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M.Sc. in Mechanical Engineering

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GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES

DESIGN, PROTOTYPE MANUFACTURING AND PERFORMANCE TESTS OF MOBILE SCALE SYSTEM FOR SMALL BALE MACHINES

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IN

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BY

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Supervisor

Prof. Dr. Sedat BAYSEÇ

by

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Burak ÖZKAN

ABSTRACT

DESIGN, PROTOTYPE MANUFACTURING AND PERFORMANCE TESTS OF MOBILE SCALE SYSTEM FOR SMALL BALE MACHINES

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M.Sc. in Mechanical Engineering
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In this study, mobile weighing system design, prototype manufacturing and performance tests, which can be integrated into small straw balers that ensure regular packaging of wheat straw, especially after harvesting wheat-like agricultural products, were investigated. The mobile weighing system basically has load cells, a weight indicator and a steel construction suitable for the size of small straw bales. Thanks to the instant weighing information that the operator can see on the weight indicator, it is aimed that the products coming out of the small straw baler have similar weights as standard, that the efficiency of the small straw baler is prevented by preventing excessive loads, and that time and financial losses are kept under control at the lowest level. While analyzing the design and steel construction, the small straw balers that are actively used in our country were examined and a design suitable for most of them was realized. Performance tests in the field were examined with prototype manufacturing and related tests were recorded. It has been ensured that the steel construction is as light as possible but has a strong resistance to vibrations and vibrations. 25 weighing tests were carried out. Optimization was made according to the results obtained.

Key Words: Small bale machines, Baler, Wheat straw, Mobile weighing system, Loadcell, Weighing indicator.

ÖZET

KÜÇÜK BALYA MAKİNALARI İÇİN MOBİL TARTIM SİSTEMİNİN TASARIMI, PROTOTİP İMALATI VE PERFORMANS TESTLERİ

ÖZKAN, Burak
Yüksek Lisans Tezi, Makine Mühendisliği
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Temmuz 2023
48 sayfa

Bu çalışmada, özellikle buğday benzeri tarım ürünlerinin hasatı sonrası ortaya çıkan buğday samanlarının, tarlada düzenli bir şekilde paketlenmesini sağlayan küçük saman balya makinalarına entegre olabilen mobil tartım sistemi tasarımı, prototip imalatı ve performans testleri araştırılmıştır. Mobil tartım sistemi temel olarak, yük hücrelerine, ağırlık göstergesine ve küçük saman balyalarının ölçülerine uygun çelik konstrüksiyona sahiptir. Operatörün ağırlık göstergesinden görebileceği anlık tartım bilgisi sayesinde, küçük saman balya makinesinden çıkan ürünlerin standart olarak birbirine benzer ağırlıklarda olması, küçük saman balya makinesinin çalışma prensiplerine aykırı aşırı yükleri engelleyerek verimin artırılması ile zaman ve maddi kayıpların en alt düzeyde kontrol altında tutulması amaçlanmıştır. Tasarım ve çelik konstrüksüyon analizleri yapılılırken, ülkemizde aktif olarak kullanılmakta olan küçük saman balya makineleri incelenmiş ve büyük oranda tamamına uygun bir dizayn gerçekleştirilmiştir. Prototip imalat ile tarlada performans testleri incelenmiş ve ilgili testler kayıt altına alınmıştır. Çelik konstrüksüyonun olabildiğince hafif ama titreşim ve sarsıntılara dayanımının kuvvetli olması sağlanmıştır. 25 adet tartım testi gerçekleştirilmiştir. Ortaya çıkan sonuçlara göre optimizasyon yapılmıştır.

Anahtar Kelimeler: Küçük saman balya makinesi, Buğday hasatı, Mobil tartım sistemi, Yük hücresi, Ağırlık göstergesi.

''Dedicated to my wife''

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I would like to thank my supervisor, Prof. Dr. Sedat Bayseç for his guidance and support throughout the study. I am thankful for his encouragement and motivation.
I would like to express my love and gratitude to my family for their support, always best wishes.
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CHAPTER I
INTRODUCTION

1.1. Introduction

Today, the human population in the world is increasing rapidly. Therefore, a serious decrease is observed in arable land areas due to this population growth rate and urbanization. In addition, the misuse of valuable resources such as water and soil, climate change, drought and flood disasters are not the only problems of cities. It also negatively affects agricultural areas, which creates a separate problem in terms of supply chain. In particular, agricultural products such as wheat and barley, which are cultivated as grains in our country, are not only used as basic foodstuffs; It also has a very important place for sectors such as pharmaceutical, bio-energy, industrial food, chemistry. Today, these products are harvested with combine harvesters. The combine takes the seeds inside the ears of wheat into its hopper and leaves the remaining straw on the field. Transfers the seeds to the transport vehicle. After the small balers take the straw in the field into its rectangular chamber, it releases the bales of straw, which it automatically compresses and binds with a rope, from the back side. It is shown in Figure 1.1. In our country, barley and wheat harvests start every year in the Adana Çukurova region in May and end in the Trakya region at the end of August. People who make a living from the harvesting process work with two drivers and auxiliary personnel for an average of 20 hours a day, approximately 3/4 months during the year. Therefore, for these machines, which work 3/4 months a year, the minutes are very important during operation. The machine should continue to harvest without malfunction and the financial situation of the machine owners during the year will depend on this. According to the current usage methods, the problems encountered in hay balers and during harvesting are briefly;

- Weight control with personnel during harvest
- Differences in humidity of harvested areas and machine failures in field lands

- It is not known how many weights of harvest was made.

A harvest bale weighing system has been designed considering that the creation of a weighing system connected to the baler during harvest will eliminate these problems. The aim of this study is to increase the working efficiency of small bale machines; is to integrate a mobile weighing system that will be installed modularly at the back. The scope of this work is design, prototype manufacturing and performance testing. According to the weighing values to be obtained from the performance tests, accurate weighing was ensured and the observations were evaluated. The working principle of the mobile weighing system, whose prototype were produced, were explained together with the 3D drawings.

Figure 1.1 Rectangular small bale machine (small baler)

1.2. Organization of the Work

This thesis organized in six chapters.

The following chapter, Chapter 2, contains a summary of the studies on literature about the mobile scale system for small bale machines.

Chapter 3 contains an overview of the history of machine harvesting, the working principles and uses of combine harvesters and small bale machines, the parts and functions of the small bale machines.

The design and prototype manufacturing of the mobile weighing system is explained in chapter 4.

The experimental performance tests and results are described in Chapter 5 in detail.

Chapter 6, where the conclusion and recommendations are explained, will be our last chapter.

CHAPTER II

LITERATURE SURVEY

2.1. Introduction

As in advanced agriculture countries, wheat harvesting is done with combine harvesters in our country. After the wheat harvest, the remaining straw is packed instantly in the field with small bale machines. In general, only some companies have conducted research on the usage areas and commercialization of wheat harvesters and small bale machines. It is aimed to obtain the highest efficiency with experimental business development studies.

2.2. Studies on Mobile Scale System for Small Bale Machines

Allied System Co. et al. [1] studied on a mobile weighing system for small rectangular hay balers to display weight information on the weighing system as they are packed in the field. This system is basically used with 2 load cells, 1 steel weighing platform and 1 indicator communicating via communication cable. In the USA, a design that allows the straw bale to roll over in accordance with the collecting apparatus of the straw bale collector has been preferred. The combine or tractor operator can instantly see the weights of the straw bales coming out of the baler during hay bale making. Additionally, preferred loadcells are shear beam loadcells. This commercial study is available in the company's product catalogue.

Agmechtronix Co. et al. [2] studied on a mobile weighing system for small rectangular hay balers to display weight information on the weighing system as they are packed in the field. This system is basically used with load cell, 1 steel weighing platform and 1 indicator communicating via communication cable. In the USA, a design that allows the straw bale to roll over in accordance with the collecting apparatus of the straw bale collector has been preferred. The combine or tractor operator can instantly see the weights of the straw bales coming out of the baler during hay bale making. Additionally, preferred loadcells are shear beam loadcells. This commercial study is available in the company's product catalogue.

CHAPTER III
SMALL BALE MACHINES

3.1. Introduction

As stated earlier, wheat harvesting is traditionally done with combine harvesters today. The wheat straw remaining in the field after the wheat harvest is shipped after being packed with straw balers. Straw bales are very important agricultural products for livestock and similar fields and are among the sine qua non of the supply chain. In this section, the types and historical development of combine harvesters used in wheat harvesting, the types of hay baling machines, their historical development and working principles will be briefly discussed.

3.2. Combine Harvester

The flourishing history of wheat has greatly influenced the way of life of people. The wheat that started in the region covering today's Mesopotamian geography is more than ten thousand years old. (Figure 3.1.) Grain products such as wheat have been the local plant species of the region since the past. People started to meet a large part of their nutritional needs from these products. While they were nomads and hunter-gatherers, they transitioned to a stable production phase.

Figure 3.1. The first wheat plantations [3]

After maize and paddy, which are the most planted crops in the world, wheat is the third most cultivated field crop. Wheat, which meets the basic nutritional needs of the society, is a very important grain. [4]

Wheat harvesting was done with human and animal power before the industrial revolution. Currently, this harvesting is done with mobile combines in many countries. Combine harvesters, which are universal agricultural machines, have made great contributions to the advancement of humanity with their ability to simultaneously carry out separation and cleaning operations, as well as additional harvesting and threshing operations.5]

Many grains can be harvested with combines. In addition to Patrick Bell, who designed a horse-drawn reaper in Scotland in 1826, which he did not patent, in 1835 Hiram Moore invented and patented the first combine harvesters in the United States. Hiram Moore's machine was capable of harvesting, threshing, but could be pulled by horses or mules. (Figure 3.2)

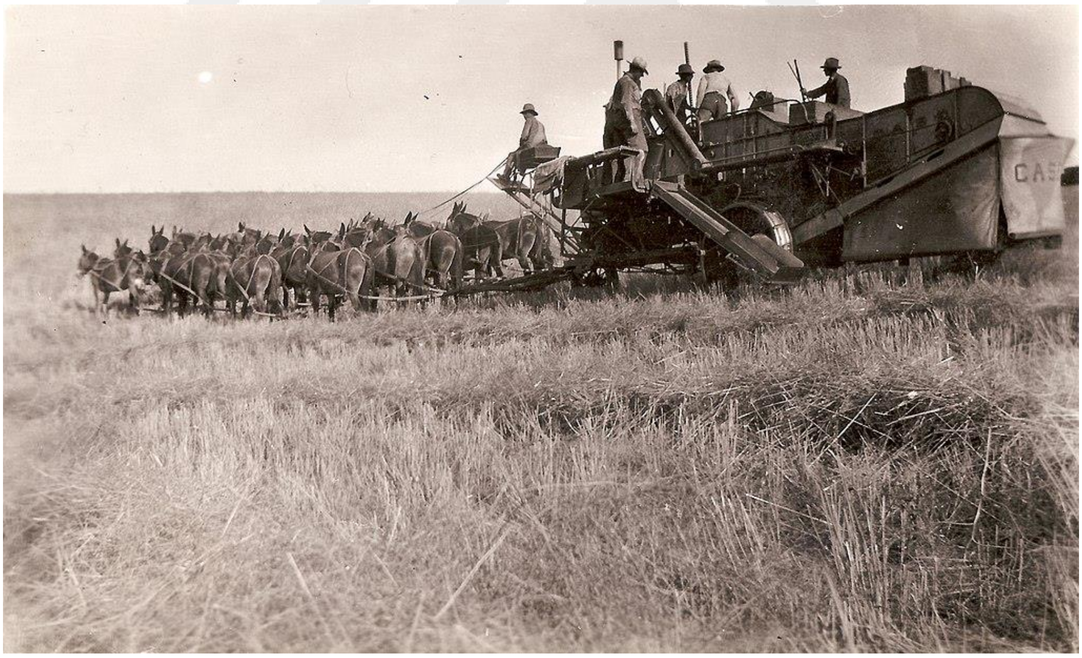


Figure 3.2 Horse-drawn combine harvester [6]

Apart from all these, the scraper developed by John Ridley had the feature of removing only the wheat ears without tossing them and leaving the straw standing. John Ridley developed this machine in Australia in 1843. In addition, Hugh Victor

McKay made a great breakthrough in this field with the Sunshine Header-Harvester he designed in 1885. [7]

Figure 3.3 Sunshine header-harvester 1885 [7]

Holt Manufacturing Company produced the first motor combine, leading to a breakthrough in this field. (Figure 3.4) This process was done in the United States of America in 1911. In the following years, the combine harvester sector, which has reached the level of technology today, has used internal combustion engine technology in different brands and products. (Figure 3.5) [8]

Figure 3.4 Self-propelled harvester 1911 (Holt Manufacturing Company) [8]

Figure 3.5 Today's combine harvester [9]

3.2.1. Working Principles

Combine harvesters are a universal agricultural machine that is moved by the integrated operation of many processes and systems with different working disciplines. (Figure 3.6)

