CUKUROVA UNIVERSITY

INSTITUTE OF NATURAL AND APPLIED SCIENCES

MSc THESIS

Weight Reduction On The Semi Trailer Chassis By Using Ultra High Strength Steel (UHSS) Instead of Metal Material

Tanver TALAS

Automotive Department

May, 2024

CUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

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This Master's Thesis was evaluated by the following Jury Members on 07/02/2024 and was approved by unanimity / majority of votes.

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This Thesis was written in the Department of Automotive Engineering Institute of Natural and Applied Sciences.
Thesis Number:

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CONTENTS

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Advisor: Prof. Dr. Mustafa ÖZCANLI

Department of Automotive Engineering

ABSTRACT

With the publication of the Paris Agreement, manufacturers producing O3 and O4 category trailers for the logistics sector have also accelerated their work within the framework of green transformation.

With this agreement, it is aimed to reduce carbon emissions by 30% in heavy-duty vehicles by 2030.

In recent years, commercial vehicles manufacturer especially heavy duty vehicles manufacturer target a produce light-weight vehicles in order to increase payload and decrease fuel consumption and emissions

Because of the transport high payload, manufacturer always use S355 with high thickness steel to reach high strength. However by using ultra high strength steel, manufacturer can reach high strength.

In this study, the mechanical properties, stresses, and deformations of ultra-high-strength steel and S355 steel in the semi-trailer chassis named SBPR27, referred to as the modular chassis by Koluman Otomotiv Endüstri A.Ş, were compared under a 30-ton load using the ANSYS software.. According to the results obtained, the analysis results of S355 and UHSS steel were compared under the same boundary conditions and when UHSS steel is used as chassis material; it is aimed to save total weight by reducing the cross-sectional thickness of the longitudinal supports. According to the new weight result obtained, the analysis was run in the VECTO Trailer application and the carbon emission rate and fuel consumption value were compared. According to these results, a 9% reduction in chassis weight of 182 kg led to a fuel saving of 2.9% per 100 km and a reduction in carbon emissions of 3% per km.

Keywords: Chassis, Ultra High Strength Steel,Fuel Consumption,Emissions

ÇUKUROVA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

YÜKSEK LİSANS TEZİ

Yarı Römork Şasisinde Metal Malzeme Yerine Ultra Yüksek Mukavemetli Çelik (UHSS) Kullanarak Ağırlık Azaltımı

Tanver TALAS

Danışman: Prof. Dr. Mustafa ÖZCANLI

Otomotiv Mühendisliği Anabilim Dalı

ÖZ

Paris Anlaşması'nın yayınlanmasıyla, lojistik sektörü için O3 ve O4 kategorisi treyler üreten üreticiler de yeşil dönüşüm çerçevesinde çalışmalarını hızlandırdılar.

Bu anlaşma ile ağır taşıtlardaki karbon salınımını 2030'ye kadar %30 azaltmak hedeflenmektedir.

Son yıllarda ticari araç üreticileri özellikle ağır taşıt üreticileri, yük taşıma kapasitesini artırmak ve yakıt tüketimini ile emisyonları azaltmak için hafif araçlar üretmeyi hedeflemekteler.

Yüksek yük taşıma gerekliliğinden dolayı üreticiler genellikle yüksek kalınlıkta S355 çeliği kullanarak yüksek dayanıklılığa ulaşırlar. Ancak ultra yüksek dayanıklılıkta çelik kullanılarak üretici yüksek dayanıklılığa ulaşabilir.

Bu çalışmada, ANSYS yazılımı kullanılarak 30 ton yük altında Koluman Otomotiv Endüstri A.Ş'nin modüler şasi olarak isimlendirdiği SBPR27 ticari adlı yarı römork şasisinde ultra yüksek dayanıklılıkta çelik ile S355 çeliğinin mekanik özellikleri, gerilmeleri ve deformasyonları karşılaştırıldı. Elde edilen sonuçlara göre, S355 ve UHSS çeliğinin analiz sonuçları aynı sınır koşulları altında karşılaştırıldı ve UHSS çeliği şasi malzemesi olarak kullanıldığında; uzunlamasına desteklerin kesit kalınlığını azaltarak toplam ağırlık tasarrufu sağlamak amaçlandı. Yeni ağırlık sonuçlarına göre, analiz VECTO Treyler uygulamasında çalıştırıldı ve karbon emisyon oranları ile yakıt tüketim değerleri karşılaştırıldı. Bu sonuçlara göre, şasi ağırlığında %9'a tekabul eden 182 kg 'lık bir azalma, 100 km'de %2.9 luk bir yakıt tasarrufuna ve km başına yine %3lük bir karbon emisyonu azalmasına yol açtı.

Keywords: Şasi, Ultra Yüksek Mukavemetli Çelik, Yakıt Tüketimi, Emisyon

GENİŞLETİLMİŞ ÖZET

12 Aralık 2015 yılında imzalanan Paris Anlaşması'nın yayımlanmasıyla birlikte dünya genelinde karbon salınımının azaltılması her birey ve her bir sanayi kuruluşu için çok önemli bir hedef haline gelmiştir. Bu anlaşmanın ana hedefi ise 2030 yılına kadar %30 oranında karbon salınımının azaltılmasıdır.

Continental firması tarafından yapılan araştırmalara göre dünyadaki emisyon oranının %25'i lojistik sektörü tarafından oluşmakta, lojistik sektörünün oluşturduğu emisyon oranının %70'i ise karayolu taşımacılığı , karayolu taşımacılığının ise %25'i ağır vasıta treyler araçlarından kaynaklandığı açıklanmıştır.

