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Design and Implementation of A Three-Wheel Multi-Purpose Electric Vehicle with Finite Elements Analysis

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Abstract

With technological developments and carbon emission reaching dangerous levels in the world, it is inevitable that electric vehicles will become the dominant transportation technology of the future. Studies on electric vehicles have become very popular today. In the automotive sector, sectoral dynamics and needs are rapidly changing; restrictions and demands are bound by strict rules and high value-added innovative studies are applied intensively. Supporting this area with academic data will contribute to research and development activities in this field. In this study, analysis and production studies were performed on a 3-wheeled vehicle chassis driven by electric energy. The chassis structure was designed and analyzed with details. The chassis aimed to be produced as a result of the study was analyzed in detail according to brake, modal and cornering analysis. As a result of these analyses, it was found that this chassis has a reliable structure according to the specified driving dynamics parameters. By adopting new requirements, technologies and analysis outputs for the system, a modular platform structure that can be used for various applications were created. The design and production processes of an innovative and applicable chassis structure for the electric vehicle ecosystem are given in detail.

Keywords: Electric vehicle, ANSYS, Finite elements method, Chassis design, Stress analysis, Natural frequency.

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1. Introduction

Today, a significant part of the world's energy needs is met by fossil energy sources such as coal, natural gas and oil. The more population of countries rises, the more passenger vehicles are used. Due to the rising number of vehicles, the need for fuel increases as well. The need for alternative and renewable energy sources is an inevitable fact both in order to balance the fossil fuel production/consumption rate and to take measures in situations that may cause significant long-term environmental downsides such as global warming [1]. 20% of the carbon dioxide (CO2) gas emissions of European Union countries are caused by road transport [2]. The polluting effect of the fossil fuels on the atmosphere and the rapid rise on the amount of CO2 gas has resulted in the need to develop alternative fuels for road vehicles and accelerated the transition to electric vehicle technology. Studies for this purpose not only present predictions on the environmental damages of fossil fuels but also reveal the necessity to take measures in the light of these predictions.

The number of electric vehicles in Turkey is approximately 1,150 units and the number of hybrid vehicles is around 15,000. According to TURKSTAT data, the number of electric and hybrid cars was 1,685 in 2017 and 5,367 in 2018. The number of electric and hybrid vehicles used in 2019 was 14,115 units, tripling that of2018. Considering this data, the number of electric cars is expected to increase significantly in the coming years (Figure 1) [3].

In parallel with the spread of electric vehicles, new production technologies have been developed as well. The design and production processes of chassis for electric vehicles are one of them. The main structural element of the vehicles is the chassis. Thus, the design procedure of the chassis is vital for vehicles. The chassis is a structure that carries both the load applied in the vehicle and the weights of the vehicle. The chassis is expected to be light, environment friendly, and should safely carry the loads it is exposed to with longevity. The research indicates that electric vehicle chassis is the most important feature worked on for being light and durable. In this study, producing a low cost and compact three-wheel multipurpose electric vehicle is aimed in order to comply with the micro mobility, which is becoming more popular in the field of transportation due to its efficiency, low production and fuel cost.

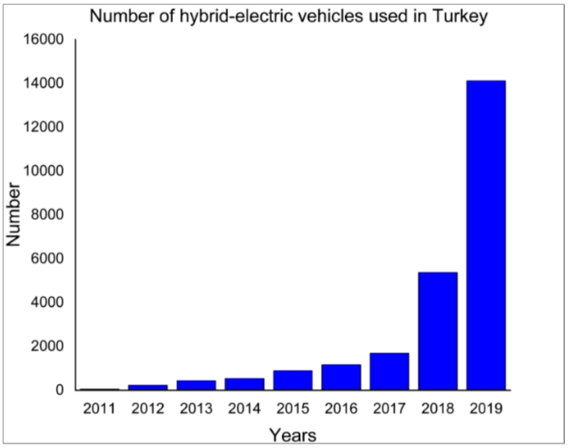


Fig. 1. Number of hybrid-electric vehicles used in Turkey [3]

Use of electric vehicles has been common the most in European countries. Only electric vehicles were used more widely in European countries until 2012, but interest in hybrid-electric vehicles also increased due to the limited number of electric vehicle models. The number of electric and hybrid vehicles in European countries is given in Figure 2 [1, 3].

