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Research Article

Obtaining of the Modal Frequency Parameters a Middle Class Armed Unmanned Combat Aerial Vehicle Using Engineering Simulation ANSYS Program

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Abstract

Baykar Bayraktar TB2 (Tactical Block 2) is a domestically armed unmanned aerial vehicle produced by Turkey-based Baykar Defense. It is accepted in the middle class armed unmanned aerial vehicle class with its dimensions and the amount of useful load it can carry. Medium UAV class is an accepted classification for UAV's that are too heavy to be carried by one person but still smaller than a light aircraft. There are also medium-sized UAV's with a rotary base. Unmanned combat aerial vehicle (UCAV), also known as fighter aircraft, colloquially abbreviated as drone, is an unmanned aerial vehicle (UAV) used for intelligence, surveillance, target designation and reconnaissance and carrying aircraft munitions. Drones can use missiles, ATGM's and/or bombs at fixed points for their attacks. Drones are often under real-time human control and have varying degrees of autonomy. Unlike unmanned surveillance and reconnaissance aircraft, SİHAs are used for both unmanned aerial vehicle attacks and battlefield intelligence. The solid model was used ready-made in 1:1 scale. All the parameters were obtained using the Rotax 912 engine with two blades used in the design of the primary models. Modal analysis is that the study of dynamic properties of systems below vibration. Accelerometers help calculate the vibration of the system when attached to a shaker. Modal analysis on aircraft emerges as the analysis of the vibration period and modes of the wind on aircraft. Analyzing the solid model according to the correct design criteria in the analysis program, making the correct simplifications, getting the mesh network properly and with success, directly have an affect on the accuracy of the modal analysis results.

Keywords: Defense and aerospace technologies, unmanned combat aerial vehicle (UCAV), bayraktar tb2, engineering simulation, ansys, mechanical engineering.

Orta Sınıf Silahlı İnsansız Muharebe Hava Aracının Modal Frekans Parametrelerinin Mühendislik Simülasyonu ANSYS Programı Kullanılarak Elde Edilmesi

Öz

Baykar Bayraktar TB2 (Taktik Blok 2), Türkiye merkezli Baykar Savunma tarafından üretilen yerli silahlı insansız hava aracıdır. Boyutları ve taşıyabileceği faydalı yük miktarı ile orta sınıf silahlı insansız hava aracı sınıfında kabul edilmektedir. Orta İHA sınıfı, bir kişinin taşıyamayacağı kadar ağır ancak yine de hafif bir hava aracından daha küçük olan İHA'lar için kabul edilen bir sınıflandırmadır. Döner tabanlı orta büyüklükte İHA'lar da vardır. İnsansız muharebe hava aracı (SİHA), aynı zamanda savaş uçağı olarak da bilinir, insanlar arasında drone olarak kısaltılır, istihbarat, gözetleme, hedef belirleme ve keşif için kullanılan ve uçak mühimmatı taşıyan insansız bir hava aracıdır (İHA). Dronlar saldırıları için sabit noktalarda füzeler, ATGM'ler ve/veya bombalar kullanabilirler. Dronlar genellikle gerçek zamanlı insan kontrolü altındadır ve değişen düzeylerde otonomiye sahiptir. İnsansız gözetleme ve keşif hava araçlarının aksine, SİHA'lar hem insansız hava araçları saldırıları hem de savaş alanı istihbaratı için kullanılmaktadır. Katı model 1:1 ölçekte hazır olarak kullanılmıştır. Tüm parametreler, ilk modellerin tasarımında kullanılan iki pallı Rotax 912 motoru kullanılarak elde edildi. Modal analiz, titreşim altındaki sistemlerin dinamik özelliklerinin incelenmesidir. İvmeölçerler, bir sisteme takıldığında sistemin titreşim frekanslarının hesaplamasına yardımcı olur. Uçakta modal analiz, uçakta rüzgarın titreşim periyodunun ve modlarının analizi olarak karşımıza çıkmaktadır. Katı modelin analiz programında doğru tasarım kriterlerine göre analiz edilmesi, doğru sadeleştirmelerin yapılması, mesh ağının doğru ve başarılı bir şekilde elde edilmesi modal analiz sonuçlarının doğruluğuna doğrudan etki etmektedir.