Treyler üreticileri bu doğrultuda gerçekleştirdikleri çalışmalarda boş araç ağırlıklarının azaltılmasına ve aerodinamik tasarımlara yönelmişlerdir.

Araç ağırlığının en büyük yüzdesini oluşturan şasinin malzeme mukavemetinin arttırılması ile araç ağırlığında hafifleme ve dolayısıyla karbon emisyon oranında azaltma sağlanabilmektedir.

Bu çalışmada; Koluman Otomotiv Endüstri A.Ş'de üretimi gerçekleştirilen SBPR27 ticari adlı modüler O4 kategori treylerin şasi ağırlığının azaltılması ve buna parallel olarak yakıt tüketimi ve karbon salınımının azaltılması hedeflenmiştir. Hafifletme sağlanması için yüksek mukavemete sahip aynı zamanda işlenebilirliği / form verme kolaylığı sağlayan çift fazlı çelikler tercih edilmiştir. Şasi analizi S355 malzeme ve Çift Fazlı 1180 çeliği kullanılarak ANSYS programında non-linear analiz yardımıyla koşturulmuştur.Şasi simetrik bir geometriye sahip olduğu için 30 ton faydalı yük yerine 15 tonluk kuvvet yayılı yük olarak şasiye uygulanmıştır.

Çift fazlı çelik, iki ana fazdan oluşan benzersiz bir mikro yapıya sahip olacak şekilde tasarlanmış yüksek mukavemetli bir çelik türüdür. Yumuşak ferrit tanecikleri ve sert martensit parçacıklarının birleşmesi sonucunda mukavemet ve süneklik arasında mükemmel bir denge sağlayarak otomotiv üretimi, inşaat ve mukavemet ve şekillendirilebilirliğin çok önemli olduğu diğer endüstrilerdeki çeşitli uygulamalar için idealdir.

Çift fazlı yapı, özel bir ısıl işlem süreciyle elde edilir. Başlangıçta, çelik belirli bir sıcaklık aralığına kadar ısıtılır ve ardından hızla soğutulur, bu da ferrit matrisini korurken mikro yapının bir kısmını martensite dönüştürür. Bu işlem, sektörde sıklıkla kullanılan çeliklere kıyasla gelişmiş mekanik özellikler sağlamaktadır.

Yumuşak ferrit fazı süneklik ve şekillendirilebilirlik sağlayarak malzemenin süneklik veya bükme gibi imalat işlemleri sırasında kolayca şekillendirilmesine veya biçimlendirilmesine olanak tanır. Sert martenzit fazı ise çeliğin genel mukavemetine ve sertliğine katkıda bulunarak yük altında deformasyona veya karşı daha dirençli olmasını sağlamaktadır

Bu iki fazın kombinasyonu, çift fazlı çeliğe, ağırlığı azaltırken çarpışma dayanıklılığını artırabileceği otomotiv gövdelerindeki yapısal bileşenler için mükemmel özellikler kazandırır. Ayrıca, mukavemet ve şekillendirilebilirlik arasında bir dengenin gerekli olduğu inşaat ve diğer endüstrilerdeki çeşitli yapısal bileşenlerde de uygulama alanı bulmaktadır.

Yapılan literatür taramasında Araçların hafifletilmesine yönelik önceki çalışmalar incelendiğinde Automotive Applications Council of AISI's Steel Market Development Institute, SMDI'nın binek araçş şasilerinde AHSS kullanımının %10-15 aralığında olması durumunda 70 kg hafifletme sağlanabileceği, TATA Group'un 2008 yılında yaptığı araştırmada bu ağırlık kazancının 100 kg'ı bulabileceği belirtilmiştir. Mehmet Hanifi Doğru tarafından yazılan "Topology Optimization of Truck Chassis Under Multi Loading Conditions" adlı makalede kamyon şasisinde von Misses yöntemiyle yapılan analizler sonucunda 2685 kg 'dan 2316 kg'a düşülerek %14 kazanç sağlandığı görülmüştür.

Massacahusetts Enstitü'sü tarafından yazılan raporda ise kamyon şasisinde gerçekleşecek 300 kg hafifletmenin yılda 4500 lt yakıt tasarrufu sağlayacağı belirtilmiştir. araç ağırlığında meydana gelecek %25'lik bir hafifletmenin yakıt tüketiminde %6.5'luk bir azalma beklenebileceği belirtilmiştir. Araç tasarımında hafif malzemelerin kullanılması neticesinde treyler ağırlığını azaltma fikri yeni bir düşünce olmayıp, son yıllarda bunu yapmanın potansiyel faydaları giderek artan bir şekilde değerlendirilmiştir.

