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Research Article

Katı Yakıtlı Roket ALP-01 Tasarımı, Modellemesi ve Simülasyonu

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Öz

Bu çalışmada katı yakıtlı alçak irtifa roketi ALP-01'in CAD tasarımı yapılmıştır. 1500 metre irtifa için roket boyutları; seçilen motor için optimize edilmiştir. Burun konisi geometrisi olarak Parabolik tip tercih edilmiş ve uzunluğu 35cm olarak hesaplanmıştır. Burun konisi ve shoulder kısmı için 3D yazıcıda kalıp hazırlanıp cam elyaf malzeme ile elle yatırma yöntemiyle bu kısımlar üretilecektir. Roketimizde iki farklı kurtarma mekanizması kullanılmıştır. Burun konisi, faydalı yük, faydalı yükün paraşütü ve roketin birinci paraşütünün roketten ayrılması için CO_2 tüp ile fırlatma mekanizması tasarlanmıştır. Faydalı yükün üzerinde telemetri sistemi olan bir uçuş bilgisayarı bulunmaktadır. Bu bilgisayar yer istasyonuna konum, yükseklik, sıcaklık, nem bilgilerini anlık olarak iletmektedir. Roketimizin birbirinden ayrı iniş yapan bütün parçalarında GPS ve telemetri sistemi bulunmaktadır. Gövde üretimi için İskenderun Teknik Üniversitesi Makine Mühendisliği Bölümü mekanik laboratuvarı kompozit atölyesinde vakum infüzyon yöntemi ile silindirik kesite sahip kompozit parça üretim denemesi yapılmıştır. Kanatçık geometrisi olarak Openrocket simülasyonları sonucunda delta tipi kanatçık uygun görülmüştür. Ayrıca tasarımı yapılıp üretilmesi planlanan ALP-01 katı yakıtlı roket ile Teknofest 2019 roket yarışmasına katılınması planlanmaktadır. Çalışma aşamalarında, ikisi statik test olmak üzere dört kez katı yakıtlı roket motoru denemesi yapılmıştır. Denemelerde kullanılan yakıt karışımı (KNO_3 Sükroz/Dekstroz) Makine Mühendisliği bölümü mekanik laboratuvarı kompozit atölyesinde bulunan hassas terazi, ayarlı ocak, hidrolik pres vb. ekipmanlar kullanılarak hazırlanmıştır.

Anahtar Kelimeler: Kati Yakıtlı Roket, Tasarım, Modelleme

Designing, Modeling and Simulation of Solid Fuel Rocket ALP-01

Abstract

In this study the design of solid-fuel low-altitude rocket ALP-01 CAD has been optimized for the selected engine of rocket sizes for an altitude of 1500 meters. Parabolic type was preferred as the cone geometry. The length is calculated as 35cm. 3D printer for nose cone and shoulder section will be prepared by hand and made from glass fiber by hand method. Two different rescue mechanisms have been used in our rocket. CO_2 tube discharge mechanism was used for the removal of the nose cone, payload, payload parachute and the first parachute from the rocket. Payload has a flight computer with a telemetry system. This computer instantly transmits location, altitude, temperature and humidity information to the ground station. There are GPS and telemetry systems in all parts of our rocket. The production of composite parts with cylindrical cross-section was performed and positive results were obtained in the composite workshop of the Mechanical Engineering Laboratory of Iskenderun Technical University. As a result of Openrocket simulations as a wing geometry, delta-type flaps were considered suitable. Furthermore, it is planned to participate in Teknofest 2019 rocket competition with ALP-01 solid fuel rocket which is planned to be designed and produced. Four times solid-fuel rocket engine trials, two of which were static tests, were conducted in the study stages. The fuel mixture used in the experiments (KNO3Sukroz / Dextrose) is located in the Mechanical Engineering Laboratory of Iskenderun Technical University.