Anahtar Kelimeler: Savunma ve havacılık teknolojileri, insansız muharebe hava aracı (SİHA), bayraktar Tb2, mühendislik simülasyonu, ansys, makine mühendisliği.

1. Introduction

The medium UAV category includes UAVs that are too large to be carried by one person but are smaller than a light aircraft. They typically have a wingspan of 5-10 m and can carry payloads of 60 to 250 kg. The Israeli-US Hunter and the UK Watchkeeper are two examples of midsize fixed-wing UAVs other brands that have been utilized in the past include the US Boeing Eagle Eye, the RQ-2 Pioneer, the BAE systems Skyeye R4E, Baykar Bayraktar TB2, and some specifications of medium class UCAVs as the RQ-5A Hunter. The Hunter has a wingspan of 10.1 meters and a length of 6.8 meters. At takeoff, it weighs around 895 kg. There are also a handful of medium-sized rotary-based UAVs (Limnaiois, G., et al., 2012), (Naidu Y.,et al., 2014).

Baykar designed and built the Bayraktar TB2 Tactical Armed / UAV System. A very advanced design that delivers all solutions required by the operator in a single integrated system. The complete system is created in-house thanks to Baykar's technical accumulation and skills (Yiğit E., et al., 2018).

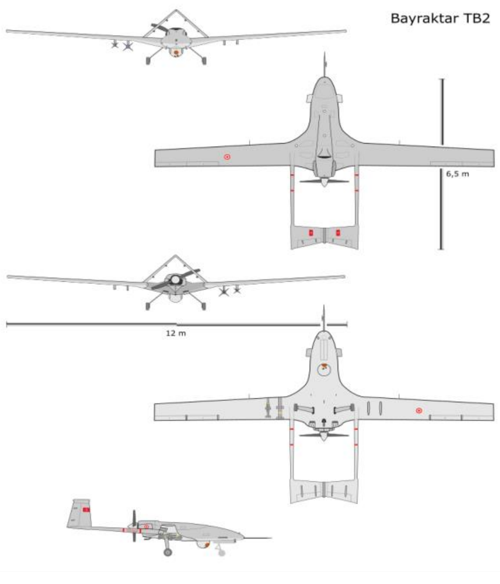

Figure 1. Bayraktar TB2 technical drawing images.

The Bayraktar TB2 is a Medium Altitude Long Endurance (MALE) Tactical Unmanned Aerial Vehicle capable of conducting ISR and armed assault missions. An onboard avionic suite with a triple redundant avionic system consists of modules that allow for completely autonomous taxiing, take-off, landing, and cruising. TB2 has shown its effectiveness. It has been effectively carrying out operations inside the Turkish Armed Forces, Gendarmerie, and Turkish National Police since 2014. At the moment, 257 Bayraktar stations are serving Turkey, Qatar, Ukraine, and Azerbaijan. Bayraktar TB2 holds the endurance altitude records in Turkish aviation history. The Bayraktar TB2 is also the first aircraft in its category to be shipped outside of the country.

It is regarded as one of the most significant achievements of Turkey's defense and aerospace industries. It had been shipped to 19 countries as of March 2022. Baykar Bayraktar TB2 (Tactical Block 2) is an armed unmanned aerial vehicle manufactured by Baykar Defense in Turkey. In the fully loaded flight test on June 14, 2014, it achieved a height of 27,030 feet (8,240 m), and in the flight test on August 5-6, it went 4040 kilometers at an altitude of 18000 feet (5,500 m) in 24 hours, 34 minutes. completed a flight It was able to hit targets with 100% accuracy during a fire test on December 17, 2015, with two Roketsan MAM-L guided missiles loaded.

It was actively utilized by the Turkish Armed Forces in Claw Actions, as well as military operations during its participation in the Syrian Civil War and the Second Libyan Civil War. He also served in the Azerbaijan Air Force during the 2020 Nagorno-Karabakh War. Bayraktar TB2s neutralized 535 of the 772 objectives eliminated by the Azerbaijan Army during this operation (Daglık Karabag, 2020). Bayraktar TB2 caused more than a billion dollars in damage to Armenia during the Nagorno-Karabakh War.

