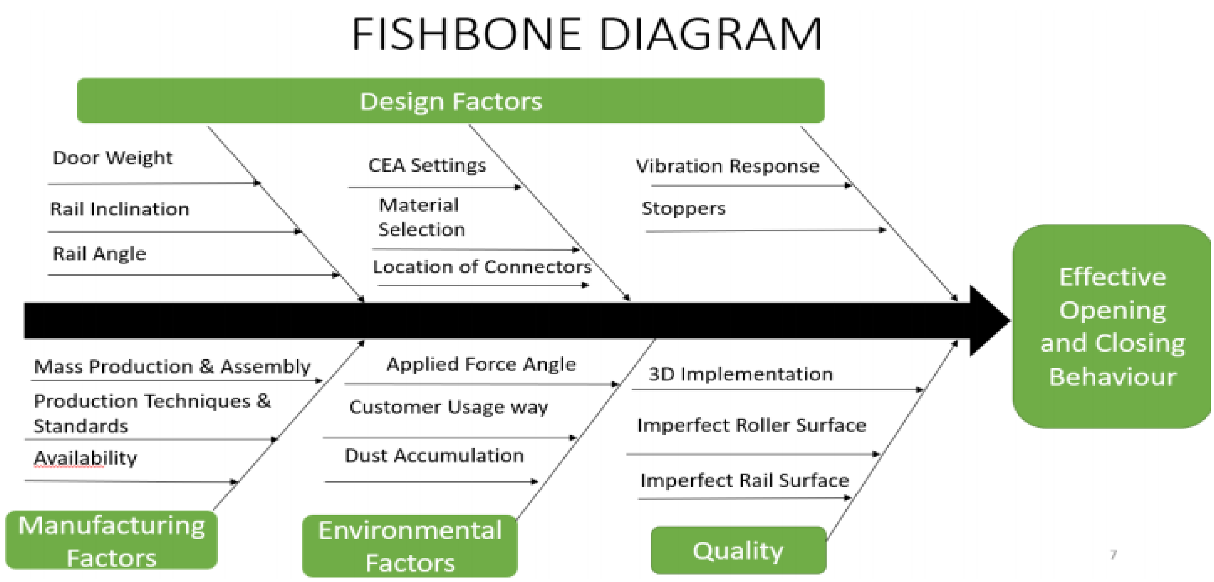

Figure 1 : The Fishbone Diagram of the Project

Design

Figure 2 : 3D Model of the complete system

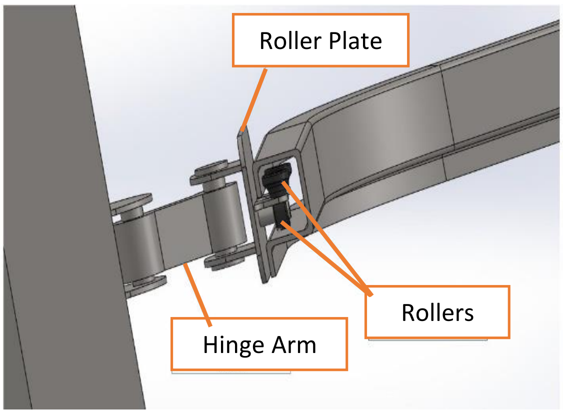

Figure 3 : Roller and Hinge Assembly

The design of the system was finalized as a 2 DOF sliding mechanism that relies on 3 sets of tracks and rollers for its motion. The system is composed of 3 tracks parallel to each other but with different curve profiles; the upper track and lower track having the same track profile and same horizontal position but different vertical position and the middle track having a different track profile from the other two and having a different horizontal and vertical position with regards to the body of the vehicle. The Upper and Middle track have the exact same roller mechanism, comprising of 3 rollers with two rollers contacting the track horizontally and one roller contacting the track vertically, while the roller assembly for the lower track consists of only 2 rollers contacting the track horizontally as the lower track only provides stability to the system and does not carry any weight unlike the upper and middle tracks. Each of the three roller mechanisms is connected to a hinge arm via a hinge pin that connects the roller assembly to the door and the hinge arm is pivoted about the roller plate (the plate on which the plastic rollers are mounted) while the other end of the hinge arm is fixed to the door to allow for control of the movement of the door parallel to the track profile.

Outcomes

This project consists solely of mechanical components and thus the project was done in progressive stages using the skills learned in Mechanics and Dynamics courses with the help of CAE software. The progress timeline followed by the group is as follows

- Literature research
- Material selection for each component and design finalization according to the constraints provided by FORD OTOSAN
- Engineering Analysis
    - Static Analysis
    - Vibration Analysis
    - Dynamic Analysis
    - Mathematical Modelling
- CAD drawings
- Design Verification
    - Governing Equations
    - GeoGebra Animations