Keywords: Solid Fuel Rocket, Design, Modeling

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1. Introduction

Solid propellant rocket engines are produced more easily and with lower cost than liquid and hybrid fuel systems; are reliable engines used in different military systems and launching systems. It is very important to make this technology used more efficient and more efficient. Research in this field can be examined under two main disciplines, namely internal ballistic performance and structural strength. Research on internal ballistics performance discipline, backward analysis, internal ballistic performance, focused on solvent development and optimization. Ricciardi has generated a code that performs the backflow analysis of fuels of various configurations with a star-shaped cross section and has provided the necessary input to internal ballistic performance analysis using this code [1]. Nisar and Guozhu conducted an optimization study for wagon wheel and roller - fin geometries [2,3]. Structural strength studies can be grouped as finite element analysis and structural strength analysis, service life determination and material model development. Heller conducted extensive research on the rocket engine shelf life [4,5]. Yıldırım and Özüpek carried out a structural analysis of a solid propellant rocket engine using the finite element method and examined the effects of aging on fuel in the analysis results [6]. As a result of the literature research, no studies have been found that optimize the disciplines of internal ballistic performance and structural strength.

The first ancestors of modern rockets are planes. The leader in this period was Orville Wright, with the support of General Motor company and Sperry Gryroscope, the first aircraft to make it. These names are the first people to use rocket. These first trials were used in wars. However, in the short term, it was understood that radio controlled aircraft may be necessary for the war. Due to the economic crisis experienced by the world in the 1930s, all of these projects took their place in the dusty shelves. In 1935, two siblings, called Good, performed the first aircraft that could be steered by radio waves. These planes were first used by the American army. In 1941, when the United States joined the Second World War, General Arnold made his first flight in a serious sense of war.

According to Goddard's studies, supersonic speed was not possible with solid fuel rockets. Goddard was the first to use the propeller blades to allow the rocket to fly into orbit at the beginning of its flight. It was Goddard who developed the mathematical theories of basic designs for long-range rockets. Thus, as a result of the Second World War, the first guided missiles developed with rocket engines began to be used. The American Rocket Organization started to develop its first rockets with the establishment of the organization in the 1930s. The first rocket engine was designed by the German Rocket Institution in 1931 by the Germans.

Some forces such as resistance, gravity, friction directly affect the aerodynamic structure of the missile. There are 4 forces acting in general. The other is the force applied by the body against the air, the other is the force of gravity and the force applied by the body against gravity. While the rocket or missile is moving on the surface, some of the air particles are projected back into the surface or vortex behind the surface (Figure 1). The vortices are closely related to the smoothness of the surface and to its sharpness and size. The density of the air, the angle of impact to the surface and the velocity of the flow directly affect the size of the vortex.

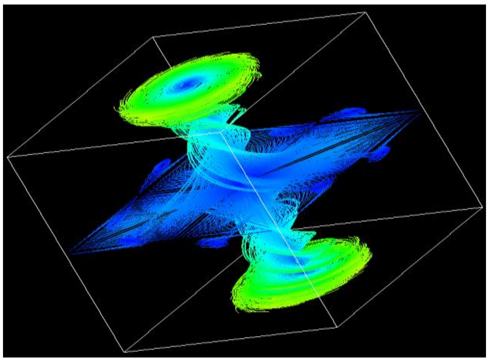

Figure 1. Vortex

In order to perform any dynamic modeling of any aircraft or any UAV, the equations of the aircraft body must first be obtained. These equations can be classified into three groups. These equations are the force equations of the body, the moment equations and kinematic equations. Newton's second law was used in the literature to extract the force equations. Equation (1) provides this law:

$$ {}^{I}\vec{F} = M_a \, {}^{I}\frac{d\vec{V}_{cg}}{dt} = M_a \left[\frac{\partial \vec{V}_{cg}}{\partial t} + {}^{I}\vec{\omega}^{A} \otimes \vec{V}_{cg} \right] \qquad (1) $$

The major forces are pressure gradient force, gravity and friction. The fixed axis in space is called the inertia axis set or Newtonian axis assembly, and Newton's second law of motion can be applied according to this fixed axis set.