Tüm bu araştırmalar ve hedefler ; treyler üretiminde kompozit malzemeler kullanılarak hafif treyler prototiplerinin geliştirilmesine ve şasilerde yüksek mukavemetli çeliklerin kullanılıp araçlarda hafifletme çalışmalarına öenm verilmesine yol açmıştır . Bu tür hafif treyler örnekleri arasında ROADLITE Treyler, CleanMould Treyler, Compositttrailer, Phoenixx Treyler ve Walmart Prototip Treyler bulunmaktadır. Karbon fiber bazlı soğutmalı Aldi treyler gibi soğutmalı treylerlere hafif malzemeler de uygulanmıştır Bu projelerin tümünde, geleneksel çeliklerin kullanıldığı treylerlere kıyasla üretilen kompozit malzemeler kullanılmıştır. Bir diğer çalışmada ise Galos ve arkadaşları iki ayrı firmaya ait iki treylerin ağırlık azaltımından nasıl etkilendiğini istatiksel olarak incelemişlerdir. Treylerlerin boş ağırlığının %30 azaltılmasının, treylerler için %11 kütle enerji performans azalması sonucuna ulaşarak. ağırlığı %10 ila %30 oranında azaltmışlardır.Fakat kompozit malzemeden üretilen treylerin çelik ve aluminyum hammaddesi kullanılarak üretilen treylerin maliyetinden 2 kat daha yüksek olması sebebiyle piyasada talep görmemektedir.

Treyler şasisini ''I'' kesit olarak adlandırılan 3 ana parça oluşturmaktadır.;

- Boyuna taşıyıcı üst laması
- Ara Destek laması
- Boyuna taşıcıyı alt laması

2 ana parçadan oluşan I kesit parçaları kaynaklı imalat yöntemi ile birleştirilmiştir. Yayılı yükün ana taşıyıcısı olan I kesit parçalarına ise ara enine traversler destek vermekte ve mukavemetin

korunmasını sağlamaktadır. Treylerin taşıyabileceği faydalı yük 27-30 ton aralığında olup, imalatçılar fazla yüklemeye karşı şasilerini tasarlamaktadır.

Bu analizde 30 tonluk faydalı yük esas alınmış ve yayılı yük olarak şasiye uygulanmıştır.Şasi, analizde 4 farklı noktadan sabitlenmiştir. Bu noktalar;

- Kingpim tablası
- 1., 2. Ve 3,aks çizmeleri

Geometrinin ve de yüklemenin simetrik bir yapıda (hem fizik hem de geometrik simetrik) olmasından dolayı analiz modeli, simetrik yani yarım olarak modellenmiş ve nonlinear analiz olarak koşturulmuştur. Böylelikle çözüm süresinden kazanılmıştır.

Elde edilen sonuçlar incelendiğinde; S355J2 malzemeden üretilen yarı römork şasisisi ‘’I’’ kesit ara parçasında 235-470 MPa aralığında gerilmeler meydana gelmiş, kingpim tablası bölgesi üzerinde ise 550 MpA seviyelerinde gerilmeler oluştuğu gözlenmiştir.

DP1180 çeliğinin şasi malzemesi olarak atandığı analizlerde ise; ‘’I’’ kesit ara parçasında 240-400 MPa aralığında gerilmeler meydana gelmiş olup, kingpim tablası bölgesi üzerinde 455 MPa aralığında gerilmeler oluşmuştur. Her iki analiz sonucuna göre Çift Fazlı 1180 Çeliğin 15 ton yayılı yük altındaki gerilme ve deformasyon değerleri S355J2’ye göre daha iyi sonuç verdiği için , boyuna taşıyıcıların ‘’I’’ kesit kalınılıklarında azaltma yapılarak analiz tekrar edilmiş ve elde edilen analiz sonuçları neticesinde şasi boyuna taşıyıcılarında 182 kg hafifletme sağlanmıştır.

Perdeli üstyapıya sahip yarı römork aracın ağırlığı 7200 kg olup, VECTO Trailer programında koşturulan analizine göre şehir içi, şehirler arası ve ülkeler arası nakliye faaliyetleri göz önüne alınarak hesaplanan ortalama yakıt tüketimi 27.6 lt /100 km olup, karbon salınımı ise 722g/km’dir.

Şasinin ağırlığı 1981 kg olup, 182 kg’lık hafifletme ile %9’luk ağırlık azaltılması yakalanmıştır. Ağırlık azaltılması ile birlikte aracın toplam ağırlığı 7018 kg olmuştur. Bu ağırlığa istinaden VECTO Trailer Elde edilen hafifletmenin karbon emisyonuna etkisi VECTO Trailer programında yapılan hesaplama 22 g/km olurken, yakıt tasarrufu ise 0.8 lt/100 km olmuştur. 1 adet treylerin yılda ortalama 200.000 km yol yaptığı göz önüne alındığında ; yıllık yakıt tasarrufu 1600 lt , karbon emisyonundaki azalma ise 4400 kg olacaktır.

Lojistik sektörünün sera gazı emisyonuna etkisi %25 ve bunun %70’i ise karayolu taşımacılığına ait olduğu için 1 adet araçtan elde edilecek yıllık 1600 lt yakıt tasarrufu ve 4400 kg karbon emisyon tasarrufu çok büyük öneme sahiptir.

TÜİK verilerine göre, 2023 yılında Aralık ayına kadar toplam 32.153 yarı römork tescil edilmiştir. Bu araçların 16.288'i AB 2022/1362 yönetmeliğinde belirtilen aerodinamik araç kategorilerine giren perdeli, kapalı kasa ve frigorifik üst yapılı araçlardır.

16.288 araç x 1600 lt/Araç hesabı yapıldığında Türkiye’de 2023 yılında trafiğe kayıtlı olan ağır vasıta treyler araçlarından 26.060.080 lt yakıt tasarrufu , 16.288 araç x 4400 kg hesabı yapıldığında ise 71.667.200 kg carbon emisyon salınımından tasarruf sağlanacaktır.