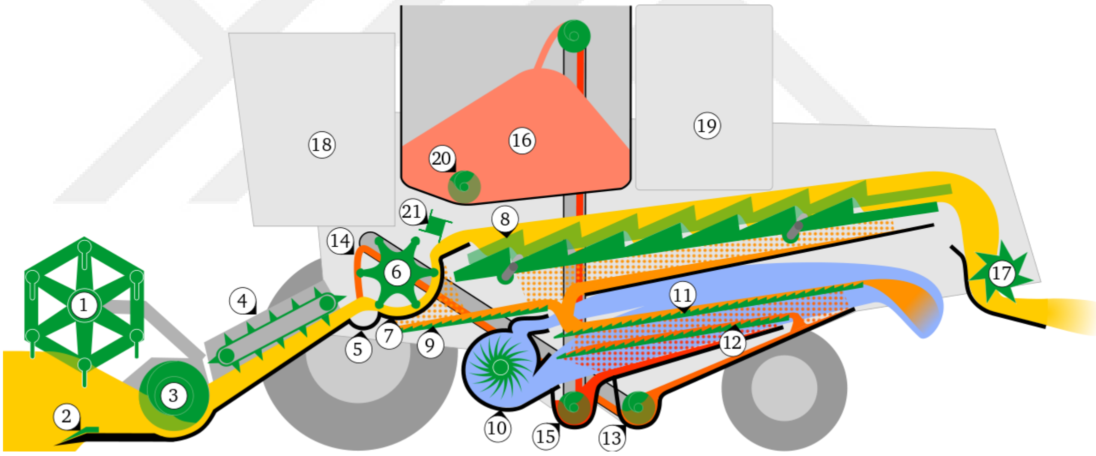


Figure 3.6 Combine harvester working principles [10]

1) Reel
2) Cutter bar
3) Header auger
4) Grain conveyor
5) Stone trap
6) Threshing drum
7) Concave
8) Straw walker

11) Top Adjustable sieve
12) Bottom sieve
13) Tailings conveyor
14) Threshing of tailings
15) Grain auger
16) Grain tank
17) Straw chopper
18) Driver's cab

9) Grain Pan 19) Engine

10) Fan 20) Unloading auger

21) Impeller

In general, it is possible to evaluate the working principle of combine harvesters in seven basic parts. These include: [11]

1) Mowing,

2) The beating and forwarding of Virgos,

3) Separation of grain and stalk (blending),

4) Cleaning the grains,

5) Leaving the stems in the field or leaving them in the field by breaking up,

6) Storage of grains,

7) Unloading of grains

In general, combines have similar operating principles. Although the equipment varies according to the product to be harvested, it continues to work with the same rules. The task of the speed-adjustable reel is to push the crops towards the cutter. The equipment used to cut crops as close to the ground as possible is the cutter bar. The cut products are pushed forward with the help of a screw. The products shipped to the processing center are sent by the conveyor. The activated threshing separates the grains from their stems and shakes them. After the vehicle's tank is full, the grains collected in the collection tank are sprayed out with the help of an elevator, passing through a pipe to be sent to the waiting truck. Unwanted straw and straw are rolled into the field behind the machine. Here, the air flow is provided by the fan. Under the influence of the air flow, materials that are lighter than grain are thrown into the field behind the combine. The straw left in the field is baled with a straw baler (balers). These are used in a wide variety of industries such as animal feeds and bedding. [12]

3.3. Bale Machines

Balers are agricultural machines that collect the scattered harvest residues of many agricultural products, including grain straw, from the field and compact them in a rectangular or circular manner. In this way, the straw bales made with packaging can be properly stacked and shipped by truck and can be easily used where it is stocked. [13]

The straw, which was previously cut with a sickle, was collected with straw forks and stacked in the barns. The invention of the manually operated bale compactor was in the early 19th century. (Figure 3.7) In 1870, the first stationary hay baler was built by Dederick from the United States. (Figure 3.8).

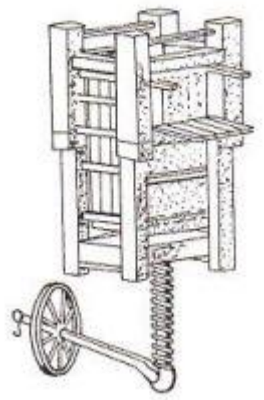


Figure 3.7 Hand-operated bale compactor [14]

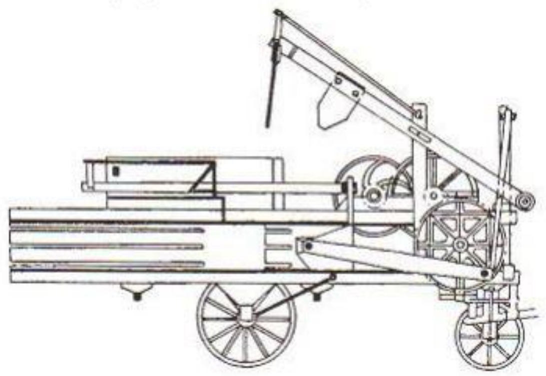


Figure 3.8 Fixed baler in 1870 [14]

These machines, which continued their development, were used until the second world war. Since it is fixed, bringing the straw from the field or from distant places causes time and labor losses, the baling machines used today were designed with the development of motorization. The basic principle is not to harm the feed quality of the hay, especially when performing these operations. [14]

Balers used today can be grouped in five ways:

1) According to the way of movement
    a. Fixed
    b. Tractor-pulled ones
        i. PTO driven
        ii. Motorized
    c. Self-propelled
2) According to the bale shape
    a. Round (cylindrical) balers
    b. Those who make angular bales in the form of rectangular prisms
3) According to bale compression pressures
    a. Low pressure balers
    b. High pressure balers
4) According to the binding material of the bale
    a. Tied with rope
    b. Wire-tied
5) According to the size of the bale
    a. Small bale (50-110 cm)
    b. Big bale (150-250 cm)

The baler, which is the most widely used in our country and on which our mobile scale system will be used; It is a small straw baler with a PTO driven, rectangular prism shape, high pressure, tied with a rope, pulled by tractor or combine harvester.

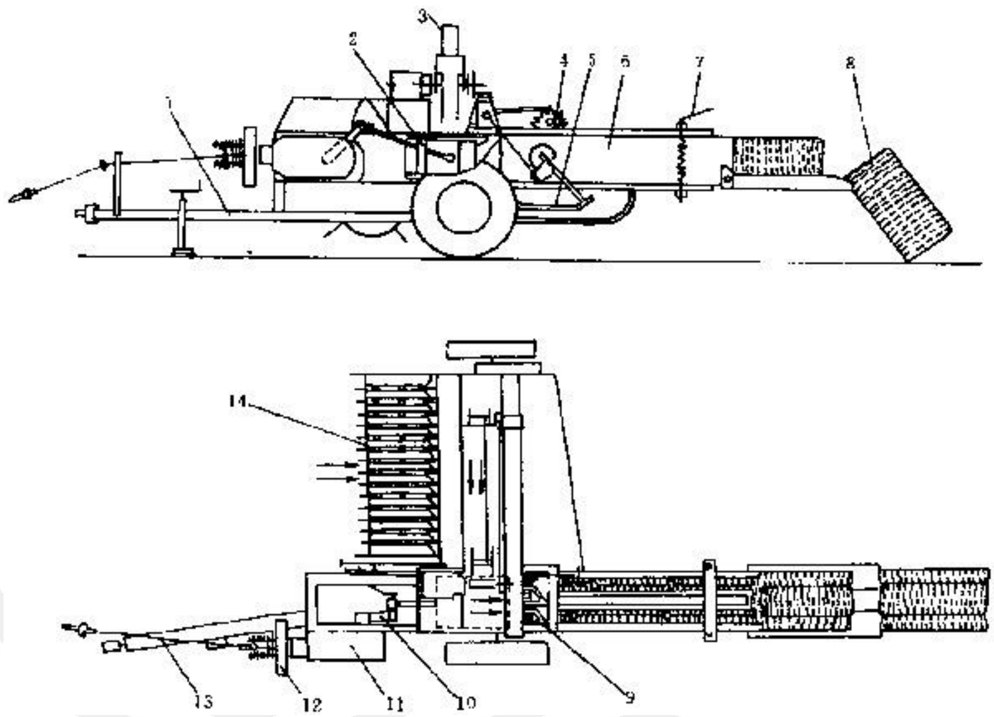
Figure 3.9 Small straw baler with a PTO driven, rectangular prism shape, high pressure, tied with a rope, pulled by tractor

3.3.1. Working Principles

The general features of PTO driven, rectangular prism shaped, high pressure, small straw balers tied with a rope and pulled by tractor or combine harvester can be listed as follows:

- Today, square balers are more preferred than other balers. Because it is easier to transport and stack the bales made by the machines and to load them on the transport vehicle (tractor, truck, etc.).
- Bale length is between 50-110 cm and height is between 30-60 cm in these machines that make small rectangular prism bales. Bale weights vary between 25-50 kg.
- The densities of the bale vary according to the harvested product (depending on its dry matter). For example, 200 kg/m3 for dry straw is around 400 kg/m3 for silage.
- In order to operate these machines, at least 60 HP tractor power is needed. The bales are tied in at least two places.

  [15]



1. Tow beam; 2. Piston; 3. Conveying and feeding equipment; 4. Bale length controller; 5. Needles; 6. Compression chamber (bale chamber); 7. Bale density adjuster; 8. Bale; 9. Needle-and-tying mechanism; 10. Crank; 11. Main gear box; 12. Flywheel; 13. Universal joint gearing axis; 14. Pick-up reel.

Figure 3.10 Baler working principles [16]

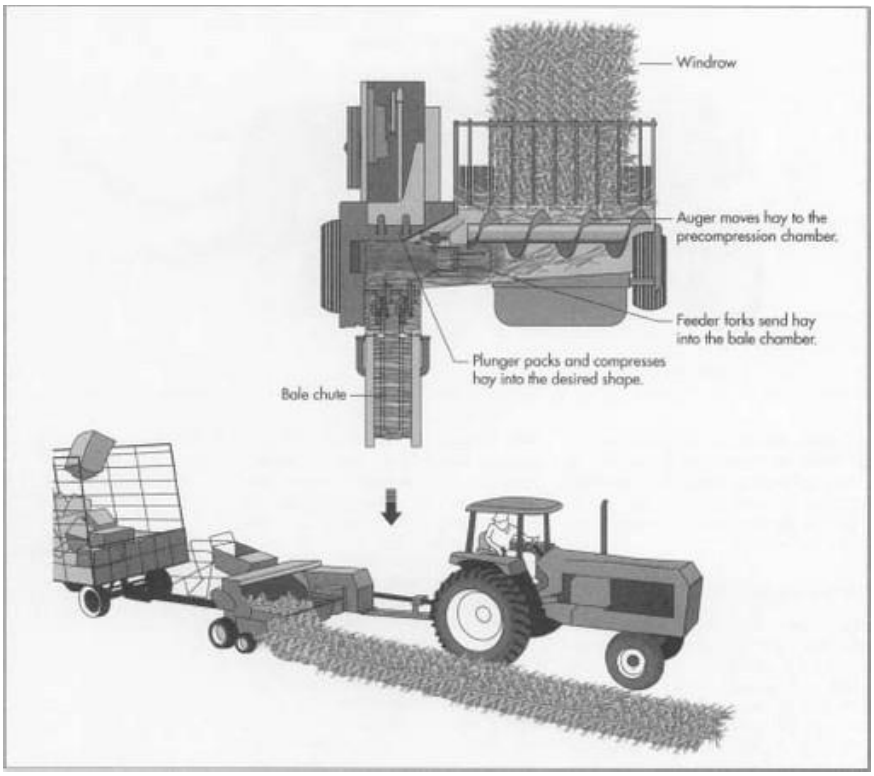


Figure 3.11 Baler working principles [17]

Thanks to the adjustable collecting reel, the straw collected from the field is transferred to the pistons with a spiral. Bale pressure can be adjusted by expanding or contracting the channel volume. The baler is driven by an articulated PTO from the tractor or the combine harvester modified accordingly. Thanks to the rotating flywheel, the movement is transmitted to the piston with the eccentric connection. The products pushed forward are collected by the collector and the bale chute is fed with the product. Thanks to the piston moving back and forth, the straw is compressed in the bale channel. The bale of straw is tied with the help of a needle that works in harmony with each other and is tied to the back with a synthetic thread. With the help of a knife, the rope is cut. The resulting bales can be loaded onto a trailer with the launcher or carrier or dropped into the field. The functions and descriptions of some parts used during the operation of the baler are shown below. [18]

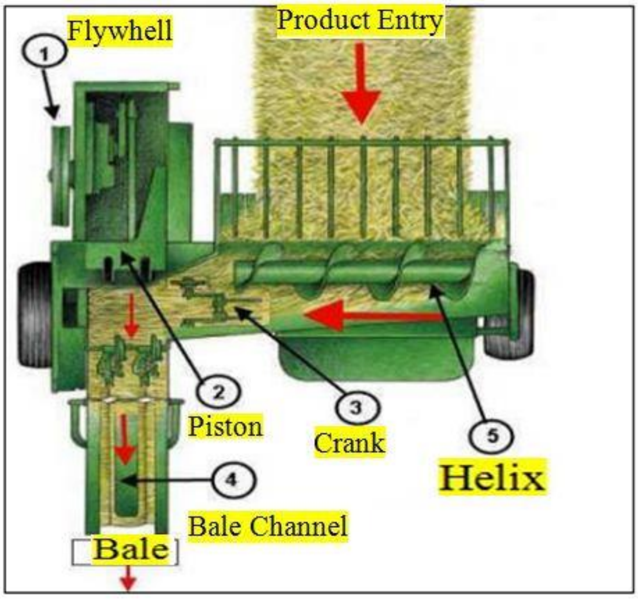


Figure 3.12 Bale Machine Working Principles [18]

CHAPTER IV
DESIGN & PROTOTYPE MANUFACTURING

4.1. Introduction

The basic features for mobile scale system design and prototype manufacturing for use in PTO driven, rectangular prism-shaped, high pressure, rope-tied small straw balers and towed by tractor or combine harvester are user needs. With this work of mine; I tried to produce optimum solutions for the problems experienced by the users during the harvest and for these problems, cost-effective, fast results and easy installation, reducing labor costs and preventing malfunctions. A second important criterion in the design of the mobile scale system; to ensure efficient and stable operation of balers. In this section, I will explain the working principle of general weighing systems, the design, prototype manufacturing and features of the mobile scale system to be used in balers in detail.