In this study a solid fuel rocket designed and optimized dimensions according to range. It’s also designed critical parts nose cone, rocket wing, composite body. And then L585 propulsion engine has been selected for designed rocket. The simulation results are presented in graphs.

2. Material and Method

2.1. Nose Cone and In-Body Structural Supports

Parabolic type has been preferred as the cone geometry. The length is calculated as 35cm. 3D printer for nose cone and shoulder section will be prepared by hand and made from glass fiber by hand method. The idea of pressing the nose cone from the 3D printer with ABS filament is also on our agenda, but the nose cone is aerodynamically the most exposed to air pressure and friction in a rocket (Figure 2)

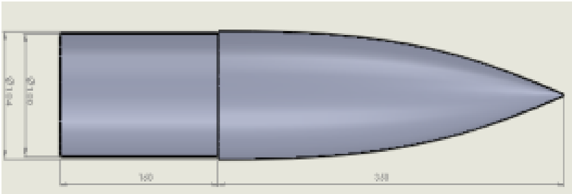

Figure 2. Nose Cone

It has been chosen to use a lightweight rocket body since chosen a motor with a lower thrust value than the other engines in the catalog and will give us flexibility in terms of the parts we will use in the sub-systems. Since the body will be able to maintain its structural integrity during flight and rescue, carbon fiber body will be produced due to the fact that our group wants to gain experience in the production of composite materials.

Aluminum and PVC pipe options are also taken into consideration as the body structure. It is thought that the body with the features which is expected will be relatively heavy and unstable compared to the composite body and it has been removed from the options. In the composite workshop of the Mechanical Engineering Laboratory of Iskenderun Technical University, the production of composite parts with cylindrical cross-section was performed and positive results were obtained. Motor centering rings will be produced from plywood material with laser cut machine. Plywood parts will be improved by using vacuum infusion method. The inner tube part will be made of fiberglass pipe. The integration bodies will be made of fiberglass pipe. The tensile, compression and vibration tests required for the materials to be used will be carried out in the mechanical workshop of İskenderun Technical University (Figure 2).

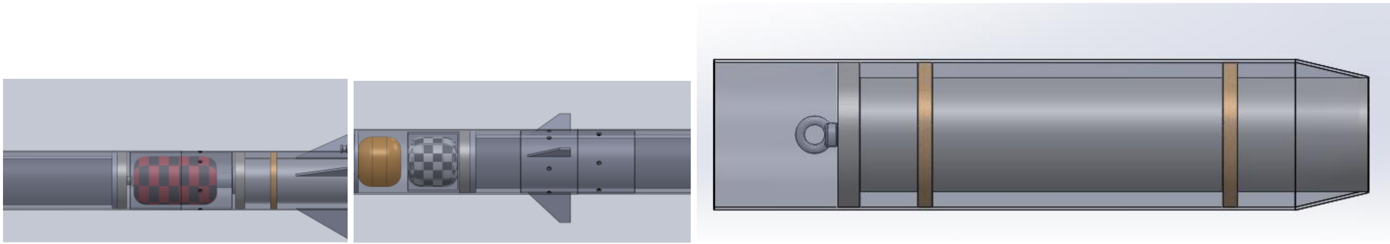

Figure 3. In-Body Structural Supports and Engine Mounting

The general design of the Open Rocket is shown in Figure 3.