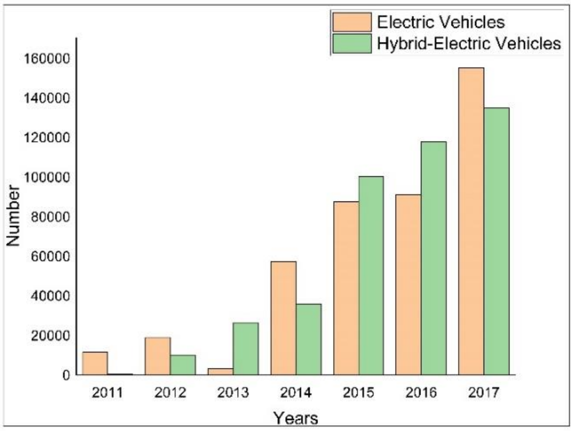


Fig. 2. Number of hybrid and electric vehicles used in Europe[1]

As shown in Figure 2, electric vehicles and related theoretical and practical applications together with development studies will be of increasing importance in the upcoming years. In this study, a chassis design was studied for use in the 3-wheel, electrically driven, freight and passenger transportation. The design boundaries of the chassis were determined and safety analyses were carried out to identify the safety coefficient of the chassis by selecting materials and batteries taking into account the weight of the vehicle. Chassis analysis; structural analysis, corner analysis and brake analysis were carried out and then prototype production of the chassis, which was proven to be reliable with detailed analyses, was performed.

In this study, some general designs based on different road loads and deformation modes as well as reseal-measured suspension connections were studied. In the study, which developed a simple mathematical model to get an idea of the design objectives suitable for the vehicle structure and compare structural hardness with suspension hardness, a finite element model was created for both the stand-alone frame and the entire chassis/suspension, taking into account these hardness targets, and this model was analyzed with ANSYS software [4].

In Cinali's 2012 study, an analysis of the vehicle produced by the university was carried out. First of all, the vehicle was modeled in 3D in CAD and the chassis, which was designed in 3D, was analyzed with the finite element method. As a result of the analysis, critical areas of the chassis were determined according to stress and deformation values, the safety coefficient and natural frequency value of the chassis were calculated [5]. Mat and Ghani's research conducted in 2012 carried out a light chassis development for "Eco-Challenge" race cars that could safely withstand loads and compulsions. Chassis analysis was carried out by addressing normal car loads such as engine and driver weight, acceleration, braking and cornering forces. When the results of the analysis were examined, it was seen that the chassis supported most loading conditions [6].

In the study conducted by Agrawal and Razik (2013), studies examining car chassis with different analysis techniques were reviewed. It was observed that there are many analytical and experimental techniques for the analysis of automobile chassis, studies such as fatigue analysis, static analysis and dynamic analysis were carried out [7]. In the 2013 study of Patil and his friends, stretching analysis was performed with the finite element method of the stair type low loader truck chassis consisting of C-beam design for 7.5-ton application. The thickness of the side element, the thickness of the intermediate element and the position of the inter-mediate element from the rear end were changed to achieve a reduction in stress size at the critical point of the chassis frame. Numerical results showed that changing the position of the inter-mediate element could be a good alternative if a change in thick-ness was not possible [8].

In 2014, Zeina Bitar and Samih Al Jabistudied the suitability of the use of an IM and a Field Oriented Control (FOC)-based inverter in electric vehicles. As a result of their work, they proved that the use of asynchronous motors in electric vehicles is appropriate [9].

Babaarslan's 2014 study investigated the design and production of an optimal vehicle for an M1-class electric sports vehicle with the help of analyses and tests. This vehicle design is planned to be a faultless, world-class vehicle by carrying out production controls [10]. In the 2015 study conducted by Contractor and his friends, the Eicher 11.10 model car chassis design and the finite element analysis of the chassis were performed. The results of the analysis were observed to be well below the allowed values and it was decided that the chassis had safety [11].

In 2015, Yılmaz examined DC motor, induction motor, permanent magnet synchronous motor (PMSM) and reluctance motors used in plug-in electric vehicles (PEVs). As a result of its review, PEVs stated that the perfect solution for vehicles is PMSM due to its advantages such as high efficiency, low volume and weight, good field-weakening capability, torque contribution of reluctance. However, the high cost of PMSMs and continuing developments in magnet technology were found to be the disadvantages of this topology. For this reason, the author stated that IMs and PMSMs are commonly preferred as driving power in PEVs today [12].

In the 2015 study conducted by Makhrojan and his friends, chassis was redesigned and analyzed to restore strength to an electric city car chassis. The chassis design was carried out with the Solidworks program, and the analysis was performed using the final element simulation software. As a result of the analysis, it was determined that the frame was still under the elastic zone until the monocoque frame design was safe to use [13]. The 2015 study by Ekapun and his friends designed a new body of the modern electromagnetic tricycle to travel at a zero-emission airport. Automotive dynamics theory and a brushless DC motor were used in the design of the electromagnetic wheels of the tricycle. Additionally, a design chassis was developed using ABAQUS with dynamic analysis based on the chassis of an existing golf cart model. Finally, a 3D printing prototype was produced to realistically represent conceptual design and verify the functionality of the final design on a small scale [14].