4.2. General Weighing Systems

Weighing instruments used in all sectors in the world are used to measure weight or mass. Traditionally, weighing instruments with two pans allow to learn the mass of a load of known mass and an object of unknown mass with the help of equal arms. There are weighing instruments that can work with different principles. Some balances can be calibrated to read in units of force (weight) such as Newtons rather than units of mass such as kilograms.

Weighing instruments, which have a history as old as human history, are thought to be older than archaeological remains. The earliest evidence found are carved stones bearing the hieroglyphic symbol of the Ancient Egyptian Civilization in 2600 BC. It shows that Egyptian traders used an established system of mass measurement when trading gold. Although no real scales from this period have survived, many sets of weighing stones and murals showing the use of scales suggest widespread use. [19]

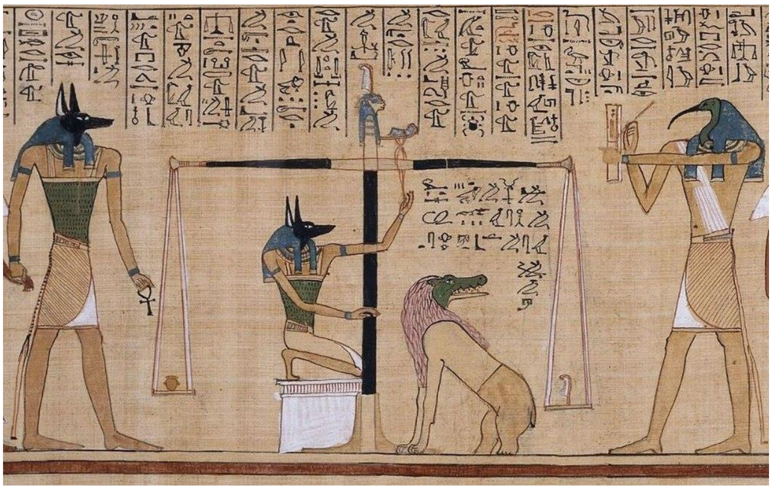


Figure 4.1 Ancient Egyptian Civilization in 2600 BC [20]

A wooden scale and bronze mass used in an ancient tomb, known to date from the 3rd or 4th century BC, is the oldest scale found in China. [21]

Great advances were made in scale design and development, but until the 17th century AD all scales remained variations of the scale. Although double-head mechanical scales are rarely used, electronic scales have been used in general since the 20th century with the development of technology. They range from precise mass measurement in laboratories to special truck scales weighing up to 300 tons. It is the universal standard of world trade.

Figure 4.2 Mechanic scale

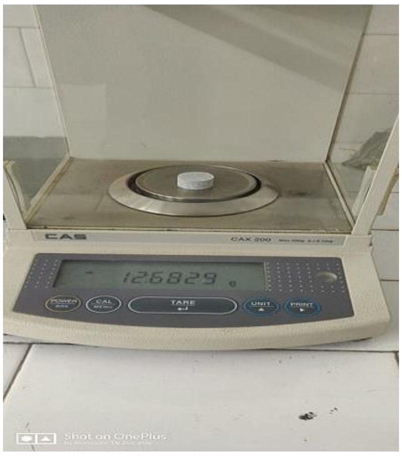


Figure 4.3 Electronic Scale

Figure 4.4 Electronic Truck Scale

4.2.1. Working Principles of Electronic Weighing System

The working principles of electronic weighing instruments generally consist of at least 3 main elements today. These;

- A platform is needed to distribute the load completely evenly over the entire surface. (These platforms are produced from steel materials, considering their machinability and costs today)
- Analogue or digital load cell is required to measure at least 1 strain.
- A digital indicator is required where you can see the total weight results numerically.

They are used in load cells for strain measurement and in static weighing processes. They are fixed in a position perpendicular to gravity and work on a single axis. Weight, which can vary slightly according to gravity and the position of objects on Earth, is different from mass. Although the force is equal to the mass multiplied by the gravitational acceleration; Weight corresponds to the gravitational force of a mass operating on the vertical axis with respect to the earth's floor. Load cells that essentially work as force transducers are generally made of alloy steels. [22]

The specially selected and shaped structure features a metal sachet called a spring element and a wheat stone bridge installed with strain gauges.

When a physical force is applied, the spring element causes deformation. This deformation is given as an electrical signal over the wheat stone foam. This signal is displayed as force or weight information on a microprocessor-based display.

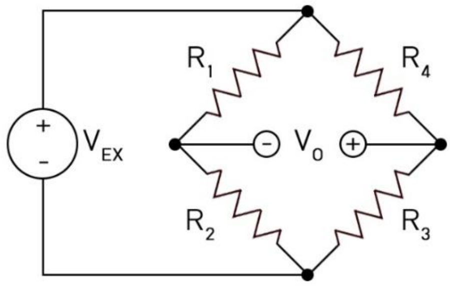


Figure 4.5 Wheatstone Bridge

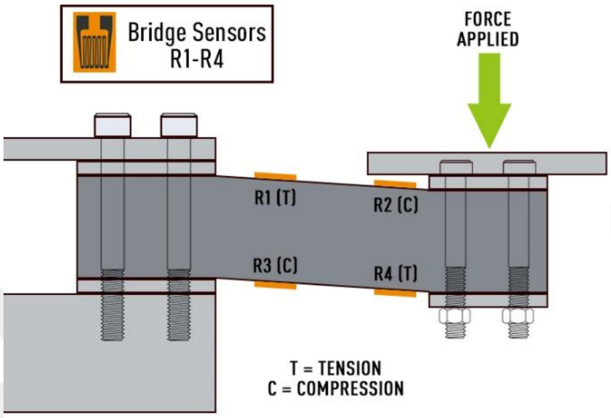


Figure 4.6 Shear Beam Loadcell Working Principles

test certificate no. TC8012 Revision 1
C of C no R60/2000-NL1-12.12

Certificate no. 12-028

- Nickel plated alloy steel IP67 shear beam load cell
- (100 kg, 250kg are bending beam load cells)
- Adhesive sealed
- Suitable platform weighing, bed weighing, etc.
- High accuracy
- High reliability
- Current calibrated (sc-option)

Available models

Capacity	Accuracy	Full article description
100kg	C3/C4/C5	H8C-C3/C4/C5-100kg-4B(-SC-W6)
250kg	C3/C4/C5	H8C-C3/C4/C5-250kg-4B(-SC-W6)
500kg	C3/C4/C5	H8C-C3/C4/C5-500kg-4B(-SC-W6)
1t	C3/C4/C5	H8C-C3/C4/C5-1t-4B(-SC-W6)
1.5t	C3/C4/C5	H8C-C3/C4/C5-1.5t-4B(-SC-W6)
2t	C3/C4/C5	H8C-C3/C4/C5-2t-4B(-SC-W6)
2.5t	C3/C4/C5	H8C-C3/C4/C5-2.5t-4B(-SC-W6)
3t	C3/C4/C5	H8C-C3/C4/C5-3t-4B(-SC-W6)
5t	C3/C4/C5	H8C-C3/C4/C5-5t-4B(-SC-W6)
10t	C3/C4/C5	H8C-C3/C4/C5-10t-4B(-SC-W6)

Specification

Accuracy class		OIML R60 C3	OIML R60 C4	OIML R60 C5	
Output sensitivity (= FS)	mV/V	3.0 ± 0.003, 2.0 ± 0.002			
Maximum capacity (E_{max})	t	0.1, 0.25, 0.5, 1, 1.5, 2, 2.5, 3, 5, 10		0.1,0.25,0.5, 1,1.5,2, 2.5,	3, 5, 10
Maximum number of load cell intervals (nLC)		3000	4000	5000	
Ratio of minimum LC verification interval Y = E_{max} / v_{min}	Y	10.000	15.000	20.000	18.000
Combined error	%FS	± 0.023	± 0.0175	± 0.014	
Minimum dead load	kg	0			
Safe overload	of E_{max}	150 %			
Ultimate overload	of E_{max}	300 %			
Zero balance	%FS	± 1.0			
Excitation, recommended voltage	V	5 ~ 12(DC)			
Excitation maximum	V	18(DC)			
Input resistance	Ω	350 ± 3.5			
Output resistance	Ω	350 ± 3.5			
Insulation resistance	MΩ	≥ 5000 (50VDC)			
Compensated temperature	℃	-10 ~+40			
Operating temperature	℃	-35 ~ +65			
Storage temperature	℃	-40 ~ +70			
Element material		Nickel plated alloy steel			
Recommended torque on fixation	N.m	M12: 100	M18:200	M24:700	
Ingress protection (according to EN 60529)		IP67			
ATEX classification (optional)		II1G Ex ia IIC T4	II1D Ex iaD 20 T73℃	II3G Ex nL IIC T4	

Figure 4.7 Technical specifications of the loadcell used for the design [23]

Technical specifications of the indicator used for the design; [24]

- 26mm. digit height LCD display
- Compact design: 190 x 104 x 122 mm
- Up to 72 hours working time with 6V 4Ah battery
- Ability to work from USB with 5 – 12V wide supply input range
- High voltage protection at the supply input, reverse connection protection, instantaneous high voltage resistant
- RS-232
- 1 kg (With Battery), 0.35 kg (Without Battery)

Figure 4.8 Weighing Indicator used for the design [24]

4.3. Design & Prototype Manufacturing of Mobile Scale System for Small Bale Machine

Small straw balers with PTO drive, rectangular prism shape, high pressure, tied with rope and pulled by tractor or combine harvester are the most widely used balers in our country. The bale chute, which is the station just before the straw bales of these balers fall into the field, usually has the same dimensions. Therefore, these standard dimensions were taken as reference while designing the mobile scale system. A design has been made in accordance with the general working principles of weighing systems and small straw balers. In the design, a foldable steel platform to hold the straw bales, 2 shear beam load cells, 6x0.50 mm signal cable and a weight indicator are used. Welded manufacturing has been done in platform construction, and a design that is as light and shock-resistant as possible has been tried to be made. The total weight of the designed mobile scale system is approximately 30.2 kilograms.