DP1180 çeliği S355J2 yerine kullanıldığında 207 dolar daha fazla üretim maliyeti olmasına rağmen, aracın hafiflemesinden dolayı 100 km'de 0.8 litre yakıt tasarrufu sağlandığı ve 1 treylerin yılda 200.000 km yol kat ettiği göz önüne alındığında yıllık 2116 dolar yakıt tasarrufu sağlanmaktadır. Aylık yakıt tüketim kazancı ise 176 dolar olup neredeyse 1 ayda üretim maliytinden kaynaklanan artış tolare edilmektedir.

ACKNOWLEDGMENT

I would like to thank my advisor, Prof. Dr. Mustafa Özcanlı, for guiding me and providing technical support throughout the preparation of this thesis, as well as Koluman Otomotiv Endüstri A.Ş for their support during my master's studies. This study wouldn't have been completed without the significant contributions of my colleague Onur Can Kırıt, who provided great support with his analyses. I would like to extend my heartfelt thanks to him. Also And of course, my heartfelt thanks go to my family for being by my side throughout this journey.

LIST OF TABLES

LIST OF FIGURES

SYMBOLS AND ABBREVIATIONS

EU	:European Union
CO2	:Carbondioxide
TUİK	:Türk İstatistik Kurumu
VECTO	:Vehicle Energy Calculation Tool
DP	:Dual Phase
AHSS	:Advanced High Strength Steel
UHSS	:Ultra High Strength Steel

1. INTRODUCTION

Climate change and environmental degradation are an existential threat for Europe and the world. The European Commission were adopted a set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 30% by 2030, compared to 1990 levels.The European Green Deal set the blueprint for this transformational change. The CO2 emission Standards for heavy-duty vehicles are important key EU policy instrument in this area

With the publication of Regulation EU 2022/1362, trailer manufacturers have given importance to the design of vehicles with high aerodynamic efficiency and lower coefficient of friction in order to reduce the carbon emissions of vehicles, but the option of vehicle light weighting in terms of lower unit cost, which affects aerodynamic efficiency, has become even more important today.

According to a study conducted by Continental in 2014, the logistics sector accounts for 25% of the world's emission rate, while the carbon emission rate created by road transportation accounts for 70% of the logistics sector. Semi-trailer vehicles account for 25% of the emission rate emitted as a result of road transportation. (https://www.continental-tires.com/tr/tr/b2b/business-know-how/co2-regulations-vecto/)

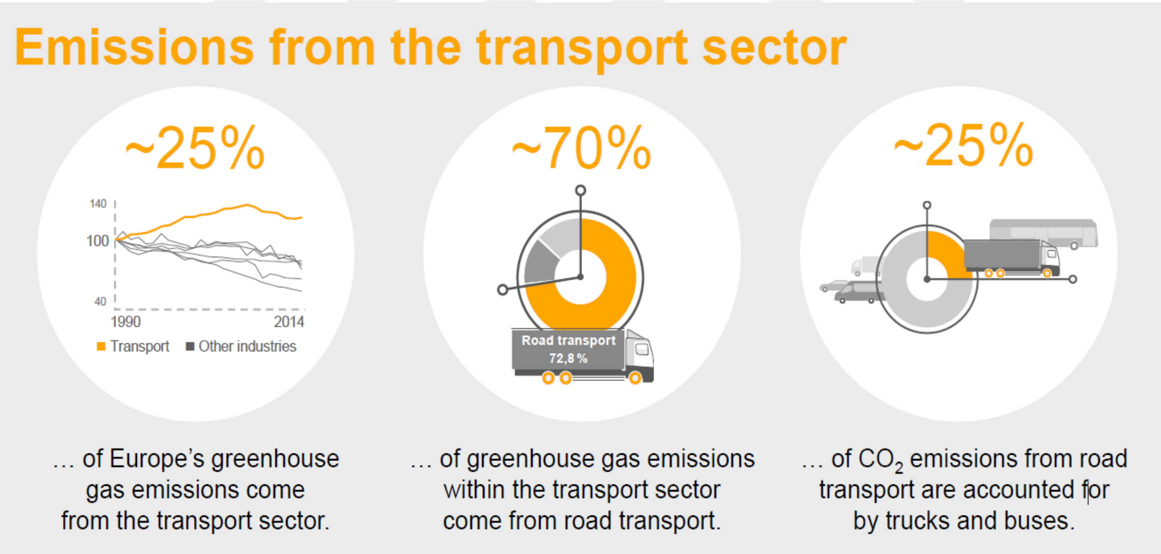

Figure 1. Emissions rates of logistic sector (https://www.continental-tires.com/tr/tr/b2b/business-know-how/co2-regulations-vecto/)

Considering all these factors, manufacturers are trying to achieve the same strength value with less weight by using high-strength steel and reducing sheet thickness in the chassis, which constitutes the largest weight of the vehicles.

Chassis materials are generally preferred as S355 and S700 because they are easily formable and easily available in the market. Although the unit cost of high-strength steels is higher, the higher tax rate to be levied on vehicles with higher emissions as a result of the effects of Regulation EU 2022/1362, which came into effect within the scope of green transformation, will be a path that manufacturers will follow to achieve weight savings by using high-strength steels.

1.1. Fuel Consumption and CO2 Emissions For Registered Vehicles in Turkey

According to TUIK data, a total of 32,153 semi-trailers were registered in 2023 until December. 16,288 of these vehicles are curtainsider, closed box and frigorific superstructure vehicles, which fall under the categories of aerodynamic vehicles specified in the EU 2022/1362 regulation.