In a 2016 study by Yang and his friends, testing and analysis were conducted for a Honda Accor PHEV, which have a serial-parallel powertrain. NEDC cycle test, dynamic acceleration test and static navigation test completed in a four-wheel-drive chassis dynamometer at the China Automotive Engineering Research Institute Power transmission system configuration design, control strategy and fuel economy of the vehicle were analyzed and the results showed that the serial-parallel configuration had the potential to reduce transmission mechanical losses and that serial operating mode tended to be more efficient in most operating conditions [15].

The 2017 study by Trovão and his friends studied the integration of a Super Capacitor (SC) package in a three-wheeled electric vehicle, taking into account the energy and power division management strategy. An energy management strategy based on a comprehensive fuzzy logic checker approach was implemented to improve the global efficiency and performance of the vehicle under review. The proposed control and management strategy made it possible for the battery to meet an average portion of power demand, while the energy level of SC's can be intelligently controlled. The proposed strategy was presented as an easily integrated strategy to other vehicles or different driving modes. The approach was implemented with power-level in-cycle hardware (HIL) platform for a reduced scale hybrid dual energy storage system [16].

In 2018, in the study of Savkin and his friends, structural analyses of car suspensions were carried out taking into account the different nature of the road surface. Loading spectrums on this construction were obtained according to the dynamic model made in the FRUND program. The possibility of replacing the material of this structure, which provides the necessary strength and fatigue properties of the structure, with the cheaper one [17].

In the 2018 study of Kurdi and his friends, vibration characteristics of the electric bus chassis and natural frequency and mode were determined. Three materials in various thickness measurements were used for the design and they were simulated with the help of the Abaqus program. As a result of the analysis, 6-mm-thick AISI 4130 Alloy steel was selected as the best model with less resonance probability [18]. In the 2018 study conducted by Sutisna and Akbar, an electric vehicle chassis design was made. A FEM simulation was used to simulate the different load and reaction on the designed chassis. Von-Misses Stress, safety factor, bending, torsional slip voltage and vibration analysis were performed with the help of ANSYS program. As a result of the analysis, it was found that the designed chassis worked well and was within safe zones [19]. A 2018 study by Ding and his friends described a common chassis control system for electric vehicles that controls longitudinal motion based on deviation movement. This system can be used to improve the agility and stability of the vehicle using the integration of the torque distribution unit and electronic stability control (ESC). In addition, this system can help drivers navigate a bend smoothly prior to ESC intervention [20].

In 2018, another study conducted by Arifurrahman and his friends modelled and analyzed the developing three-wheeled electric vehicle chassis for the delivery of goods. Three different types of Alpha chassis were examined, and their amplitudes and natural frequencies were determined thanks to their dynamic analysis. As a result of the study, the Alpha 2 framework did best [21]. In 2019, Gürel and his friends conducted a study of the parameters necessary to optimize electric vehicles; engine selection, design criteria, battery sizing and energy management. In the study, especially the battery problem of electric vehicles was emphasized. Basic problems with the battery; high cost, weight problem and long charging problem were handled in three main sections[22].

In the 2019 study conducted by Tsirogiannis and his friends, an integrated methodology of developing an electric car chassis was demonstrated. The main criteria for the development of the electric car chassis are the elimination of cost and time, as well as an increase in hardness and strength, which is subject to mass reducing. They designed a chassis in accordance with the regulations of the Shell Eco Marathon competition. With the designed chassis FEA method, the condition of the chassis under stress was examined with ANSYS program. Thus, the chassis design was realized with an accurate ultra-fast and cost-effective method [23]. A structurally balanced chassis was designed for an electric motorcycle in a 2018 study by Joel et al. simulated the real-time forces on the chassis and suspension geometries. In the simulation, the voltage, safety factor and deformation of the same structure were compared with different materials in accordance with the strength, cost and weight of the chassis to determine the material most suitable for the chassis [24]. In 2019, Harušinec and his friends emphasized the importance of the material in the three-wheeled vehicle chassis design study and aluminum material was selected to make the vehicle light. Safety criteria were determined by analyzing the designed chassis [25].

27 works in 2019 featured a lightweight chassis design. A combination chassis consisting of both steel and carbon-carbon composite components (CFRP) was created by replacing heavy steel cross elements with CFRP cross-elements, resulting in a 14.6% reduction in weight. Collision analysis was performed on all cases using Radioss and the most suitable chassis combination was selected depending on the result obtained from the collision analysis and the torsion, cornering hardness values. In combination chassis, weight was further reduced by 7.91% [26]. In the 2020 study of Sánchez and his colleagues, an iteration algorithm was proposed, during which a path and reference period were given to determine the chassis that best suited to electric vehicles. Thanks to the proposed methodology, battery weight was reduced by about 20% compared to normal designs [27]. In the 2020 study conducted by Nandhakumar and his friends, an electric motor-powered bus chassis design was made. Aluminum alloys were used for the design of the chassis, reducing chassis weight but not compromising safety. Structural analyses of the designed chassis were carried out with the help of an ANSYS program [28].