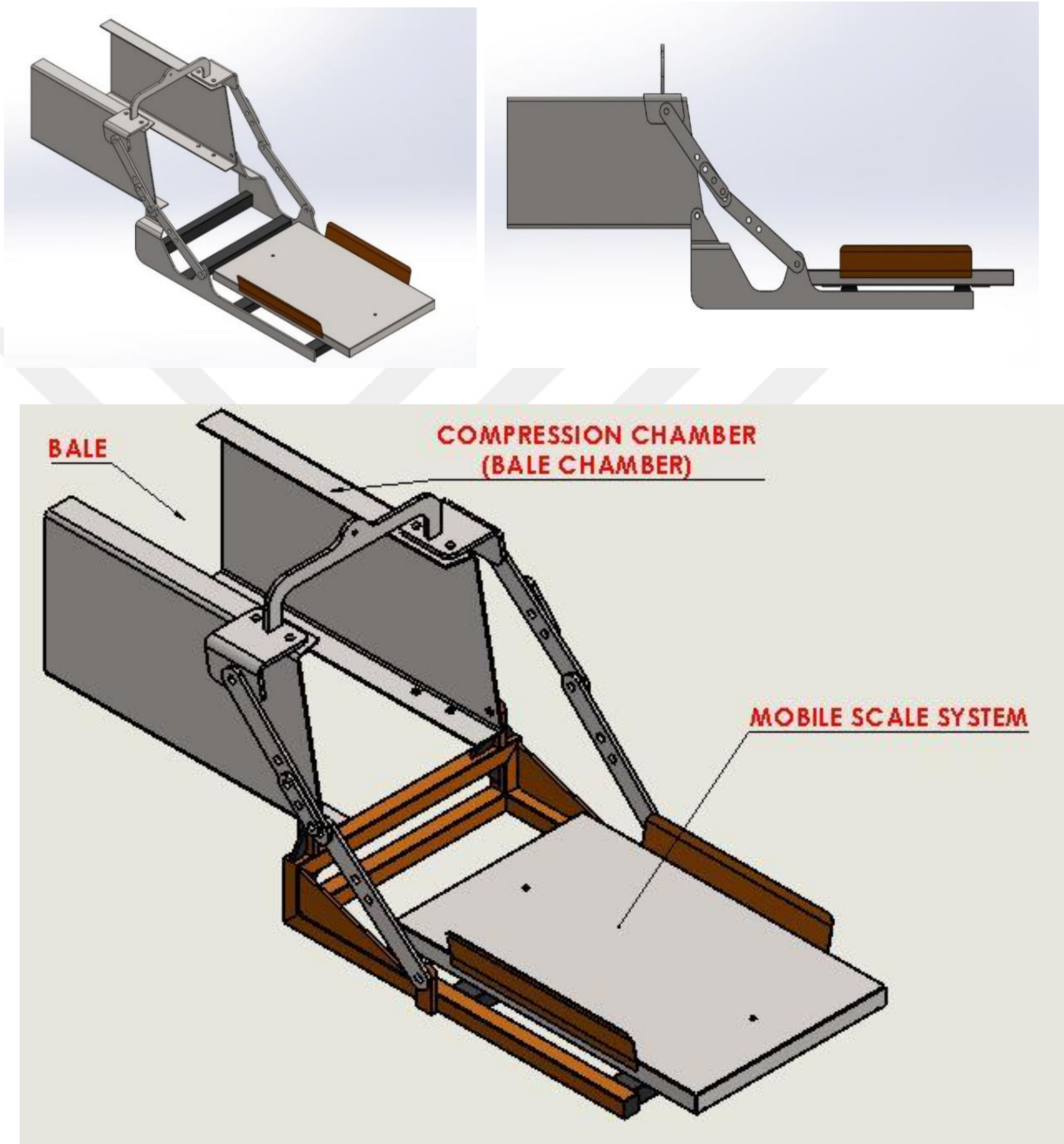


Figure 4.9 Mobile Scale System

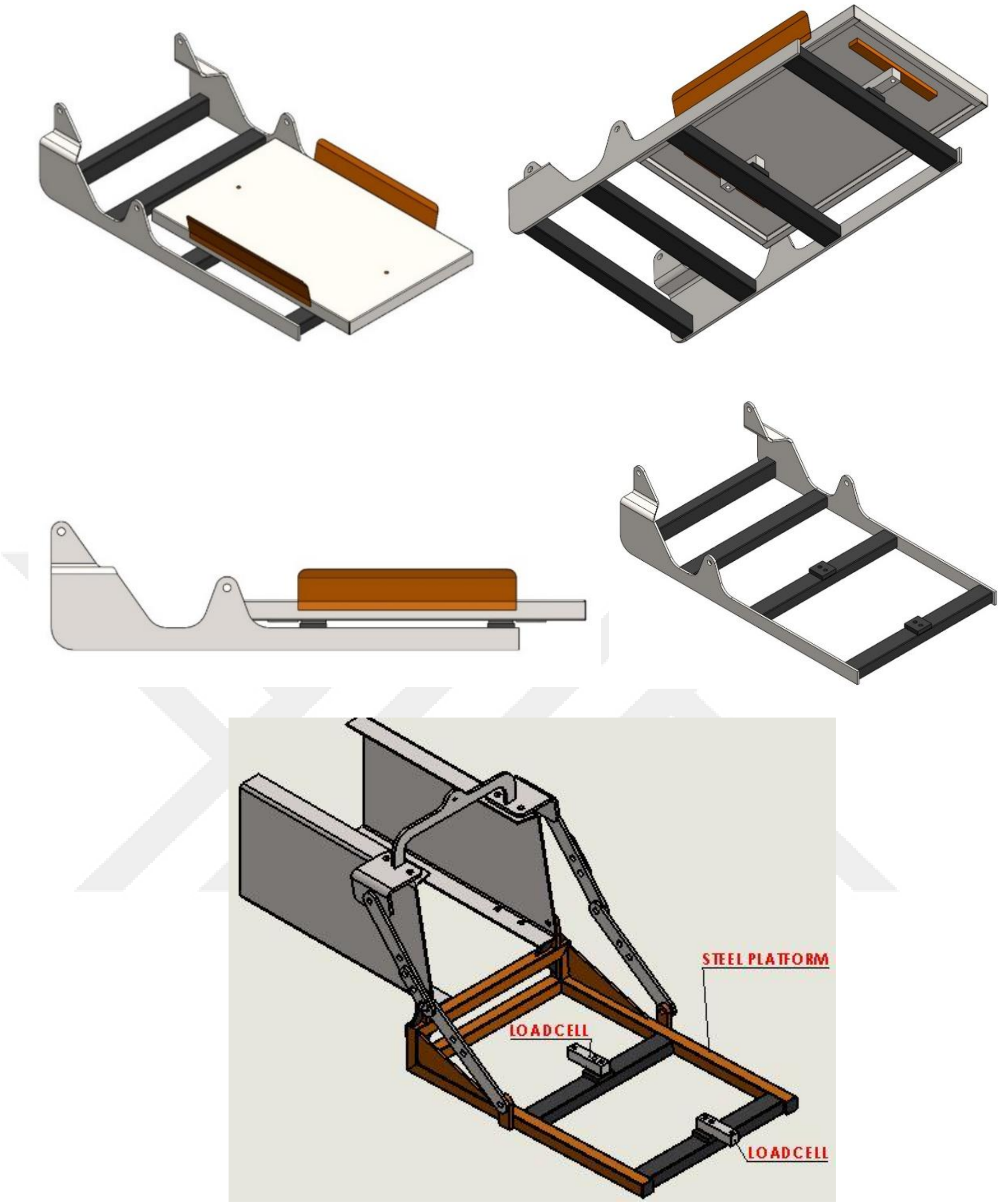


Figure 4.10 Loadcells and Steel Platform

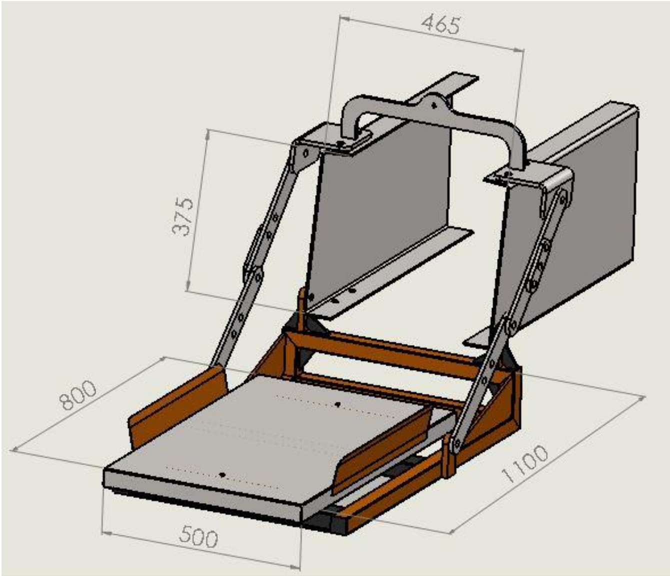


Figure 4.11 Dimensions of Mobile Scale System

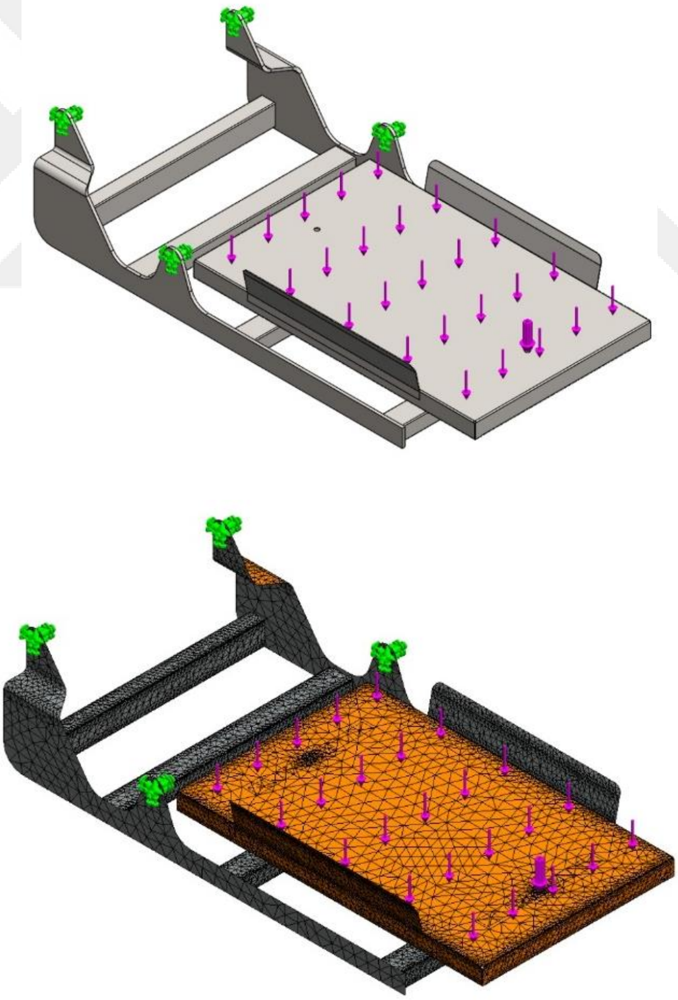