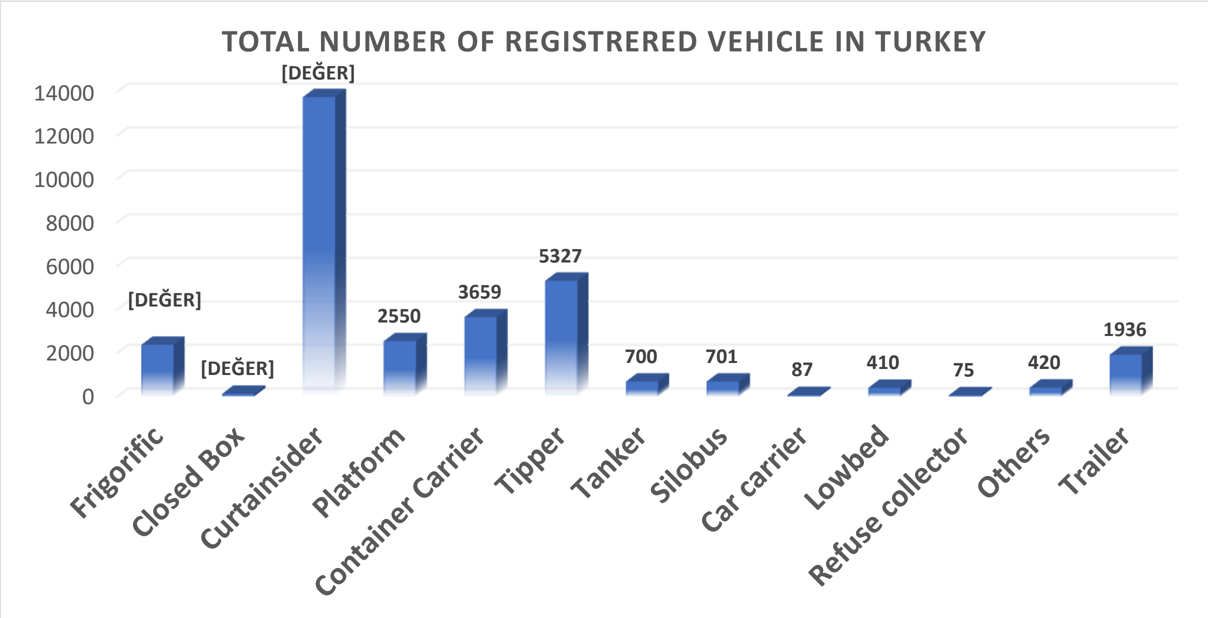

Figure 2. Registered Vehicle List According to the Superstructre(**https://raporlama.treder.org.tr/satis-rapor**)

A trailer travels an average of 200,000 km per year. In the VECTO Trailer application, the fuel consumption of a curtain-sided trailer weighing 7200 kg when simulated for urban, interurban, and international operations is calculated as 27.6 liters per 100 km. Also CO2 emissions is 722 g/km as shown in Figure 3.

Weighted Results

Payload:	13842	kg
Fuel consumption:	27.6	l/100km
Fuel consumption:	0.0199	l/t-km
Fuel consumption:	0.00292	l/m^3-km
Fuel consumption:	230.6	g/km
Fuel consumption:	16.7	g/t-km
Fuel consumption:	2.45	g/m^3-km
CO2 emissions:	722	g/km
CO2 emissions:	52.1	g/t-km
CO2 emissions:	7.65	g/m^3-km
Efficiency ratio:	0.979	km-based
Efficiency ratio:	0.979	t-km-based
Efficiency ratio:	0.945	m^3-km-based

VECTO Trailer Tool Version:

0.9.0.3168-RC !!NOT FOR CERTIFICATION!!

Date:

2023-12-22T08:01:04.8789236Z

Cryptographic hash manufacturer's records file:

jeMFehSCy1NG4gHMyVbYR5jAXCOV40S21VSZClr+0E8=

Figure 3. Fuel Consumption and CO2 Emissions Rate According to The VECTO Trailer

When a simple calculation is made, the amount of total fuel consumed by 16,288 trailers per year is 899,097,000 liters.

Odhams AMC and friends (2010) study indicated that by reducing the unladen weight of trailers by 25%, an approximate decrease of 6.5% in fuel consumption is expected. Accordig to this calculation, a 25% reduction in chassis weight will result in a fuel saving of 58,441,000 liters per year.

1.2. Importance of Chassis

A semi-trailer chassis refers to the framework or undercarriage of a semi-trailer, the part that supports the trailer's body and cargo. It includes the structural frame, axles, wheels, suspension, and braking system. The chassis is designed to handle the weight of the cargo and endure the stresses of transportation. It's a crucial component that allows the semi-trailer to be towed by a tractor or semi-truck, enabling the transportation of goods over long distances. The design and construction of the chassis are important factors in determining the trailer's load capacity, stability, and overall performance on the road.