In the 2020 study of Chandramohan et al., they aimed to transform the internal combustion Go-Kart engine into an electric-powered engine. They indicated that the Go-kart chassis, powered by an electric motor, has a more complex structure than the chassis used in the internal combustion engine and that some changes are required for the conversion. Both chassis were designed by Solidworks program, and analyzed for different types of impacts with the help of ANSYS program. As a result of the analysis, load distributions and deformation results were compared [29]. In the 2020 study of Krishnamoorthi and his friends, electric Go-Kart design and analysis calculations were made. The main purpose of the study is to obtain a light and high-performance electric vehicle. AISI 1018 was found to be suitable for the vehicle material. The SolidWorks program was used to design the chassis. With the ANSYS program, deformation and equivalent stress were found by analyzing the front, rear and side impacts of the chassis [30].

In the 2020 study conducted by Saplinova et al., the design and test results for the main passive safety feature of Formula type open-wheel racing cars and tubular space frame chassis were examined. A chassis strength analysis, results of front and side impact tests and torsional stiffness calculations were performed for the chassis of a racecar used by the team representing Shukhov Belgorod State University of Technology [31]. Mohammed empirically addressed this interim connection by analyzing the application of an electric vehicle designed and built by automotive engineering students at the Technical University of Munich (TUM) in Germany. The students designed the tool to address mobility issues for rural populations in Africa and aimed to provide better access to local people's living needs such as health, education and transport [32].

In the 2020 study of Shantika et al., the chassis design of a crossover vehicle was made. In the chassis design process, stress analyses were carried out to determine the stresses formed on the chassis. The design was done in CAD program and the analysis was performed using FEA SolidWorks analysis. As a result of the analysis, the safety factor of the vehicle chassis was found to be 1.69 [33].

In this article, the first chapter discusses the studies about the use of electric and hybrid electric vehicles usage both in Turkey and worldwide. In the second part, material selection and necessary equipment for the chassis design of the electric vehicle was determined. The reliability of the chassis is explained in the third section, was determined by making modal, brake and cornering analyzes. Electric vehicle chassis production presented as a result of the analysis was given in the fourth chapter. Finally, the result was discussed in the fifth chapter.

2. The Design of Multi-Purpose Electric Vehicle Chassis

Engineering design is an approach in which basic concepts such as functionality, reliability, manufacturability, usability, and cost of the resulting product are dealt with [34]. In this study, a design with minimum cost and maximum safety has been introduced by using an engineering approach. Factors affecting the chassis design are shown in Table 1.

Table 1. Factors affecting chassis design

Passengers and load safety
Chassis Manufacturing
Easy removal and installation of parts during assembly process
Ease of manufacture (Technology compatibility)

While designing the chassis, criteria such as passenger safety, ease of manufacture and technology compatibility were taken into account. The ladder type chassis was chosen as the chassis type to be designed. Figure 3 shows the ladder type chassis visually. This type of chassis is a frequently used in production and used mainly as automobile and truck chassis today [35].

Fig. 3. Ladder type chassis [35]

In cases where the chassis is desired to be light, aluminum is used as the frame material [26]. However, being an unsafe frame structure, it is risky for load, passenger and navigation safety. In this study, steel (St 37) with higher strength values than aluminum was preferred because safety was at the forefront as chassis material, see Table 2.

Table 2. Mechanical properties of the material (St 37) to be used

Material	Density (kg/m3)	Yield Strength (MPa)	Tensile Strength (MPa)
St-37 Steel	7850	235	360

The three-wheeled chassis is a new intelligent transport system that is a more convenient alternative to the mobility of the vehicle than other four- and two-wheeled vehicles [36]. The vehicle is designed to carry two passengers in the rear seat and one driver in the front seat, single and three-wheeled. The driver will be carried at the front and the load will be carried in the rear cab. Because the designed vehicle is three-wheeled, driven by an electric motor, and its design speed is lower than 45 km / h, it is classified as a three-wheeled moped, namely L2e, according to the vehicle classification criteria. General features of the L2e class vehicle are given in Table 3.

Table 3. L2e class vehicle features

Driven by three wheels and electric motor
The maximum design speed of the vehicle ≤ 45km / h
Maximum drift rated power or net power ≤ 4000W
Mass in walking position ≤ 270 kg
A maximum of two seats, including the driver's seat

High torsional rigidity chassis are obtained when empty sections are used in longitudinal and transverse carriers. Closed empty sections are used in longitudinal and transverse carriers and they have a high mass, high cornering, and torsional strength moments. The profile to be used in the chassis was selected as a 40x40 closed empty section, see Figure 4. The chassis design performed using the 40x40 empty sections is shown in Figure 4. Welded condition is showed in Figure 5.