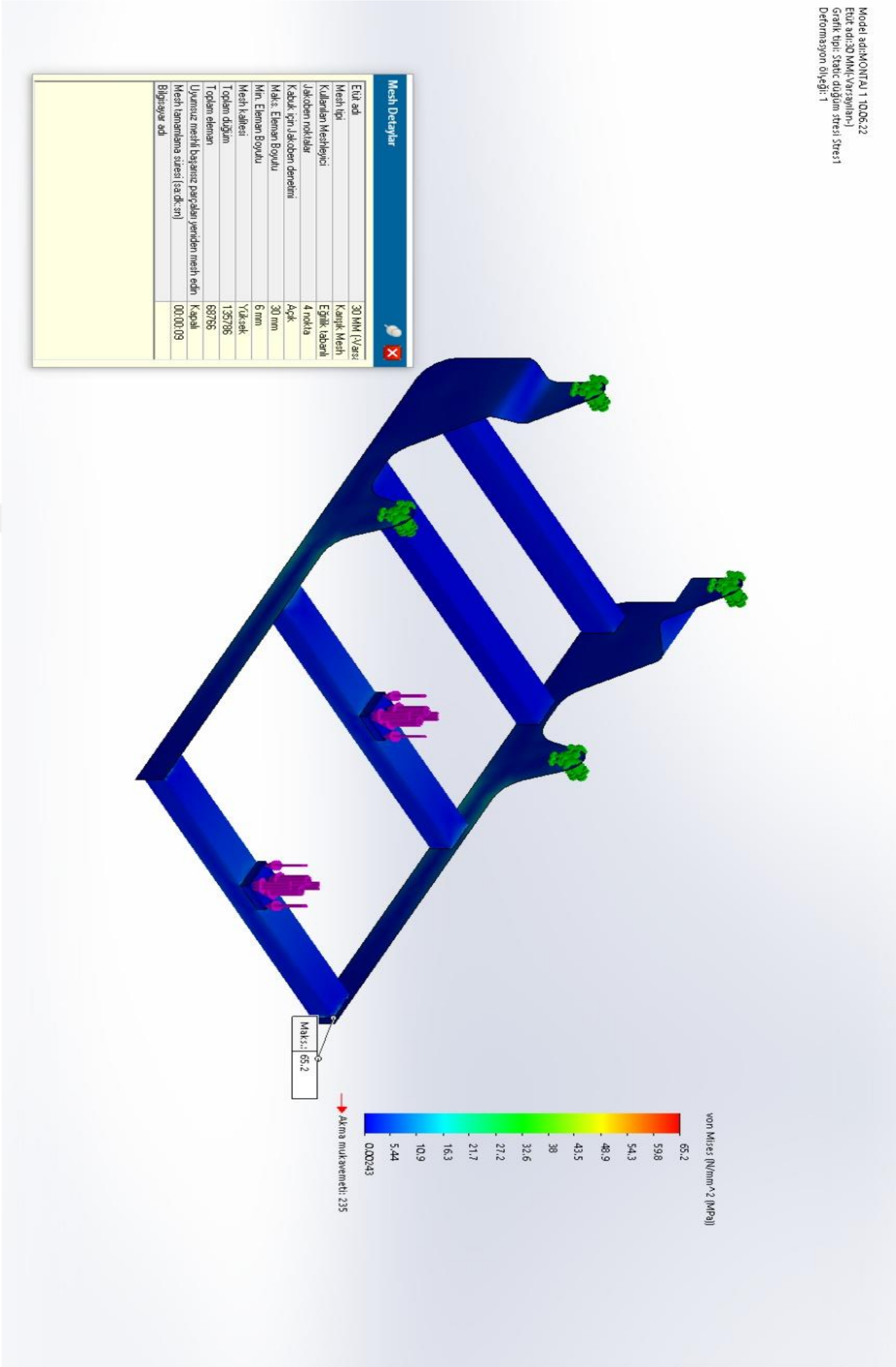
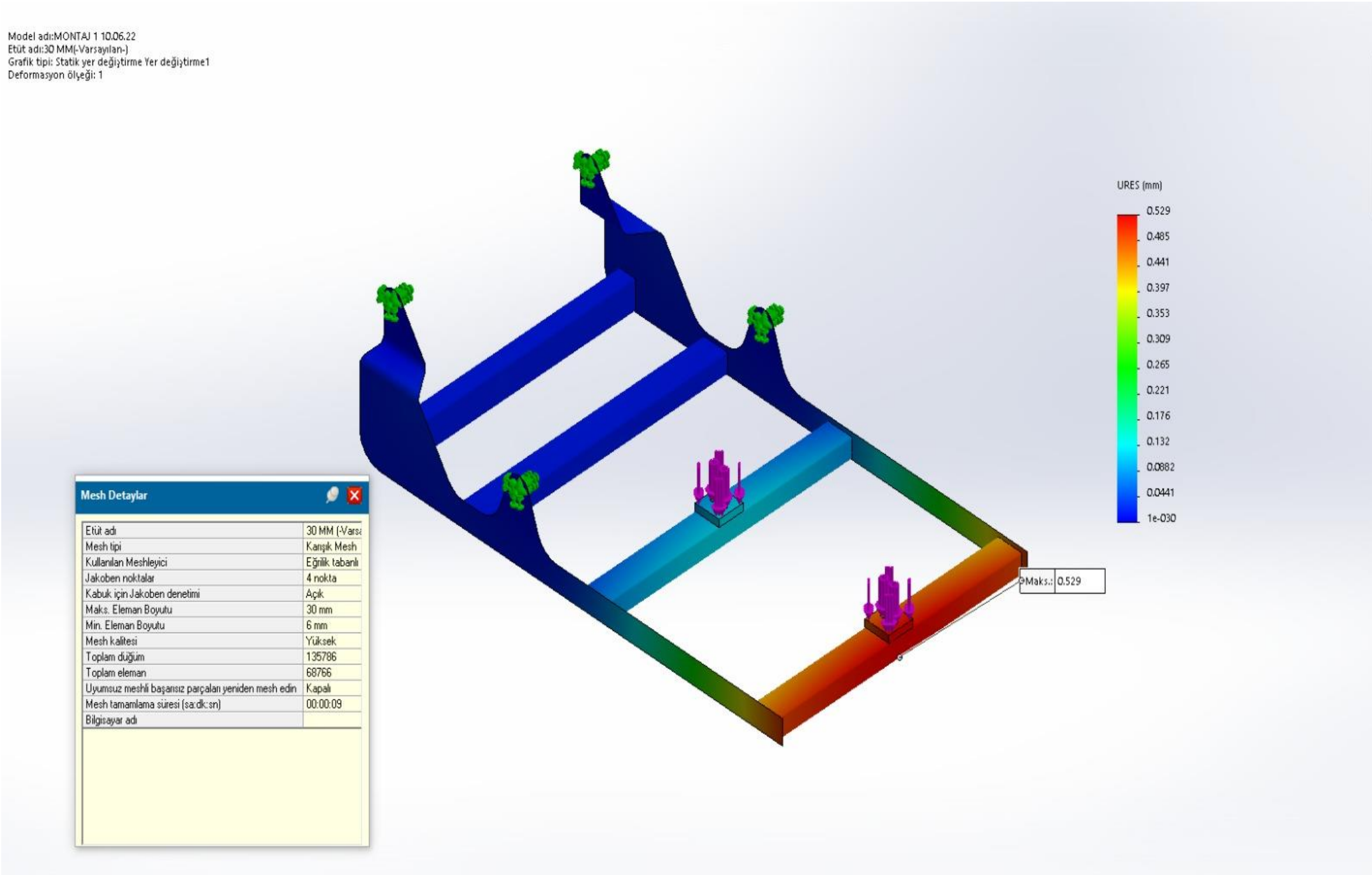
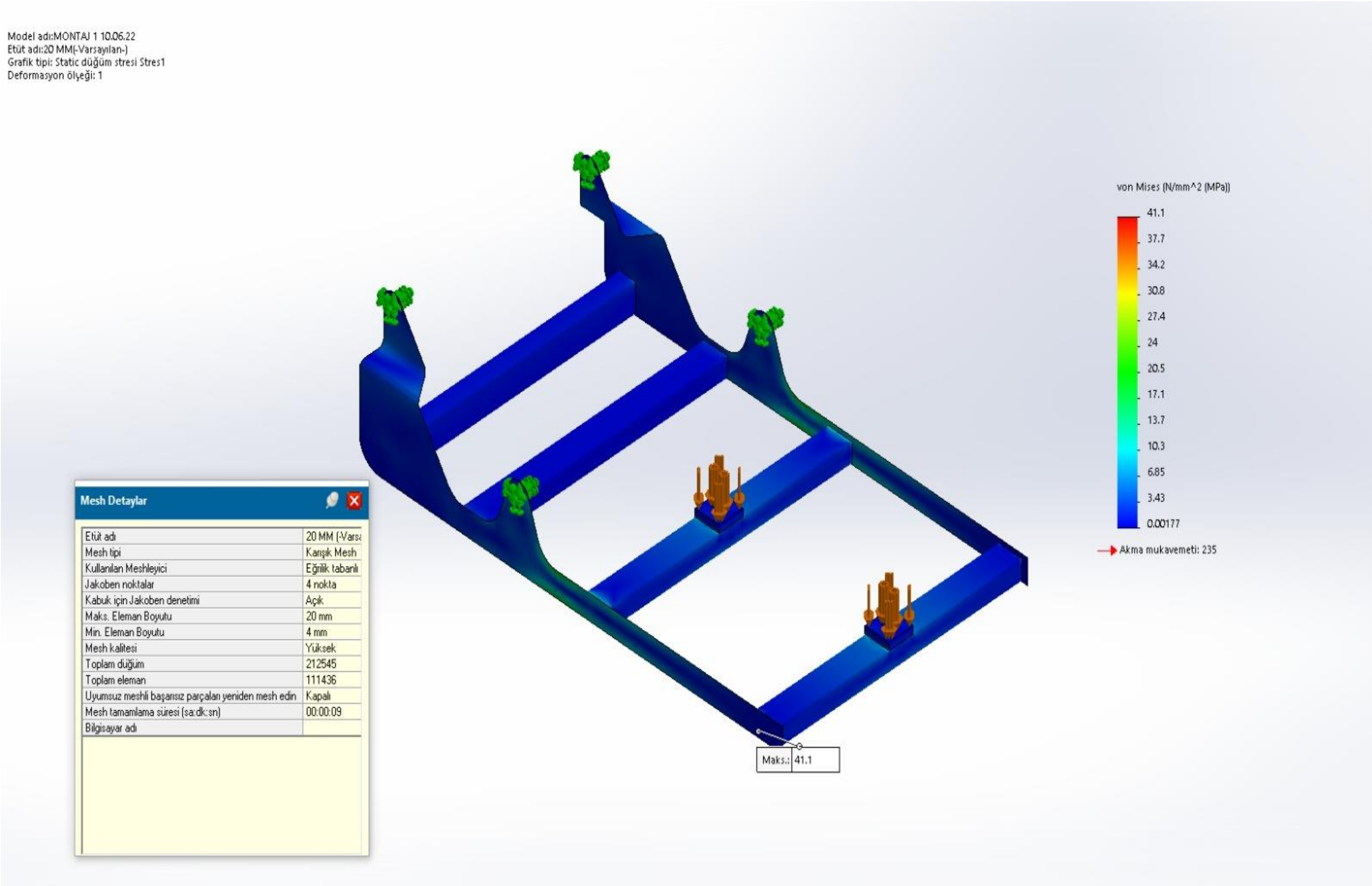
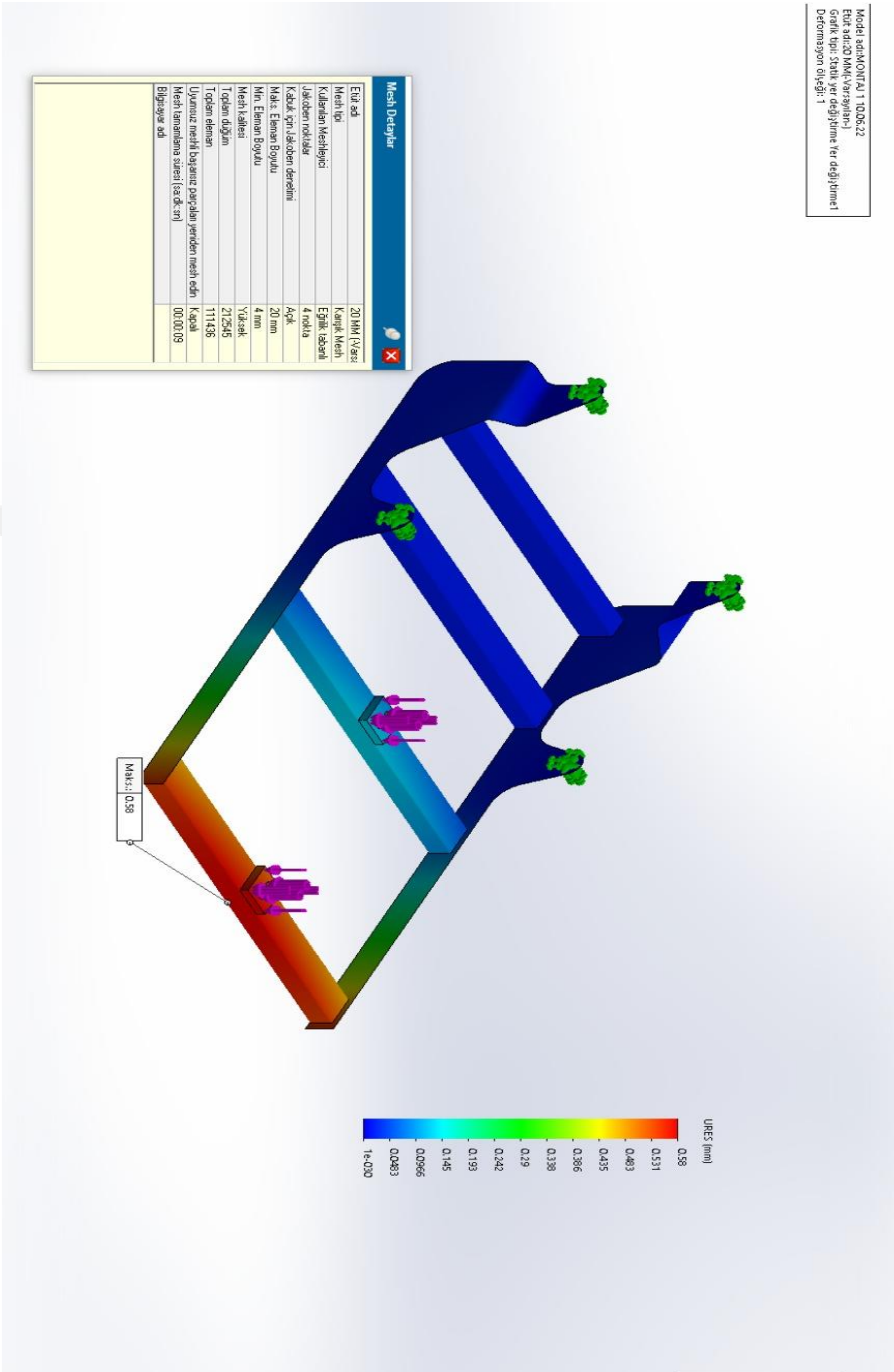


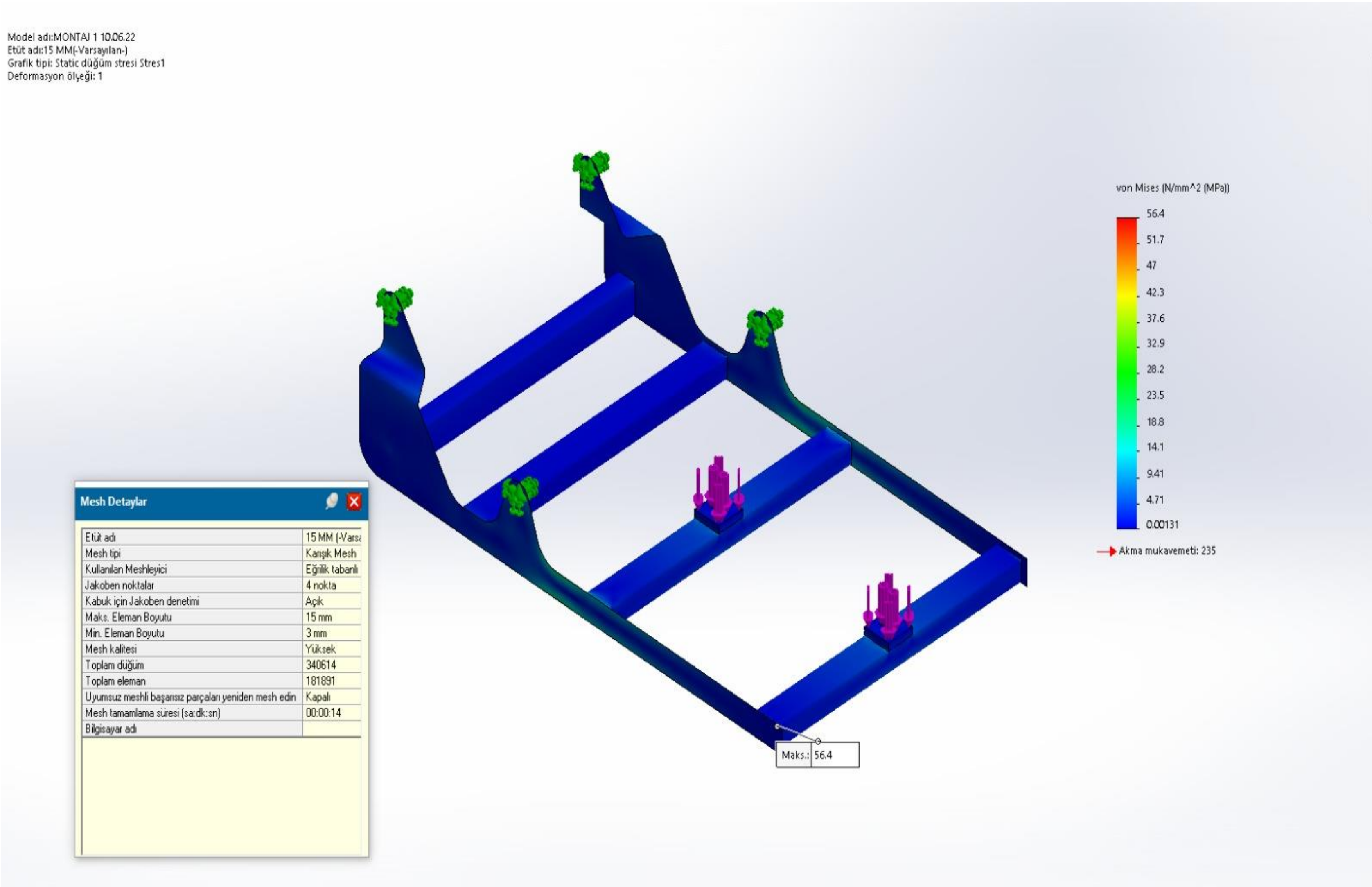
Figure 4.12 Structural Static Analysis with Solidworks Simulation Program