The design parameters of a semi-trailer chassis encompass various factors that engineers consider when creating these structures. These parameters are crucial to ensure the chassis meets safety, performance, and regulatory standards while accommodating the specific needs of the intended application. Some key design parameters include:

- **Load Capacity**: Determining the maximum load the chassis can bear safely without compromising structural integrity is fundamental. This involves considering weight distribution, payload requirements, and axle configurations.
- **Structural Integrity:** The chassis must withstand various stresses, including tension, compression, bending, and torsion, while maintaining its shape and stability under normal operating conditions and potential unexpected loads.
- **Material Selection:** Choosing appropriate materials (such as steel grades like S355 or dual-phase steel) that balance strength, weight, durability, and cost is crucial in chassis design.
- **Suspension and Axle Configuration**: Determining the type of suspension system (e.g., leaf spring, air suspension) and axle arrangement (single, tandem, or multi-axle) based on load distribution, road conditions, and ride quality requirements.
- **Compliance with Regulations:** Ensuring the design adheres to local and international regulations regarding weight limits, dimensions, structural integrity, and safety standards is essential.
- **Durability and Fatigue Resistance:** Designing for long-term durability involves considering factors like corrosion resistance, fatigue strength, and the ability to withstand repetitive loading cycles without failure.
- **Manufacturability and Cost Efficiency:** Creating a design that is not only functional but also feasible for manufacturing within cost constraints is important. This includes considering fabrication processes, assembly techniques, and material usage efficiency.
- **Safety Features:** Incorporating safety features such as reinforcements at critical stress points, proper attachment points for securing cargo, and potential crashworthiness considerations to enhance occupant and road safety
- **Weight Distribution and Balance:** Ensuring proper weight distribution across the chassis to maintain stability and handling characteristics, especially when navigating varied terrain or encountering high winds.

Designing a semi-trailer chassis involves a comprehensive understanding of these parameters to create a structure that is robust, safe, and capable of meeting the demands of transportation while adhering to industry standards and regulations.

Considering all these parameters, when it comes to the chassis, the most crucial components are the longitudinal beams. They are directly exposed to static and dynamic loads, positioning themselves as the parts that exhibit the highest resistance against these forces.

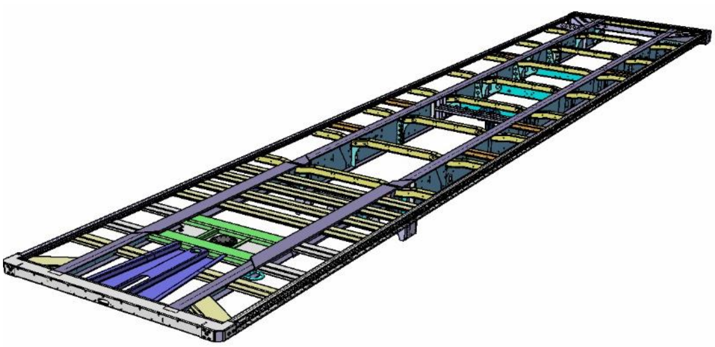

Figure 4. Semi Trailer Chassis

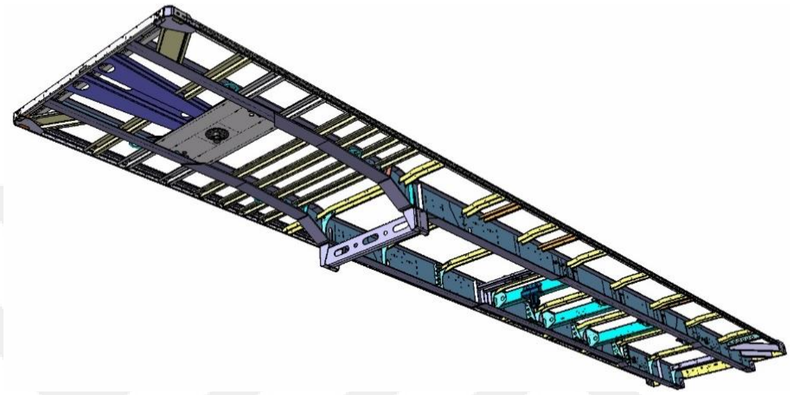

Figure 5. Semi Trailer Chassis

1.3. Application Area of S355 and Dual Phase 1180 Steel

S355 is a grade of steel that's commonly used in various applications due to its strength and mechanical properties. Its application areas can include construction, structural engineering, machinery, automotive components, and shipbuilding, among others. Its versatility and durability make it suitable for a wide range of uses where strong and resilient materials are required.**(https://blog.thepipingmart.com/grades/s355-grade-steel-composition-properties-and-uses/)**

Dual Phase 1180 steel is a high-strength automotive steel known for its excellent crash performance. It's commonly used in the automotive industry for safety-critical components in vehicle structures. This type of steel is employed in parts that require high-energy absorption during collisions, such as reinforcement panels, pillars, side impact beams, and other safety-related areas within vehicles. Its high strength and deformation properties make it ideal for enhancing vehicle safety while reducing overall weight. **(Ishikawa T.,2012)**

Figure 6 and Figure 7 show the distribution of steel and steel types with which strength in which parts of the car.

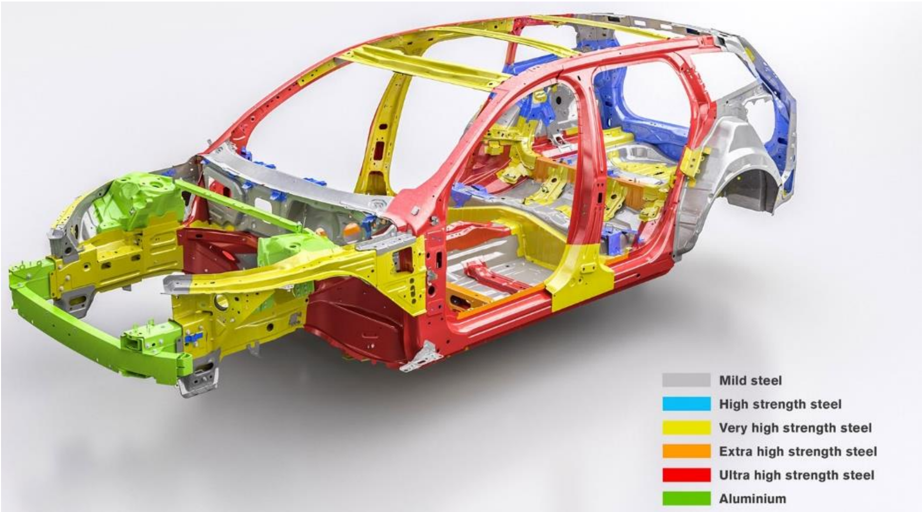

Figure 6. Application Area of DP Steels on Passenger Cars Chassis-1 **(Tasan C.C,2015)**