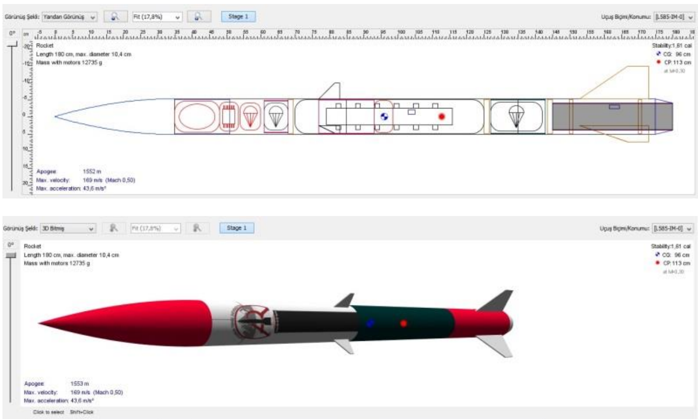

Figure 4. General Design Of The Open Rocket

2.2. Rescue System

There is a two-stage rescue system in ALP-01. When the rocket body is at its peak, it will open its small parachute and drop at 21.3 m/s. 500 m from the ground will open the second parachute and complete the landing at 8.64 m/s. The reliability of our system will be checked by many tests. There are GPS and telemetry systems in all parts of ALP-01. In this way, location and flight information at all stages of flight information can be informed simultaneously (Figure 5).

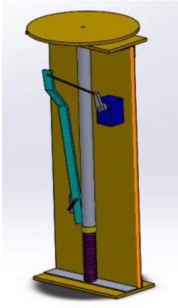

Figure 5. Rescue System

2.3. Avionics System

The dual-deployed flight computer easymini v2.0 model of the Altusmetrum brand, which was triggered by a barometric pressure sensor as a backup computer that performed the same functions in ALP-01, was preferred (Figure 6). The avionics control diagram is also shown in figure 6.

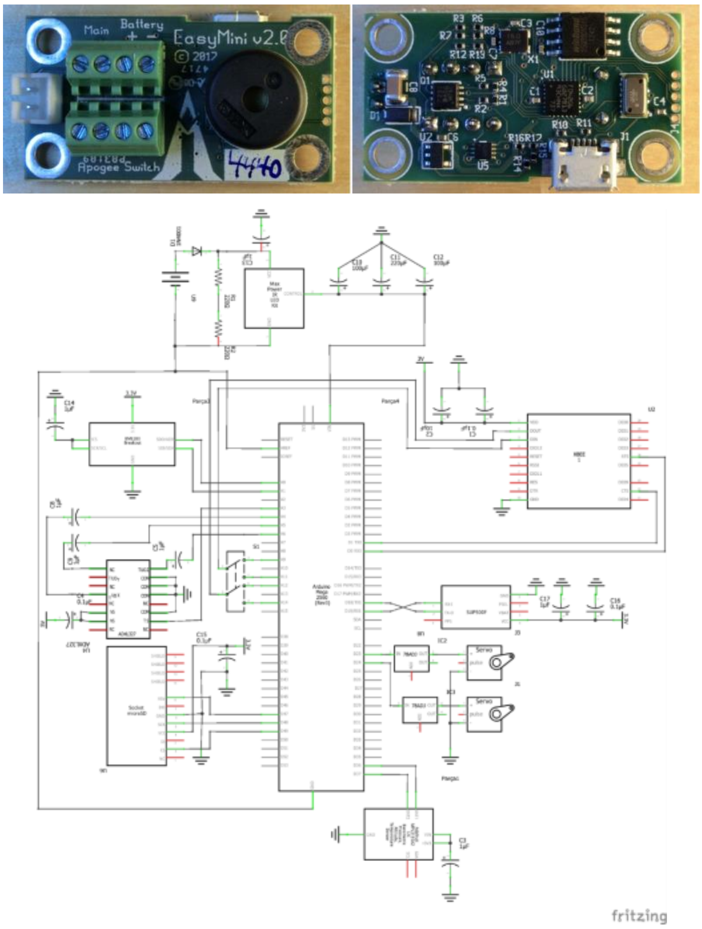

Figure 6. Avionics System

The main body of the rocket will consist of three parts. The integration body shall be fixed to the body where the motor is located by 6 M3 countersunk head screws and shall be connected to the middle body by tightening. Since the rocket is likely to rotate during flight, there are two release pins on the body to prevent separation of the bodies. In the separation of the main parachute these pins will be broken. The front body to which the middle body and the nose cone are attached will be fixed with the integration body mounted on the flight computer. There will not be any separation here. On the large flap, there is a bed for attaching the fins to the motor centering rings. When these bearings are used to fix large fins, small fins will be glued to the body with epoxy resin. The rocket body will be produced in three parts for easy production. The two fixed parts of the body will also be fixed together with the integration body which is the body of the flight computer. In this way, it is planned to facilitate the assembly processes during and after transportation as well as ease of production.