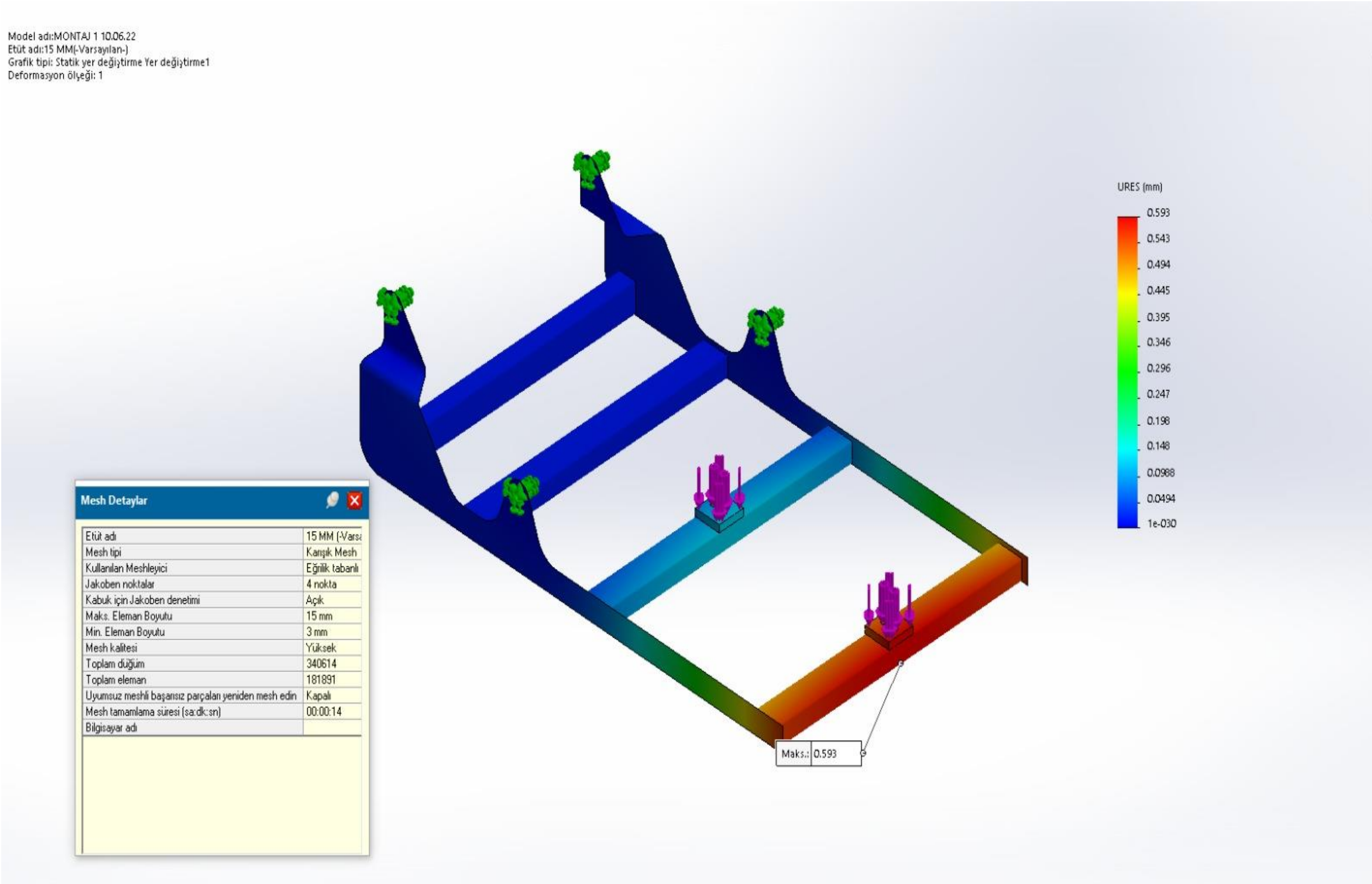

Model adı:MONTAJ 1 10.06.22
Etüt adı:30 MM(-Varsayılan-)
Grafik tipi: Static düğüm stresi Stres1
Deformasyon ölçeği: 1
Mesh Detaylar
Etüt adı 30 MM (-Varsa
Mesh tipi Karışık Mesh
Kullanılan Meshleyici Eğrilik tabanlı
Jakoben noktalar 4 nokta
Kabuk için Jakoben denetimi Açık
Maks. Eleman Boyutu 30 mm
Min. Eleman Boyutu 6 mm
Mesh kalitesi Yüksek
Toplam düğüm 135786
Toplam eleman 68766
Uyumsuz meshli başarısız parçaları yeniden mesh edin Kapalı
Mesh tamamlama süresi (sa:dk:sn) 00:00:09
Bilgisayar adı
Maks.: 65.2
von Mises (N/mm^2 (MPa))
65.2
59.8
54.3
48.9
43.5
38
32.6
27.2
21.7
16.3
10.9
5.44
0.00243
Akma mukavemeti: 235

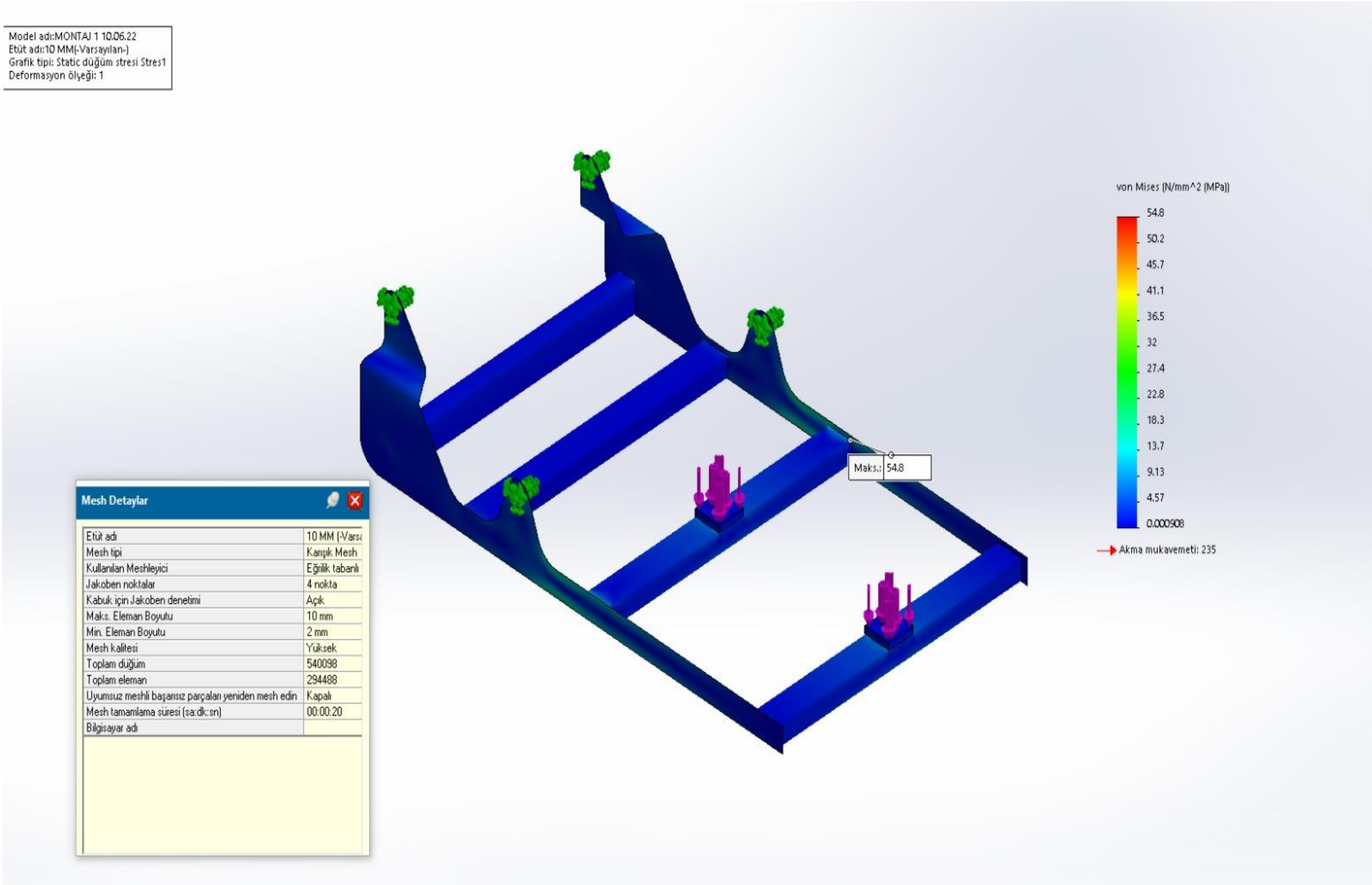

Model adı:MONTAJ 1 10.06.22
Etüt adı:30 MM(-Varsayılan-)
Grafik tipi: Statik yer değiştirme Yer değiştirme1
Deformasyon ölçeği: 1
URES (mm)
0.529
0.485
0.441
0.397
0.353
0.309
0.265
0.221
0.176
0.132
0.0882
0.0441
1e-030
Maks.: 0.529
Mesh Detaylar
Etüt adı 30 MM (-Varsa
Mesh tipi Karışık Mesh
Kullanılan Meshleyici Eğrilik tabanlı
Jakoben noktalar 4 nokta
Kabuk için Jakoben denetimi Açık
Maks. Eleman Boyutu 30 mm
Min. Eleman Boyutu 6 mm
Mesh kalitesi Yüksek
Toplam düğüm 135786
Toplam eleman 68766
Uyumsuz meshli başarısız parçaları yeniden mesh edin Kapalı
Mesh tamamlama süresi (sa:dk:sn) 00:00:09
Bilgisayar adı