The cumulative number of flying hours in difficult conflicts and operations using the Bayraktar TB2 has surpassed 500,000 (Bayraktar Tb2, 2022). In summary, the Bayraktar TB2 has become the Turkish-made UCAV, that has served the longest in the skies.

2. Material and Method

2.1. ANSYS

ANSYS is a computer-aided engineering tool that allows for analysis and simulations in computer-assisted engineering research. The ANSYS program enables efficient research in a variety of areas, including mechanics, structural analysis, computational fluid dynamics, and heat transfer. The finite element approach is employed by the ANSYS software, which is one of the most widely used CAE(Computer Aided Engineering) applications in our nation and throughout the world. Separate analysis of things with complicated geometry that are difficult to analyze in one piece using the finite element method by breaking them into tiny and many portions. The findings of an analysis of a finite number of elements are merged to provide a single and consistent analysis result. ANSYS Mechanical can evaluate objects in complicated architectures. This application replicates the real-world behavior of components and subsystems using the finite element approach to get realistic results. ANSYS can perform research and analyses on both fluid and solid models. ANSYS Fluent can model not just liquids, but also gases and semi-fluids. The ANSYS application can readily model air flow over aircraft wings, circulation systems in living things, flow in turbines, and water flow in building installations. This study's numerical findings were produced using the ANSYS 2019 R2 and ANSYS 2021 R2 versions (Özgen S., 2017).

2.1.1. Finite Element Model (Mesh Results)

Mesh manufacturing is used in a variety of technical applications. Its primary application is in the finite element technique. Surface definition ranges include triangles, quadrilaterals, and so on. While it is possible to split volumetric definition intervals into forms such as tetrahedra and hexahedra. Automatic mesh creation techniques define the form and distribution of the components. Finite Element Approach (FEM) is a numerical method and a technology with advanced application fields that uses computers to solve problems in solid mechanics, fluid mechanics, heat transport, and vibration. Models are partitioned into a finite number of elements in the Finite Element Method (FEM). These pieces are linked to one another at specific sites known as nodes. The Finite Element Method is used to try to solve displacements in these nodes. As a result, the stress is about equivalent to the imposed load. These nodes must be fixed at specific places in order to be stationary.

The Finite Element Method converts the stated conditions for the joint locations into algebraic linear equations, which are then solved to determine the real stresses in all members. As a result, the more elements the model has, the more accurate the output will be based on the stress given to that piece. The model is partitioned into tiny elements when the element attributes are determined. So the model has been meshed. What matters here is how you use the selected element to better divide the model into smaller sections. Some package applications will accomplish this for automatically. In the meshing of a single-engine civilian aircraft, for example, it is common to utilize 10 million components against about 1.5 million nodes (Wandono F.A., et al., 2020), (Weibel, Roland E., 2002) (Turgut T., 2018).

Mesh values were derived in a solid model 1:1 scale using the actual measurement values supplied in the article (Figure 1). The mesh structure with full load is as follows. After the necessary simplifications are completed; The detailed Mesh has been successfully obtained in the Figure 2. A total of 329482 meshes were detected in the mesh structure below.

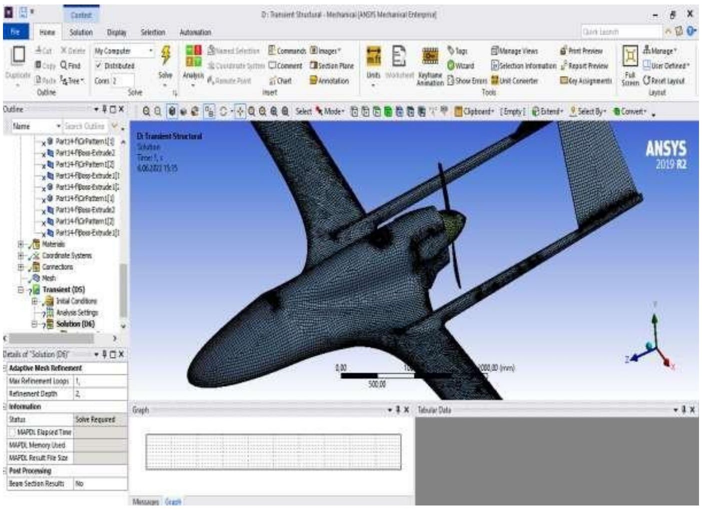

Figure 2. Bayraktar TB2 Solid Model after simplification, detailed mesh structure (with ANSYS 2019 R2).