The nose cone and body parachute will be opened when the rocket reaches the maximum altitude after the launch. The nose cone and the associated payload will descend with a certain drift depending on the wind speed. The useful load will be tracked instantly with the included GPS module. Our avionics system will be able to track the data in the interface that we have created in the computer and the data will be kept as well as the height pressure position speed (Figure 7).

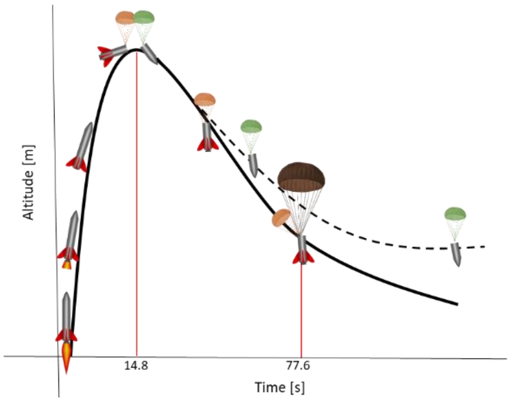

Figure 7. Operation Concept

The design of the fins to be used is given in the Figure 8. As a result of openrocket simulations as a wing geometry, delta-type flaps were considered suitable. On the large flap, there is a bed for attaching the fins to the motor centering rings. Small fins will be glued to the body with epoxy resin.

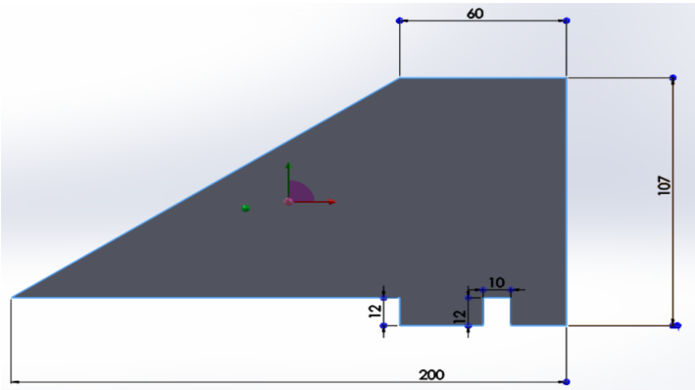

Figure 8. Rocket Wing

In the continuation of solid fuel tests, a mechanical parachute launching mechanism was designed and the tests were completed successfully. A pressure recovery mechanism has been made for the rescue mechanism and the parachute ejection process has been completed at the end of solid fuel.

In the Mechanical Engineering Laboratory of Iskenderun Technical University, composite body pipe manufacturing with cylindrical cross-section with vacuum infusion method has been made and positive results have been obtained. As shown in Figure 9, a cylindrical composite body experiment was carried out using glass fiber.

Figure 9. Manufacturing of Composite Body Pipe with Cylindrical Cross Section

3. Results and Discussion

The thrust time graphs of the selected engines are given in the appendix. Since both motors have the same diameter and length, the two engines will be placed in the rocket with the same strategy.