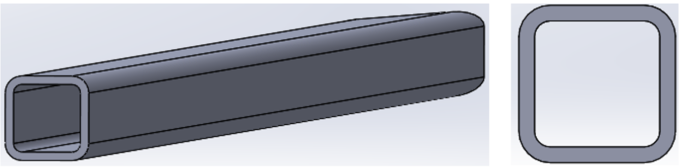


Fig. 4. Profile used in chassis design

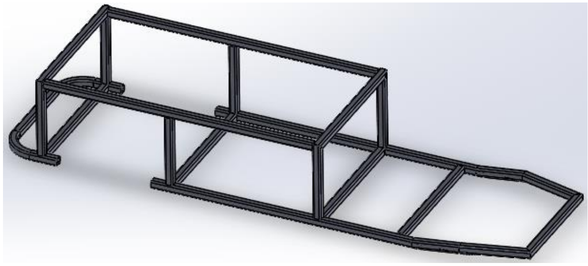


Fig. 5. 3D Model of designed chassis.

Suspension systems are used to dampen or minimize loads that provide the connection between the chassis and the wheels and they have a chassis effect. Thanks to suspension systems, both vehicle and driving become more stable, making the car easily adapting to harsh road conditions. The suspension system consists of four different sections: the suspension that connects the car body to the chassis, the suspension that connects the steering system to the chassis and the suspension system that connects the front and rear wheels to the chassis. These suspension systems work in coordination with each other [22]. In this study, these four different suspension systems mentioned above were used in the vehicle designed in this study, see Figure 6.

Fig. 6. Vehicle suspension systems

When the preferred motor topologies in electric vehicles are examined historically, the DC motor can be listed as Induction Motor (IM) and Permanent Magnet Synchronous Motor (PMSM). Today, electric vehicles on the market mostly use IM or PMSM with mechanical single-rate differential system [37]. PMSMs have started to be preferred in electric vehicles in recent years due to their high efficiency, high torque and power densities. The reason why PMSMs have this advantage is because of the high energy density neodymium magnet used in their rotors. However, the high cost of neodymium magnets and the large disadvantage of PMSMs is that almost all of the neodymium reserves are in China [38].

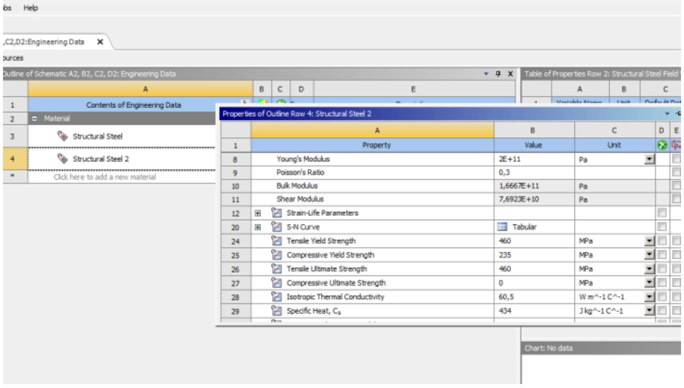
Table 4. Properties of the motor used in the study [40]

Rated Frequency	135 Hz
Rated Speed	3900 d/d
Rated Stress	28 V
Working Regime	S2-60 min.
Rated Power	4 kW
Connection Type	B9/A flanged
Isolation Class	F/155°C
Temperature Sensor	KTY 84-130

IMs are the most preferred electric motor topology not only in electric vehicles but also in all applications due to their simple and robust structure, high efficiency at high speeds and the ability to produce high maximum torque similar to PMSMs [38-39]. IMs are also the most preferred motor topology in light electric vehicles due to their smooth operation at high temperatures and low costs depending on the insulation class. Thanks to the advantages indicated in the electric vehicle, which is analyzed and manufactured, the given IM specifications in Table 4 are preferred. Electric vehicles commonly use lead acid, nickel cadmium, nickel-metal hydride, lithium-ion, lithium-ion polymer battery technologies [41]. Lithium-ion-based batteries have a high energy and power density, which is the type of battery that global electric vehicle manufacturers such as Tesla, AUDI and Volkswagen benefit from in solving range-weight problems. However, another aspect that is at least as important as the range-weight problem in L2e class electric vehicles is the cost. For this reason, gel batteries, a type of lead acid battery, are used in light electric vehicles because they are durable and cost-effective with a maintenance-free and deep discharge cycle. The path taken by an electric vehicle depends on the type of battery used and the number of batteries used [18].

3. The Finite Element Analysis of Vehicle Chassis Design

Stress distribution in chassis design is one of the most important factors in determining the safety coefficient of the chassis. In order to determine the safety coefficient, it is required to have stress distributions that will occur as a result of the forces affecting the designed chassis. The 3D chassis model designed for chassis analysis was transferred to the ANSYS finite elements package program. Material mechanical properties were defined to the program from ANSYS Engineering Data, see Figure 7.