Table 1. Obtained Modal Frequency Parameters

Parameters No	Modal Frequency
1.	0 Hz.
2.	$6.391.10^{-5}$ Hz.
3.	$2.8722.10^{-4}$ Hz.
4.	0.36298 Hz.
5.	0.50623 Hz.
6.	0.72167 Hz.
7.	3.9566 Hz.
8.	7.005 Hz.
9.	9.6974 Hz.
10.	10.022 Hz.
11.	13.576 Hz.
12.	13.814 Hz.

3. Results and Discussion

The study of dynamic characteristics of systems under vibration is known as modal analysis. When connected to a shaker, accelerometers assist determine the system's vibration.

Modal analysis in aviation may be calculated by computing the vibration period and wind modes on aircraft. Modal analysis is the process of establishing the factors (such as natural frequency, vibration pattern, and internal damping) required to develop a mathematical model of a vibrating system's dynamic behavior (Wandono F.A., et al., 2020).

Every object has a natural frequency (also known as a resonant frequency) at which it may vibrate. This frequency is also the frequency at which the item allows energy to be transferred from one form to another with the least amount of loss (here from vibration to kinetic). The amplitude of the system's response rises asymptotically to infinity as the frequency approaches the resonant frequency. In other words, modal analysis determines the frequency at which the amplitude reaches infinity. Modal analysis is used to describe the system's inherent frequencies and mode shapes, to evaluate the connections between the components if there are stiff modes in the system, to assess whether the system's limitations are proper, and to determine the system's behavior under dynamic loads.

The data from the modal analysis report was successfully collected using the ANSYS application. The screenshots above include Modal Analysis Reports. For the first six modes, a value of around 0 (zero) was achieved. The modal frequency valuesobtained for the first 12 modes are in the table 1.

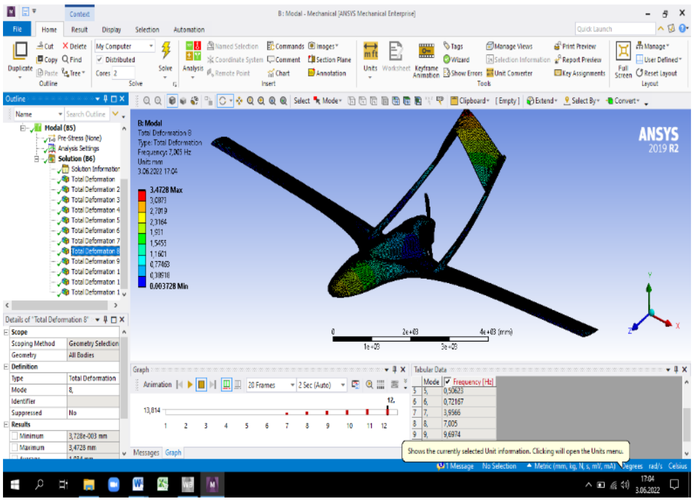

Figure 3. Modal Analysis Report Bayraktar TB2 (8.Mod).

While performing modal analysis with the finite element method, it is critical to create a model in the size and shape that best depicts the system's mode forms. To properly calculate the natural frequencies and mode forms at these frequencies (bending, torsion mode, etc.), the elements must represent the geometry in the best way possible (Tunca C., 2018).

Thanks to the modal analysis parameters; prior to dynamic analysis, we may enhance working circumstances by boosting the system's natural frequency values (Unay E., 2015).

Modal analysis also plays an important role when dynamic analysis needs to be compared to physical tests. It allows to identify the right equipment and the right place to be used for accelerometers and strain gauges. It helps to understand the test results and associate the virtual model with the prototype during testing (MIL-STD-810H, 2019) (Technion IIT, 2016).