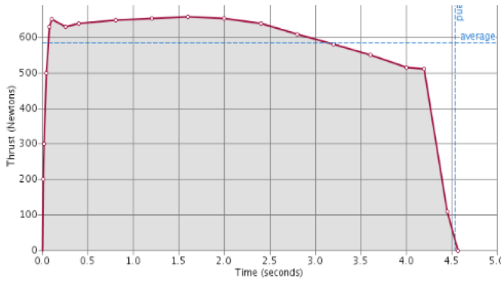

Figure 10. Thrust-time graph for L585

Since the payload and nose cone should have a descent rate of max 9 m/s, a 125 cm diameter parachute will be used. The rate of decrease calculated in this way is 8.81 m/s. The maximum drift distance for the 10 m/s wind speed is 1700 m. Xbee modules to be used in the parts of the shooting distance of 3.2 km, the location will be calculated instantly over the GPS and the location will be calculated. The weight of the empty body, which is finished after the separation of the nose cone, is 6150 grams. The diameter of the first parachute was 65 cm. The calculated descent speed is 21 m/s. The diameter of the large parachute which will be opened 500 m to the ground is 150 cm. In this way, the downward velocity of the descent and body is 8.4 m/s. According to our calculations, the body will drop approximately 650 meters behind the shooting area (Figure 11).