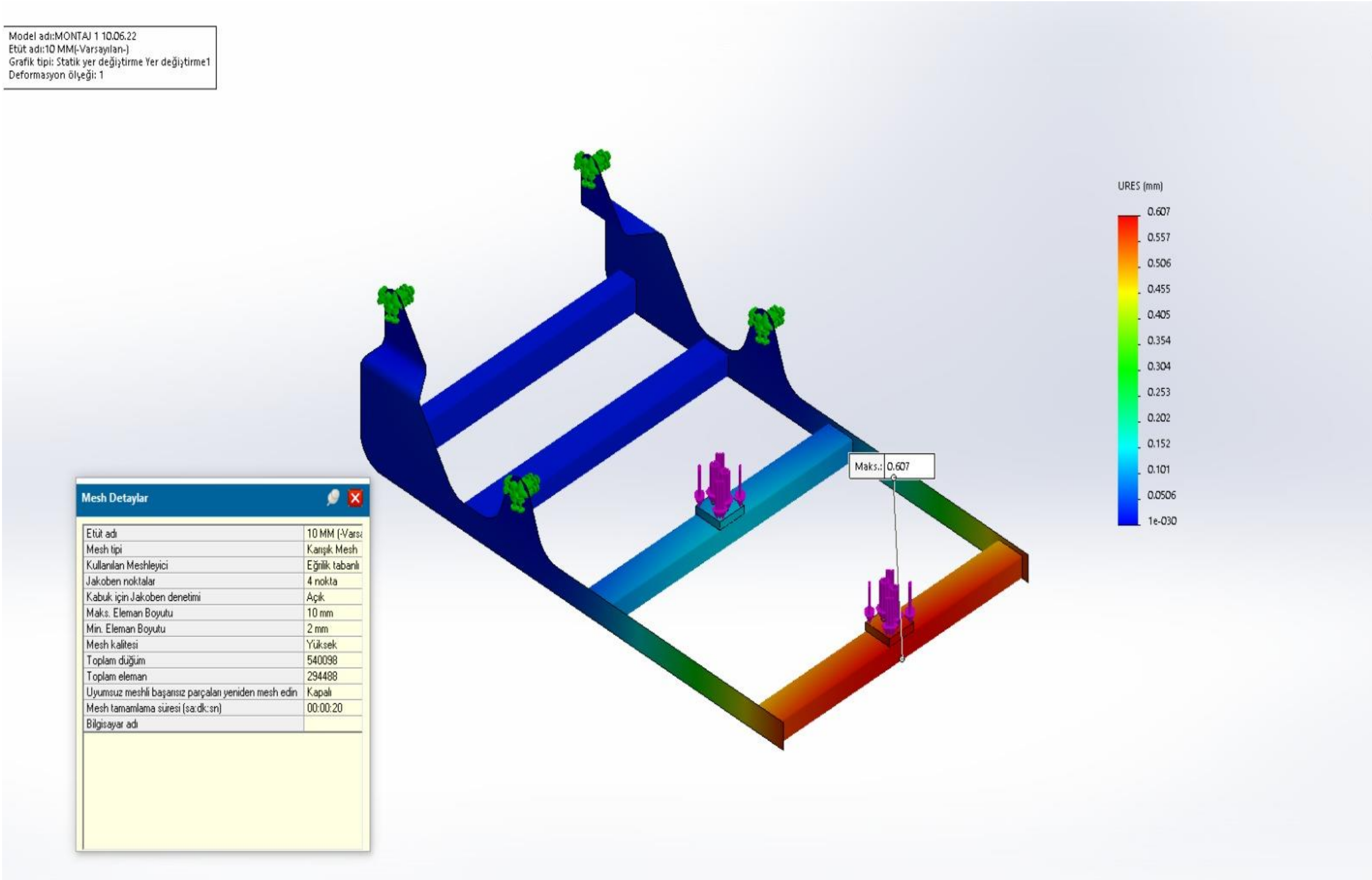

Model adı:MONTAJ 1 10.06.22
Etüt adı:20 MM(-Varsayılan-)
Grafik tipi: Static düğüm stresi Stres1
Deformasyon ölçeği: 1
von Mises (N/mm^2 (MPa))
41.1
37.7
34.2
30.8
27.4
24
20.5
17.1
13.7
10.3
6.85
3.43
0.00177
Akma mukavemeti: 235
Maks.: 41.1
Mesh Detaylar
Etüt adı | 20 MM (-Vars
Mesh tipi | Karışık Mesh
Kullanılan Meshleyici | Eğrilik tabanlı
Jakoben noktalar | 4 nokta
Kabuk için Jakoben denetimi | Açık
Maks. Eleman Boyutu | 20 mm
Min. Eleman Boyutu | 4 mm
Mesh kalitesi | Yüksek
Toplam düğüm | 212545
Toplam eleman | 111436
Uyumsuz meshli başarısız parçaları yeniden mesh edin | Kapalı
Mesh tamamlama süresi (sa:dk:sn) | 00:00:09
Bilgisayar adı |


Model adı:MONTAJ 1 10.06.22
Etüt adı:20 MM(-Varsayılan-)
Grafik tipi: Statik yer değiştirme Yer değiştirme1
Deformasyon ölçeği: 1
Mesh Detaylar
Etüt adı 20 MM (-Varsa
Mesh tipi Karışık Mesh
Kullanılan Meshleyici Eğrilik tabanlı
Jakoben noktalar 4 nokta
Kabuk için Jakoben denetimi Açık
Maks. Eleman Boyutu 20 mm
Min. Eleman Boyutu 4 mm
Mesh kalitesi Yüksek
Toplam düğüm 212545
Toplam eleman 111436
Uyumsuz meshli başarısız parçaları yeniden mesh edin Kapalı
Mesh tamamlama süresi (sa:dk:sn) 00:00:09
Bilgisayar adı
Maks.: 0.58
URES (mm)
0.58
0.531
0.483
0.435
0.386
0.338
0.29
0.242
0.193
0.145
0.0966
0.0483
1e-030


Model adı:MONTAJ 1 10.06.22
Etüt adı:15 MM(-Varsayılan-)
Grafik tipi: Static düğüm stresi Stres1
Deformasyon ölçeği: 1
von Mises (N/mm^2 (MPa))
56.4
51.7
47
42.3
37.6
32.9
28.2
23.5
18.8
14.1
9.41
4.71
0.00131
Akma mukavemeti: 235
Maks.: 56.4
Mesh Detaylar
Etüt adı: 15 MM (-Varsa
Mesh tipi: Karışık Mesh
Kullanılan Meshleyici: Eğrilik tabanlı
Jakoben noktalar: 4 nokta
Kabuk için Jakoben denetimi: Açık
Maks. Eleman Boyutu: 15 mm
Min. Eleman Boyutu: 3 mm
Mesh kalitesi: Yüksek
Toplam düğüm: 340614
Toplam eleman: 181891
Uyumsuz meshli başarısız parçaları yeniden mesh edin: Kapalı
Mesh tamamlama süresi (sa:dk:sn): 00:00:14
Bilgisayar adı


Model adı:MONTAJ 1 10.06.22
Etüt adı:15 MM(-Varsayılan-)
Grafik tipi: Statik yer değiştirme Yer değiştirme1
Deformasyon ölçeği: 1
Mesh Detaylar
Etüt adı | 15 MM (-Varsa
Mesh tipi | Karışık Mesh
Kullanılan Meshleyici | Eğrilik tabanlı
Jakoben noktalar | 4 nokta
Kabuk için Jakoben denetimi | Açık
Maks. Eleman Boyutu | 15 mm
Min. Eleman Boyutu | 3 mm
Mesh kalitesi | Yüksek
Toplam düğüm | 340614
Toplam eleman | 181891
Uyumsuz meshli başarısız parçaları yeniden mesh edin | Kapalı
Mesh tamamlama süresi (sa:dk:sn) | 00:00:14
Bilgisayar adı
Maks.: 0.593
URES (mm)
0.593
0.543
0.494
0.445
0.395
0.346
0.296
0.247
0.198
0.148
0.0988
0.0494
1e-030


Model adı:MONTAJ 1 10.06.22
Etüt adı:10 MM(-Varsayılan-)
Grafik tipi: Static düğüm stresi Stres1
Deformasyon ölçeği: 1
von Mises (N/mm^2 (MPa))
54.8
50.2
45.7
41.1
36.5
32
27.4
22.8
18.3
13.7
9.13
4.57
0.000908
Akma mukavemeti: 235
Maks.: 54.8
Mesh Detaylar
Etüt adı 10 MM (-Varsa
Mesh tipi Karışık Mesh
Kullanılan Meshleyici Eğrilik tabanlı
Jakoben noktalar 4 nokta
Kabuk için Jakoben denetimi Açık
Maks. Eleman Boyutu 10 mm
Min. Eleman Boyutu 2 mm
Mesh kalitesi Yüksek
Toplam düğüm 540098
Toplam eleman 294488
Uyumsuz meshli başarısız parçaları yeniden mesh edin Kapalı
Mesh tamamlama süresi (sa:dk:sn) 00:00:20
Bilgisayar adı



Model adı:MONTAJ 1 10.06.22
Etüt adı:10 MM(-Varsayılan-)
Grafik tipi: Statik yer değiştirme Yer değiştirme1
Deformasyon ölçeği: 1
Mesh Detaylar
Etüt adı | 10 MM (-Varsa
Mesh tipi | Karışık Mesh
Kullanılan Meshleyici | Eğrilik tabanlı
Jakoben noktalar | 4 nokta
Kabuk için Jakoben denetimi | Açık
Maks. Eleman Boyutu | 10 mm
Min. Eleman Boyutu | 2 mm
Mesh kalitesi | Yüksek
Toplam düğüm | 540098
Toplam eleman | 294488
Uyumsuz meshli başarısız parçaları yeniden mesh edin | Kapalı
Mesh tamamlama süresi (sa:dk:sn) | 00:00:20
Bilgisayar adı
Maks.: 0.607
URES (mm)
0.607
0.557
0.506
0.455
0.405
0.354
0.304
0.253
0.202
0.152
0.101
0.0506
1e-030

Table 4.1 Stress Convergence Analysis Table

Stress Convergence Analysis				
Analysis Number	1	2	3	4
Mesh (mm)	30	20	15	10
Node Number	135786	212545	340614	540098
Unit Number	68766	111436	181891	294488
Stress (Mpa)	65.2	41.1	56.4	54.8
Elastic Deformation (mm)	0.529	0.58	0.593	0.607
Stress Difference (Mpa)		24.1	15.3	1.6
Success Rate (%)		63.04	62.78	97.17

Table 4.2 Material List

Material List	
Part	**Unit**
Steel Platform of Mobile Scale System	1 piece
Weighing Indicator	1 piece
Loadcell	2 pieces
6x0,50 mm Signal Cable	15-20 meter
Junction Box (Buat)	1 piece
Interconnect Components	1 set

Figure 4.13 Prototype Manufacturing of Mobile Scale System

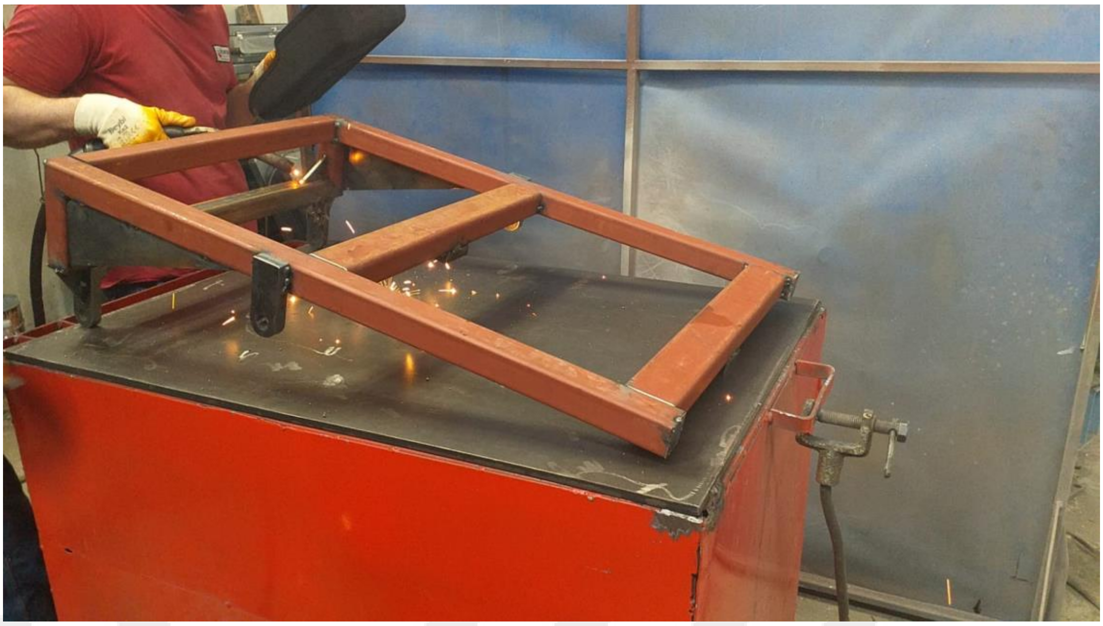


Figure 4.14 Prototype Manufacturing of Mobile Scale System

Figure 4.15 Prototype Manufacturing of Mobile Scale System

Figure 4.16 Prototype Manufacturing of Mobile Scale System

Figure 4.17 Prototype Manufacturing of Mobile Scale System

Figure 4.18 A sample mobile scale system that has been assembled

Figure 4.19 Mobile scale system prototype

Figure 4.20 Driver's cabin weighing indicator display

4.3.1. Working Principles

The mobile scale system instantly displays the weight of the straw bales, which come from the bale channel at a certain speed and vary according to their humidity. The straw bale falling on the weighing system shows the weighing value to the indicator for about 10 seconds until the next straw bale affects the weight. The strain in the load cells is transmitted to the indicator via the signal cable. This strain is converted into weight by the microprocessor cards inside the indicator. In addition to the battery the indicator has, the indicator can get its energy from the in-car cigarette lighter socket of the combine or tractor. The weighing system, which is assembled and calibrated with standard masses, is ready for use. Timely loosening and tightening of the bale density regulator arm at the end of the baler requires instant monitoring of the weight of the straw bales. Because not every part of the harvested field has the same humidity. Otherwise, users are exposed to serious breakdowns and time losses caused by balers.

In addition, the mobile scale system, which is a foldable design, saves space when traveling from one field to another or when the baler is transported to another city, and thanks to less vibration, the negative impact of the weighing system is reduced.