	A
1	Contents of Engineering Data
2	Material
3	Structural Steel
4	Structural Steel 2
*	Click here to add a new material

Properties of Outline Row 4: Structural Steel 2

	A	B	C
1	Property	Value	Unit
8	Young's Modulus	2E+11	Pa
9	Poisson's Ratio	0,3	
10	Bulk Modulus	1,6667E+11	Pa
11	Shear Modulus	7,6923E+10	Pa
12	Strain-Life Parameters		
20	S-N Curve	Tabular	
24	Tensile Yield Strength	460	MPa
25	Compressive Yield Strength	235	MPa
26	Tensile Ultimate Strength	460	MPa
27	Compressive Ultimate Strength	0	MPa
28	Isotropic Thermal Conductivity	60,5	W m^-1 C^-1
29	Specific Heat, C_p	434	J kg^-1 C^-1

Fig. 7. ANSYS engineering data.

Finite element analyzes were modelled in 3D using the "Static Structural" module of ANSYS Workbench software. The chassis designed in the SolidWorks program was saved in the "Parasolid" format. Then it was transferred to the ANSYS Workbench program and the finite element model was created by mesh. As a finite element type, a 3-dimensional 10-node structural solid type tetrahedral element wasused. The mesh consists of 51,872 element and 118,245 points. The net mesh on the chassis is shown in Figure 8.

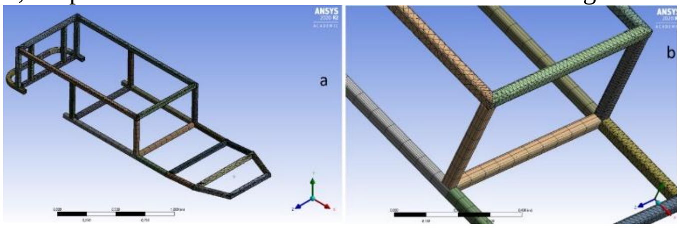


Fig. 8. Chassis mesh image. a) General view, b) Close view.

3.1 Modal Analysis of Chassis Design

Modal analysis was made to determine the natural frequency of the chassis. The main purpose of doing this analysis was to see the dynamic response to reach a vibrational result and to express this answer in a mathematical model. Modal analysis was done for the first 10 modes of vibration. The deformation and natural frequency obtained for 10 modes are given in the tables.

Table 5. Chassis natural frequency and deformation values

Mode	Natural Frequency (Hz)	Deformation (mm)
1	20,226	7,709
2	23,401	9,164
3	37,955	6,061
4	50,252	7,303
5	58,248	7,853
6	59,664	7,332
7	68,006	6,387
8	86,796	8,821
9	101,23	8,626
10	103,99	10,65

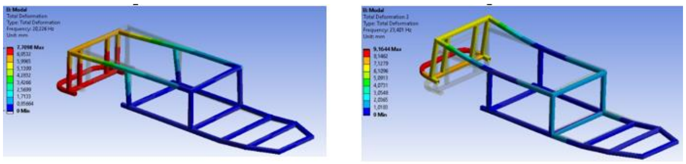


Fig. 9. a) Mode 1, b) Mode 2

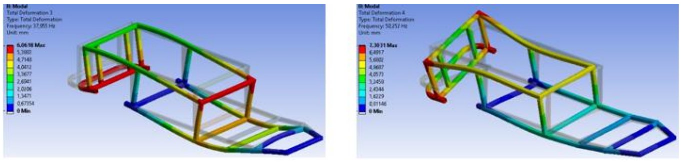


Fig. 10. a) Mode 3, b) Mode 4

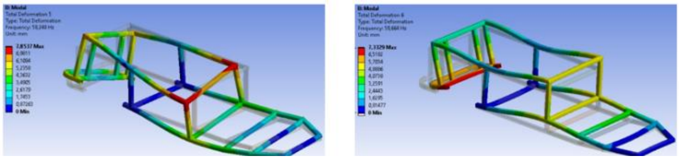


Fig. 11. a) Mode 5, b) Mode 6

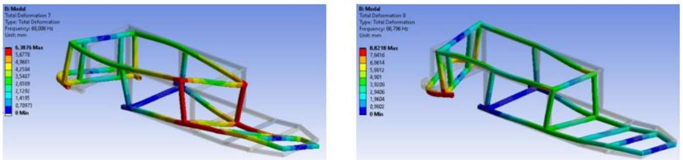


Fig. 12. a) Mode 7, b) Mode 8

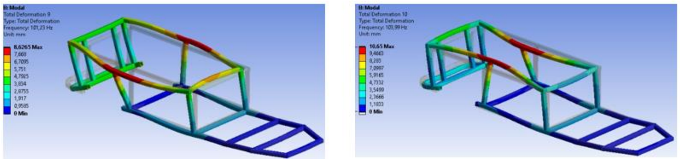


Fig. 13. a) Mode 9, b) Mode 10

As shown in Table 5. and Figure 9-13, the resulting stress and deformation values were significantly small and did not cause plastic deformation on the chassis.