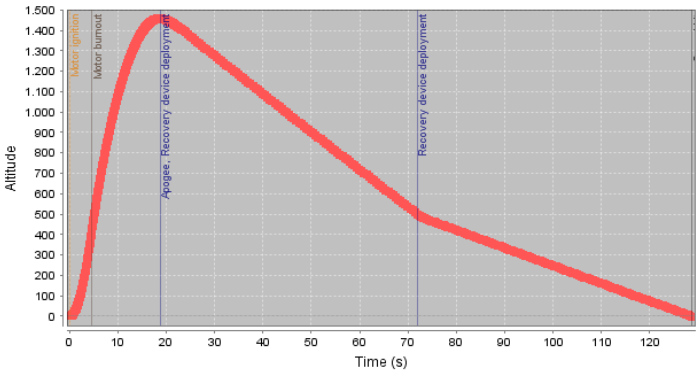

Figure 11. Altitude of Simulation Results of ALP-01

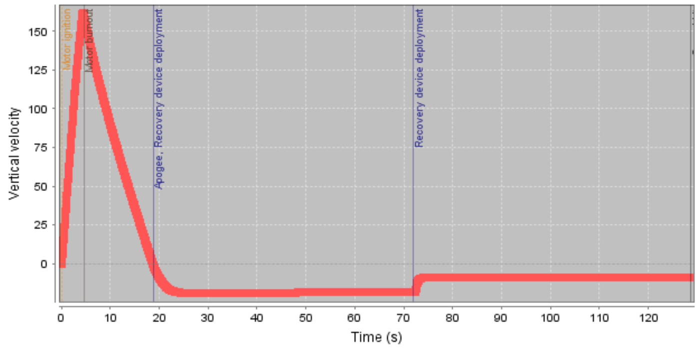

Figure 12. Vertical Velocity of Simulation Results of ALP-01

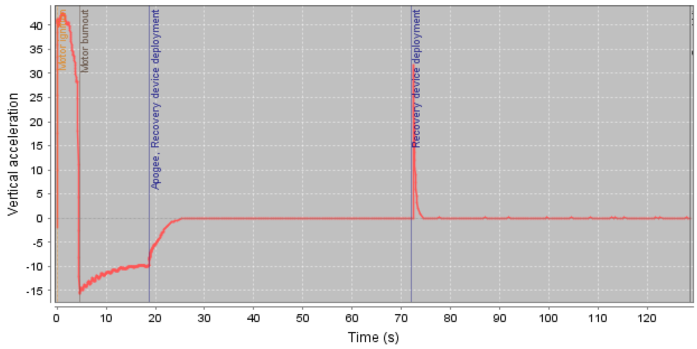

Figure 13. Vertical Acceleration of Simulation Results of ALP-01

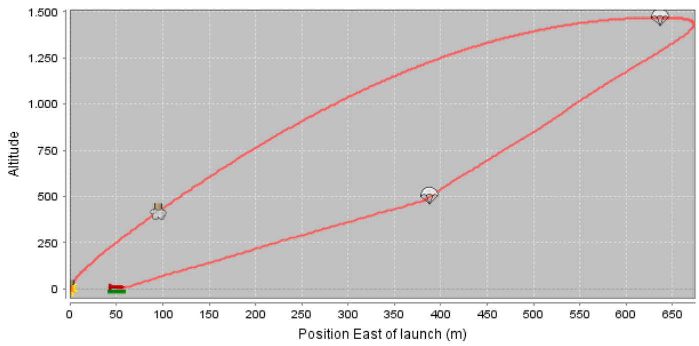

Figure 14. Position of East Launch of Simulation Results of ALP-01

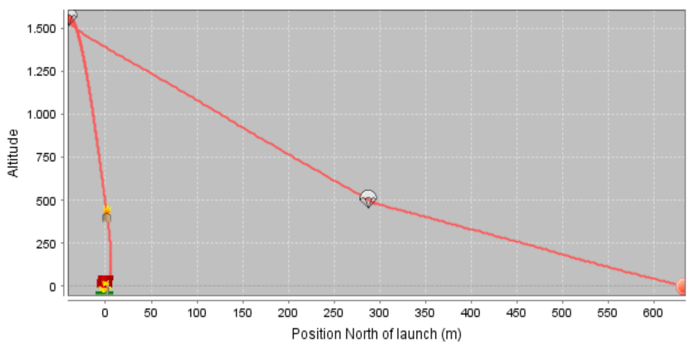

Figure 15. Position of North Launch of Simulation Results of ALP-01

As a result of the successful results achieved in the continuation of the studies, the idea of joining this competition occurred. Four times solid-fuel rocket engine trials, two of which were static tests, were conducted in the study stages. The fuel mixture used in the experiments (KNO_3 Sukroz/Dextrose) is located in the Mechanical Engineering Laboratory of Iskenderun Technical University in Figure 16.

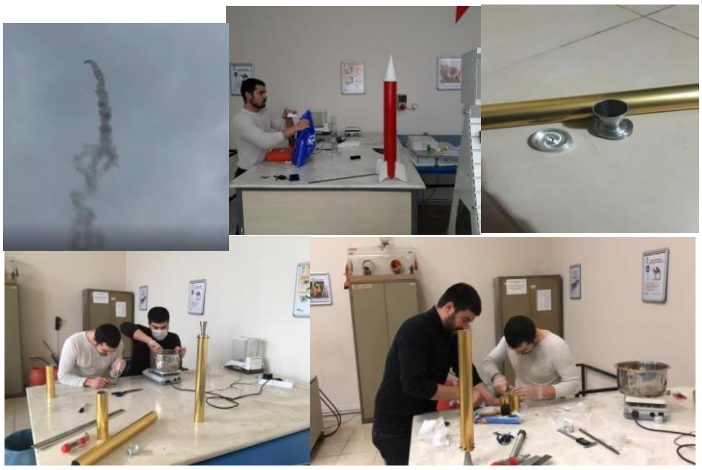

Figure 16. Manufacturing and Testing

4. Conclusions and Advice

The study was designed in a SolidWorks environment for ALP-01, a solid propellant rocket. The trust time graph of the L585 type solid fuel engine was taken into account when designing. Then the rocket sizes for the 1500m altitude were optimized in the Open rocket program. The body is planned to be made of carbon reinforced composite material for selection of smaller capacity motor. For this purpose, glass fiber reinforced composite pipe body has been manufactured and the feasibility of the composite body has been verified. A unique avionics system was designed for the system and a commercial flight computer was included in the system to measure its success. The rescue system is designed by selecting the GPS module for each of the separated parts of the rocket. In the continuation of the study, the entire system will be manufactured and mechanical tests of the body will be made. Then, the flight information of the rocket is planned to be tracked with an interface to be prepared on the computer. Then the whole system will be launched.

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