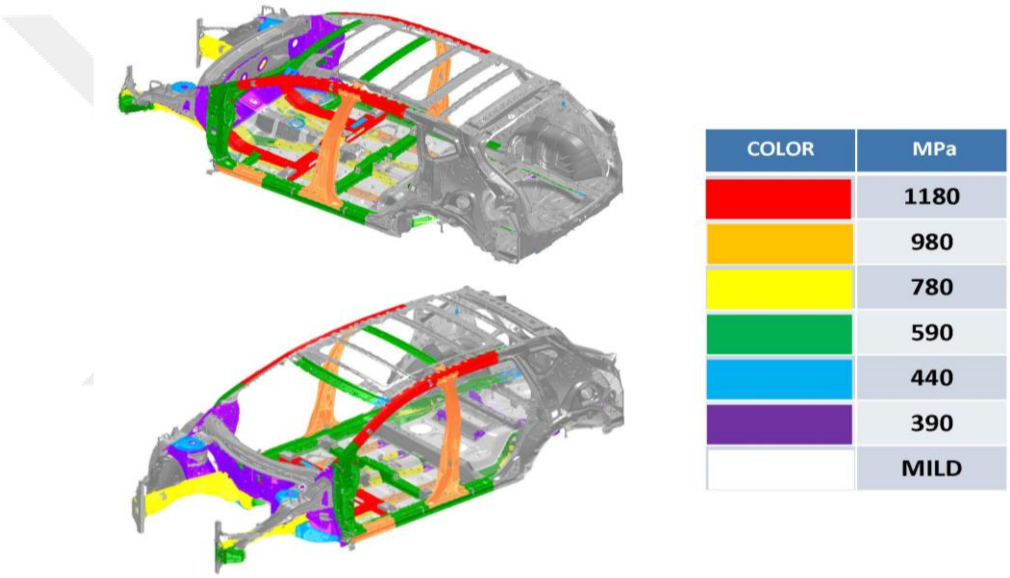

Figure 7. Application Area of DP Steels on Passenger Cars Chassis-2
(https://lovessivs.life/product_details/55838012.html)

The superior balance between strength, formability and ductility of DP steels comes from their particular composite microstructure, consisting mainly of ferrite and martensite. This article traces first the history of DP steels from their discovery in the 1960s to the most recent industrial developments. (**Goro Miyamoto and Michael C.Gao,2022)**

2. PRELIMINARY WORK

The research is continuously conducted with the aim of reducing the weight of the vehicle chassis and decreasing fuel consumption.

Lightweighting of vehicles has been the main goal of the automotive industry for many years. Especially the using of composite materials in vehicle chassis has become a popular practice in the sector, especially due to their low density.

21st Century Steel, The World Steel Association,2009 announced that CO2 emissions, reporting that if the use of advanced high-strength steel instead of other grades of steel is increased in vehicles that can carry 5 people, CO2 emissions will decrease by 6%.

According to the studies, an average vehicle causes 4 tons of CO2 emissions per 22,000 km per year. According to the European Commission's 2009 report, it plans to reduce emissions to 120 kg CO2/km by 2012 with strong competition and weight reduction of high-volume B and C segment vehicles .

In another study, it was reported that the maximum strength of materials around 600 MPa significantly reduces the loss of life in terms of safety. For example, according to DaimlerChrysler service information, they used DP600 (dual phase steel) steel to increase the impact performance of 2006 Jeep Grand Cherokee and Commander vehicles **(Advanced High-Strength Steels–A Collision Repair Perspective", Technical Information for the Collision Industry,2006)**

A report by AISI's steel development institute (Automotive Applications Council of AISI's Steel Market Development Institute, SMDI) found that the use of AHSS steels increased from 10% to 15% between 2007 and 2009 model vehicles. With the increase in the use of AHSS steel, it was reported that the total body weight decreased by 70 kg .

Corus Research,2008 mentioned on their report ,Tata Group reported that it had reduced the weight of its cars by 60 kg by increasing the use of AHSS steel, and that this weight saving could be increased to 100 kg by using more AHSS steel, saving 1 ton of CO2 emissions over the life of each vehicle

ArcelorMittal the world's number one steel producer, reported in its 2008 report that ultra-light high reported that with the use of strength steels, weight was reduced by 50% in gas cylinders and 40% in automobile parts, while gas emissions were also reduced

In another study, **Arcelor Auto** reported that the weight reduction with the use of advanced steels in automobiles varies between regions of the car To give an example from one area of the car; it has been reported that with the use of advanced steel (TRIP, DP steel, etc.) in the rear panel area, the weight decreased from 22 kg to 17 kg and a weight saving of 24% was achieved.