CHAPTER V

EXPERIMENTAL PERFORMANCE TESTS & RESULTS

5.1. Introduction

The mobile scale system, which was calibrated in the field before the experimental tests, had a capacity of 100 kilograms and its scale was determined as 1 kilogram. Calibrated with accredited standard masses. The accuracy of the mobile scale system was checked with an electronic hand scale approved by another accredited institution according to the results of the mobile scale system. In conjunction with user recommendations and the baler manufacturer, existing balers are designed to produce an average of 20-30 kg of straw bales. Therefore, in order to avoid straw bales of 40 kg or more, and considering that the mobile weighing system will operate in a severely shaky environment, target is to operate with a maximum margin of error of 10% per straw bale. 25 pieces weighing were examined experimentally and the results were tabulated

5.2. Mobile Scale System Performance Tests

Figure 5.1 Performance Tests

Figure 5.2 Verification of mobile weighing system

AS KALİBRASYON İÇ VE DIŞ TİCARET SAN. PAZ. LTD.ŞTİ.

Güzelyalı Mah.Süleyman Demirel Bul.81215 Sok.No:43
Maşuk Apt. Asmakat Çukurova / ADANA
T: 322 247 07 43 F: 322 247 07 44
E: info@askalibrasyon.com
W: www.askalibrasyon.com

TÜRKAK
AB-0068-K
2213060505
06-22

Kalibrasyon Sertifikası
Calibration Certificate

Cihazın Sahibi / Adresi: *Customer / Address*	ÖZKANLAR BASKÜL BİLGİSAYAR YAZILIM ETALON İNŞAAT VE MALZEMELERİ DEMİR NAK. VİNÇ VE İŞ MAK. SAN. VE TİC. LTD. ŞTİ. Hacı Sabancı Organize Sanayi Bölgesi Atatürk Cad.No:32 Sarıçam / ADANA
İstek Numarası: *Order No*	A-22-0672 / 1
Makine / Cihaz: *Instrument / Device*	ASKILI TERAZİ
İmalatçı: *Manufacturer*	OCASSA
Tip: *Type*	OCS-0012
Seri Numarası: *Serial Number*	TER-01 — **Müşteri Cihaz Kodu:** *Customer Product Code:* -
Kalibrasyon Tarihi: *Calibration Date*	13.06.2022
Sayfa Sayısı: *Number of Pages*	3

Bu kalibrasyon sertifikası, Uluslararası Birimler Sisteminde (SI) tanımlanmış birimleri realize eden ulusal ölçüm standartlarına izlenebilirliği belgeler.
This calibration certificate documents the traceabity to national standards, which realize the unit of measurement according to the International System of Units (SI).

Kalibrasyon laboratuvarı olarak faaliyet gösteren AS KALİBRASYON İÇ VE DIŞ TİCARET SAN. PAZ. LTD.ŞTİ., TÜRKAK'tan AB-0068-K dosya numarası ile TS EN ISO/IEC 17025:2017 standardına göre akredite edilmiştir.
AS KALİBRASYON İÇ VE DIŞ TİCARET SAN. PAZ. LTD.ŞTİ. accredited by TÜRKAK under registration number AB-0068-K for TS EN ISO/IEC 17025:2017 as test laboratory

Türk Akreditasyon Kurumu(TÜRKAK) kalibrasyon sertifikalarının tanınırlığı konusunda Avrupa Akreditasyon Birliği(EA) ile Çok Taraflı Anlaşma ve Uluslararası Laboratuvar Akreditasyon Birliği(ILAC) ile karşılıklı tanıma anlaşması imzalamıştır
Turkish Accreditation Agency (TURKAK) is a signatory to the European co-operation for Accreditation (EA) Multilateral Agreement (MLA) and to the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA) for the recognition of calibration certificate

Ölçüm sonuçları, genişletilmiş ölçüm belirsizlikleri ve kalibrasyon metotları bu sertifikanın tamamlayıcı kısmı olan takip eden sayfalarda verilmiştir.
The measurements, the uncertainties with confidence probability and calibration methods are given on the following pages which are part of this certificate.

Mühür / Kaşe *Seal*	**Yayım Tarihi** *Publication Date*	**Kalibrasyonu Yapan** *Calibrated by*	**Onaylayan / Tarih** *Approval / Date*
	13.06.2022	**Samet ÜNALIR** Kalibrasyon Personeli Calibration Responsible e-İmzalıdır	**Metin KURAL / 13.06.2022** Teknik Müdür Technical Manager e-İmzalıdır

Bu sertifika 5070 sayılı elektronik imza kanununa göre güvenli elektronik imza ile imzalanmıştır. Teyit için karekod, karekod okuyucu ile okutulabilir.
This certificate is signed using secure digital signature according to article of law, number 5070. For confirmation, read the QR Code using QR Code reader.
BİM.FRM.002/Rev.01/17.12.2021

Sayfa No: 2/3 *Nr. of Pages*	**AS KALİBRASYON** *İç Ve Dış Tic.San.Paz.Ltd.Şti.*	AB-0068-K 2213060505 06-22

Kalibrasyonu Yapılan Cihaz Bilgileri:
Instrument Details in Marking Calibration

Adı *Designation*	Ölçme Aralığı *Meas. Range*	Seri No. *Serial Nr.*	Muayene Sabiti(e) *Inspection Constant*	Çözünürlük(d) *Resolution*	Bulunduğu Yer *Place*
TERAZİ	10/50 kg	TER-01	-	0,005/0,01 kg	-

Cihazın Laboratuvara Kabul Tarihi : -

Kalibrasyon Yöntemi ve Prosedürü : Kalibrasyon; EURAMET cg-18 v 4.0 "Non-Automatic Weighing Instruments 01" standardına uygun olarak oluşturulmuş MEK-SİT-013 "Terazi Kalibrasyon Talimatına" göre yapılmıştır.
Calibration Method and Procedure

Kalibrasyon Çevre Şartları :
Calibration Environment Details
Ortamın yıllık maks. sıcaklık değişimi (ΔT) : 2 °C
Terazinin sıcaklık katsayısı (TK) : 10 ppm/K
Kalibrasyon başlangıç / bitiş sıcaklığı : 22,6 °C / 22,5 °C

Ölçüm Şartları : Cihaz, normal kullanım yerinde kalibre edilmiştir ve ölçüm sonuçları cihazın sadece bu yerdeki kullanımında geçerlidir.
Measurement Conditions

Teraziye Ait Bilgiler :

Gösterge Tipi : Dijital
Display Type

Gösterge Sistemi : [-] Tek bölüntülü [-] Çok skalalı [x] Çok bölüntülü
Display System

Ayar : [-] Dahili [-] Harici [X] Yapılmadı
Adjustment

Ayar Ağırlığı : **Ayardan önce:** **Ayardan sonra** :
Adjustment Load *Before Adjustment* *After Adjustment*

Ön Yükleme : 50 kg
Preloading

Kalibrasyonda Kullanılan Referans(lar):
Reference(s) used in calibration

Adı *Name*	İmalatçı *Manufac.*	Tipi *Type*	Seri No *Code No*	İzlenebilirlik *Traceability*
F1 Kütle Seti 01 (1g - 2 kg)	Hüray	F1	01	AB-0184-K
F1 Kütle (5 kg)	LV	F1	166	AB-0012-K
F1 Kütle (10 kg)	LV	F1	57	AB-0012-K
M1 Kütle(20kgX50adet)	LV	M1	8940...41/8964/10192-93...10126	AB-0068-K

Genel Muayene
General Inspection

Görsel Kontrol: Uygun **Fonksiyonellik Kontrolü:** Uygun
Visual Check *Function Control*

Ölçüm Sonuçları :
Measurement Results

1- Tekrarlanabilirlik Testi
Repeatability Test

Ölçüm No	Test Ağırlığı *Test Load* kg	Gösterge *Display* kg
1	20	20,00
2		20,00
3		20,00
4		20,00
5		20,00
6		20,00
	Standart Sapma S	0,000

Kontrol edildi

Ölçüm Sonuçları (Devam) :
Measurement Results (Cont.)

2- Doğrusallık Testi
Linearity Test

Ölçüm Sayısı	Test Ağırlığı *Test Load* kg	Gösterge *Display* kg	Sapma *Deviation* kg	Belirsizlik *Uncert. U(E)* kg
1.	1	1,000	0,000	0,0041
2.	2	2,000	0,000	0,0041
3.	5	5,000	0,000	0,0041
4.	10	10,000	0,000	0,0041
5.	15	15,000	0,000	0,0042
6.	20	20,000	0,000	0,0043
7.	2	2,000	0,000	0,0041
8.	30	30,000	0,000	0,0046
9.	35	35,000	0,000	0,0047
10.	40	40,000	0,000	0,0049
11.	50	50,000	0,000	0,0053

Uygunluk Değerlendirmesi / *Conformity Assessment* : Uygunluk Değerlendirmesi Müşteriye bırakılmıştır.

Karar Kuralı / *Decision Ruler* :

Kontrol edildi ☑

Ölçüm Belirsizliği :
Measurement Uncertainty

Beyan edilen genişletilmiş ölçüm belirsizliği, standart belirsizliğin, k=2 olarak alınan genişletme katsayısı ile çarpımı sonucunda bulunan değerdir ve %95 oranında güvenilirlik sağlamaktadır. Standart ölçüm belirsizliği GUM ve EA-4/02 dokümanlarına uygun olarak belirlenmiştir.

The reported expanded uncertainty of measurement is stated as the standart uncertainty of measurement multiplied by the coverage factor k=2 which for a normal distribution corresponds to a coverage probability of approximately 95%. The standart measurement uncertainty is determined in accordance with GUM and EA-4/02.

Açıklamalar ve Uygunluk Beyanı :
Remarks and Statement Compliance

Kalibrasyon sonuçları sadece TER-01 seri no' lu cihaza ait olup kalibrasyon tarihinden itibaren ve sertifikada belirtilmiş şartlar altında geçerlidir. Bu sertifikada verilen sonuçlar, cihazın kalibrasyon tarihindeki durumuna ait olup, cihazın uzun dönem kararlılığını içermez. Cihazın performansı için gerekli çevre şartlarında kullanımından ve gelecek kalibrasyon tarihinin belirlenmesinden

The calibration results given in this certificate belong to the instrument with the serial number TER-01 and indicate the conditions of the instrument under test only at the time of calibration and do not include the long term stability. It user's responsibility to use the device at the nece ssary environmental conditions for the device performance and to determine next calibration date.

Table 5.1 Average Error Ratio

Number	Mobile Scale System (kg)	Verification (kg) (Electronic Hand Scale)	Diffrence (kg) (+ /-)	Error Ratio (%)
1	26	25,11	0,89	3,42
2	26	25,11	0,89	3,42
3	27	25,49	1,51	5,59
4	25	22,98	2,02	8,08
5	24	22,93	1,07	4,46
6	23	22,49	0,51	2,22
7	23	21,76	1,24	5,39
8	20	19,42	0,58	2,90
9	20	19,75	0,25	1,25
10	19	18,8	0,2	1,05
11	18	17,6	0,4	2,22
12	18	17,26	0,74	4,11
13	18	17,5	0,5	2,78
14	16	15,4	0,6	3,75
15	16	15,36	0,64	4,00
16	16	14,94	1,06	6,63
17	18	17,4	0,6	3,33
18	21	20,3	0,7	3,33
19	22	20,96	1,04	4,73
20	23	22	1	4,35
21	23	22	1	4,35
22	23	23,3	0,3	1,30
23	24	22,35	1,65	6,88
24	24	23,01	0,99	4,13
25	25	24	1	4,00
Total Error Ratio				97,67
Average Error Ratio (%)				3,91
RESULT (Average Error Ratio (%) < 10 %)				SUCCESSFUL

5.3. Results

According to the experimental test results, the average error margin per straw bale remained below 10% and the mobile weighing system successfully completed the targeted accurate weighing operation.

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Considering the increase trend of the world population with the development of technology, traditional harvesting methods are developing and food supply is increasing rapidly in parallel with the world population. While the main goal of this development is to get faster results with lower costs, it is also to be able to produce solutions for the increasing demands of the supply chain. Therefore, the aim of this study is to minimize material and time losses thanks to the integration of mobile weighing system into the balers used in the field packaging of straw, which is a secondary product used in fields such as livestock.

Before this work, the straw coming out of the balers was weighed manually by a helper. Many combine owners, who are not able to have auxiliary personnel from time to time, can cause serious damage to the balers due to uncontrolled bale density during the harvest; This situation caused both loss of time and financial failures. In addition, because they could not know the average weight of the bales of straw packed by the balers, they were not able to verify the weighing results on the large truck scale for the bulk sales of the products.

Thanks to this study, the design and performance tests of which were completed, it was ensured that the bale machines could see the instant bale density and the operator was informed to change the bale density instantly when necessary. In this way, malfunctions of the bale machines caused by excessive compression are prevented. Another issue is that there is no need for an additional auxiliary personnel and labor costs are significantly reduced. Finally, the average weight information of the straw bales packed by the bale machines was obtained and the weighing of the transport vehicle filled with straw bales, whose transportation process was completed, on the large truck scale was relatively verified.

6.2. Recommendations for Future Work

Possible further research on this study could be as follows:

- The mobile weighing system can be automated with a software that can work integrated with the system whose bale density is adjusted.
- The mobile weighing system can be made in another design to suit other types of bale machines and It can make the installation easier.

- Remote access may be possible with the mobile application.

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