3.2. Brake Analysis and Chassis Design

Braking analysis was carried out in order to examine what changes would occur on the vehicle chassis when a sudden brake occurred with the vehicle. While calculating the brake acceleration, the stop time and the maximum speed of the vehicle were taken into account. The stop time of the vehicle varies depending on personal and environmental conditions and it is between 0.3-0.7 seconds on average [42]. When the maximum speed of the designed vehicle was 45 km / h and the vehicle stop time was 5 seconds, the braking acceleration was calculated as 2.5 m / s2.

The forces acting on the chassis; The effects of the driver, passengers and / or load, battery, engine weights and braking acceleration planned to be transported in the trailer part were considered in the chassis analysis. The forces acting on the chassis are given in Table 6. The chassis was fixed from the wheel parts and the forces and braking acceleration acting on it are shown in Figure 14.

Table 6. Forces acting on the chassis

Loads to be Applied on the Chassis	Mass(kg)
Load	250
Driver	80
DC Motor	20
Gel Battery	160

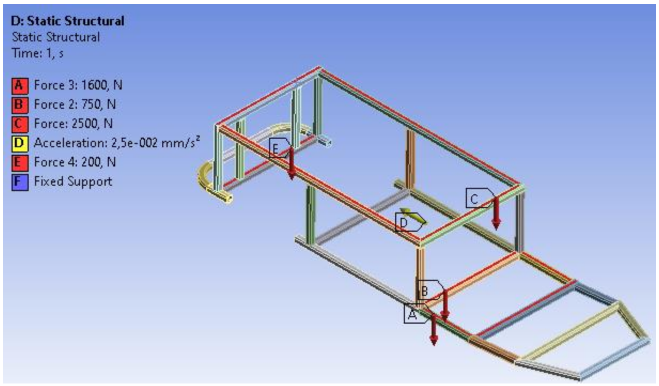


Fig. 14. Forces affecting the chassis in braking analysis.

As a result of the braking analysis, a yield value of 274.49 MPa was found on the chassis. Equivalent stress and total deformation values showed that permanent deformations will not occur on the vehicle chassis during sudden brakes and the vehicle will continue on its way. The yield value and safety coefficient values formed on the chassis are shown in Figure 15. and Figure 16.

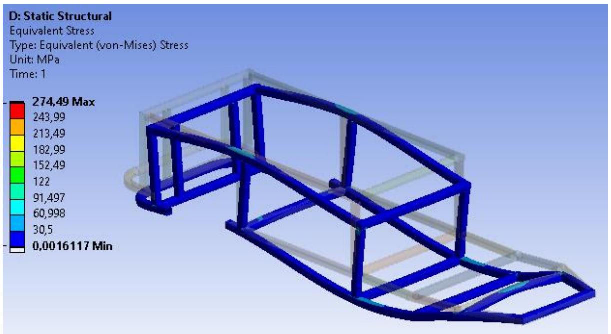


Fig. 15. Yield value in the chassis

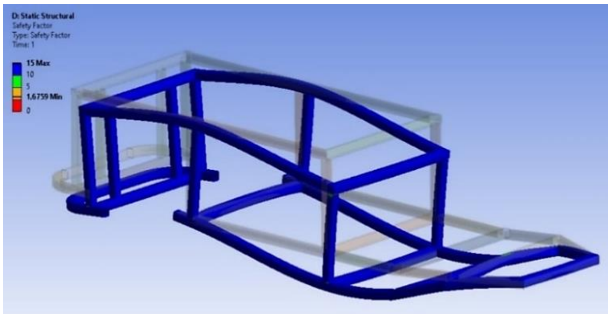


Fig. 16. Safety coefficient at braking

3.3. Cornering Analysis and Chassis Design

The cornering analysis was carried out to examine the reaction of the vehicle chassis when it enters a sharp corner that it may be encountered in today's conditions. In the vehicle corner analysis, the corner with a sharp corner size of 50 m and the maximum speed of the vehicle were considered as 45km / h, and the cornering acceleration was calculated as 3,125 m / s2. The forces acting on the chassis are given in Table 6 and fixed from the wheel parts. The forces acting on the chassis and the cornering acceleration are shown in Figure 17.

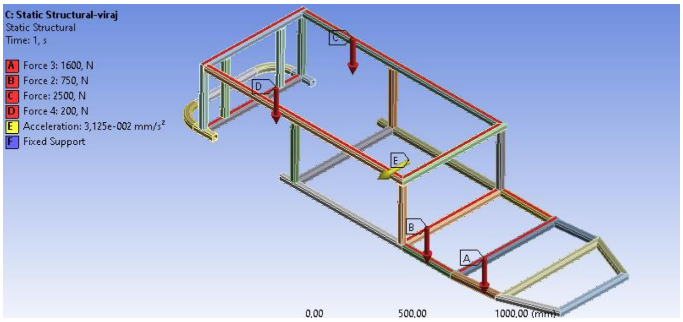


Fig. 17. Forces affecting the chassis in corner analysis.