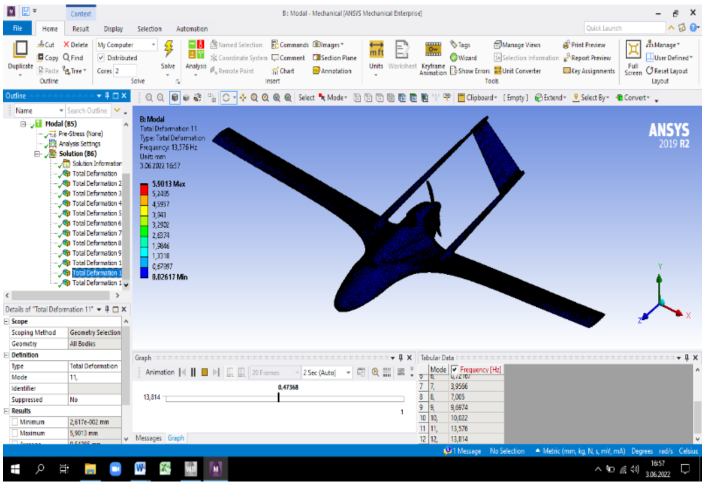

Figure 4. Modal Analysis Report Bayraktar TB2 (11.Mod).

Modal analysis provides an overview of the limits of a system's responses. For example, it gives a general answer to the question of what are the limits of the system response (like when and how much maximum displacement) for a given input (like a load applied at a given amplitude and frequency).

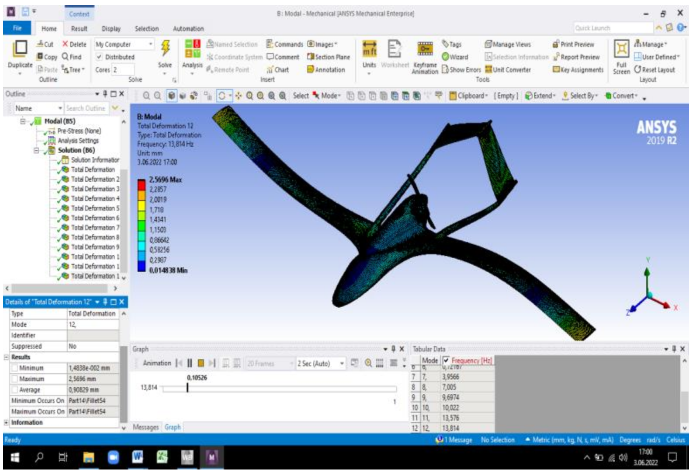

Figure 5. Modal Analysis Report Bayraktar TB2 (12.Mod).

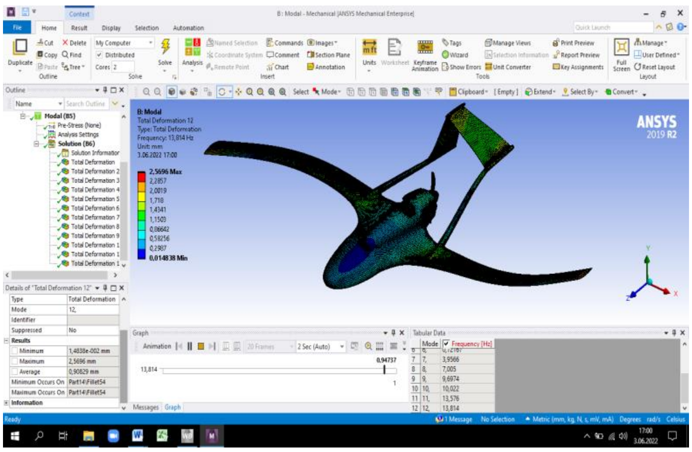

Figure 6. Modal Analysis Report Bayraktar TB2 (12.Mod)

4. Conclusions and Recommendations

The outcomes of my investigations in ANSYS 2019 R2 (My Own Laptob) and ANSYS 2021 R2 Karatay KTO University Engineering Faculty Numerical Analysis Laboratory are as above. There were initially delays owing to first CAD model selection. The shell model could not produce the intended outcomes. Then, with success, robust result analyses at a 1:1 real scale were produced.

The results acquired from the modal analysis, in particular, are of academic and very good quality. In static structural analysis, successful findings were achieved with a load factor of 6g. The g (load factor) of the Bayraktar TB2, which I believe is a trade secret, was not found in any source. Bayraktar's g factor, in my opinion, is between 4.5 and 5.5 g. The computations, however, were performed using the closest number (6g) supplied in the sources. 100 m over the Aegean Sea calculated using fluent flow analysis using 2400 RpM rotation and wind maps. At height, limit values of 17.8 m/s were utilized.

5. Acknowledge

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