As a result of the corner analysis, a yield value of 274.44 MPa was found on the chassis. As a result of this analysis, it was observed that the value stress and total deformation values examined were low. This showed that the vehicle will remain intact when it enters a sharp corner, and permanent deformations will not occur on the car chassis. The yield value and safety coefficient values formed in the chassis are shown in Figure 18.-19.

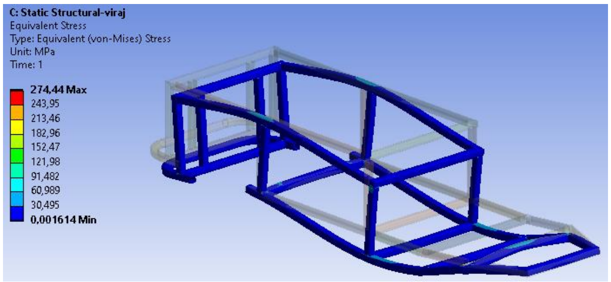


Fig. 18. Chassis yield value

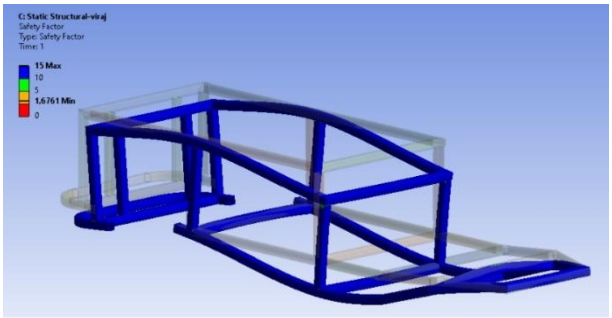


Fig.19. Cornering instant safety coefficient

4. Electric Vehicle Chassis Manufacturing

As a result of the analysis, it was seen that the designed chassis was a safe chassis in all cases. In line with this result, prototype production of the chassis was carried out taking into account the design criteria, dimensional characteristics and analysis values of the vehicle.

Welding operation was performed in combining profiles in the chassis production. The most preferred welding types in the automobile sector are friction source, Oxy-Acetylene welding, sub-gas (MIG and MAG) welded with melting electrode and resistance point source [43]. In chassis production, MIG-MAG welding type was preferred because it was fast and its cost was lower than the other methods, see Figure 20.

Fig. 20. a) Chassis manufacturing b) Welded chassis

Suspension systems have the task of connecting the wheel to the chassis, as well as dampening the chassis loads in certain proportions, allowing the vehicle to move safely. After the completion of welding operations and assembly of all profiles, the steering, suspension and wheel systems were assembled, see Figure 21.

Fig. 21. Suspension and wheel system installation

After the production and supply processes of the chassis and all the subsystems connected to the chassis were completed, the basic structure of the vehicle was formed by going to the final assembly and the integration of these subsystems were ensured. Figure 22 shows the final version of the chassis in the design environment.

Fig. 22. Vehicle assembly

5. Conclusion

In this study, the chassis design of a 3-wheeled and electrically driven vehicle and different analyses of this chassis were made. These analyses were modal analysis, brake analysis and cornering analysis. Modal analysis was first made before these analyses were carried out in the software environment. As a result of this analysis, the results of the software showed that the stress and deformation values that appeared in the chassis structure for the first 10 modes of the frequency were within safe limits. After modal analysis, brake analysis was performed in the software environment. Brake analysis was carried out to see the reaction of the chassis in case of any sudden brakes.

The results of this analysis showed that when acceleration sudden brake took place, according to the calculated value, there will be no problem in terms of stress and deformation amplitudes in the vehicle and there will be no problem caused by the chassis braking effect in the movement of the vehicle after braking. Finally, corner analysis was performed. The main reason for the corner analysis was to see the reaction of the chassis to the corner at a certain radius considering the condition when the vehicle enters the corner at the maximum speed it can reach. For this purpose, for the condition that the vehicle enters a corner with a radius of 50 m with a speed of 45 km/h, acceleration was calculated, and this acceleration value was applied in the chassis software environment and analyzes were made. Analysis results; deformation and stress values at the specified speed and corner radius values of the chassis remain within the appropriate limits. According to this, the car chassis can continue its course without damage from the corner.

After seeing the suitability of the analysis results, the first pro-to type production of the chassis was carried out. In line with the requirements and other analyses made in the following stages, revisions will be made on this chassis. Thus, the chassis structure laid the foundation with this work will become a platform. The basic logic of creating the platform structure is to allow you to use this structure for different functions.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest.

CRediT Author Statement

Gülüstan Tuğçe Alvalı: Analysis; **Ali Balbay and Serkan Güneş:** Mechanical design and manufacturing; **Burak Yenipınar**: Electronic component selection; **Cem Çatalbaş**: Electronics; **Turan Şişman**: Project general management, purchasing and material supply

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