In the front panels, the weight savings increased to 28%, while in the rear and front doors, the weight reduction rate was reported to be 18%. In addition, **Arcelor Mittal** reported that in 2007 the production of TRIP 1200 and DUAL 1200 steels, which have been developed with the latest studies, has started as of 2007 In the BMW-6 (2009 model) automobile series produced worldwide, the proportion of AHSS steel in the body structure and main parts increased to 32%. has been removed.

Mehmet Hanifi Dogru,(2019) examines the vehicle chassis design within the scope of loads that can be carried as a name of work study ‘’Topology Optimization of Truck Chassis Under Multi Loading Conditions’’,In this study, topology optimization was applied to reduce the weight of the truck chassis exposed to various types of loads. It was found that the weight of the non-optimized model was 2685 kg, and the structural analysis results indicated a von Mises stress value of approximately 194 MPa. It was concluded that the weight of the chassis obtained after topology optimization was approximately 2316 kg, and the von Mises stress value was approximately 220 MPa. According to the results of the topology optimization, the weight of the recreated truck chassis decreased by approximately 14%

According to the **MITrepor**t (2008), trucks save 3000 liters of fuel per 200000 km, if the weight of the truck decrease nearly 300 kg Based on the fact that the trucks drive approximately 300,000 km per year, it was found that approximately 4,500 liters of fuel can be saved per year for each truck. When the trucks moving on the roads in our country are taken into account, it is revealed that this fuel saving will contribute to the national economy significantly. In another study, efficiency analysis can be made by taking into consideration the production difficulty and cost of optimized geometry.

Patel Vijaykumar V., Prof. R. I. Patel (2012) focused their work towards weight reduction of chassis by performing structural analysis. Basic calculations for the chassis frame were done analytically based on the bending theory and values of stress and deflection were obtained. Finite element analysis for the existing chassis was performed for overload condition and stress and deflection values were obtained. For weight reduction design modifications were made by doing a sensitivity analysis. In sensitivity analysis section modulus and flange width were kept constant. Three cases were considered for weight reduction in which thickness and height of the flange were varied. Comparison of the results showed that out of three cases third case resulted in weight reduction of about 7% and stress and deflection values were reduced by about 12% and 11% respectively.

The idea of reducing the empty trailer mass by implementing lightweight materials in design is not a new concept, and the potential benefits of doing so have been increasingly evaluated over the past decade. This has ultimately led to the development of a series of lightweight trailer prototypes that utilize lightweight composite materials in their structures **(Odhams A.M.C, etc al, 2010).** Examples of such lightweight trailers include: the ROADLITE trailer **(Turner M and Boyce G, 2005**),the CleanMould trailer **(EPL Composite Solutions, 2010)**, the Composittrailer (**Verhaeghe J,2006**), the Phoenixx trailer (**Jarvis B,2006)** and the Walmart prototype trailer**(Gardin G,2014)** Lightweight material1s have also been applied to refrigerated trailers, such as carbon fiber-based refrigerated Aldi trailers **(Kaiser,2010).** In all these projects, successful results have been achieved with a reduction in empty trailer weight ranging from 10% to 30% compared to traditional steel trailers

The ROADLITE Trailer, developed by the University of Nottingham and EPL Composites, is a remarkable design using composite materials and designed for lightweighting The side hatch trailer, called the platform type, incorporates a glass fiber reinforced thermoplastic chassis, while the first prototype used a sandwich panel floor covering placed on top of the glass fiber chassis. The trailer is reported to be 20% lighter and 18% stronger than the standard steel chassis design.

Similar to the ROADLITE trailer, the 13.6 m CleanMould trailer project, developed by six partners including EPL composites, has developed a new glass fiber reinforced thermoplastic material that combines a low viscosity resin and high fiber content continuous fiber reinforcement. The composite design is reported to be around 10% lighter and more aerodynamic than the steel structure, leading to a reduction in fuel consumption of over 10%.**(Verhaeghe J,2006)** However, the stated benefits of the CleanMould trailer, as with other composite trailers, are difficult to verify and this probably plays a role in its lack of market acceptance. (**Jarvis B,2006)**

In a study conducted by Galos amd Sutcliffe they examined the combination of structural optimization and material selection on a lightweight truck trailer. Their developed finite element model and material optimization showed a potential weight savings of 67% (1326 kg). **(Galos, J., Sutcliffe, M., 2019)** In another study, **(Galos and et al.,2015**) statistically analyzed how the weight reduction of two trailers from different companies with moving floors was affected. They found that a 30% reduction in the empty weight of the trailers resulted in an 11% decrease in mass-energy performance for the trailers.

In another study, Germany-based 'The Team Technology' (TTT) Composite AG ("A composite glimpse of the future," 2006) has designed a carbon fiber/epoxy-based monocoque three-axle curtainsider trailer.The new trailer weights 3700 kg and it has a weight advantage over a similarly sized steel trailer with an unladen weight of 5500 kg. The chassis producmed consists of carbon fiber reinforced epoxy monocoque chassis. It is aimed to transport palletized products. Kogel, the company that produced the trailer, stated that the production costs of the trailer were twice that of a similar steel trailer and about 30% more than an equivalent aluminum trailer. **(Galos J, Dr.Sutcliffe and Prof. Cebon ,2014 ETC Conference)**

Also in 2014, Great Dane Trailer in the USA produced a prototype trailer with a carbon fiber composite structure. The length of the trailer consists of 2 layers of 16 meters in length, and it is stated that the composite structure is 1814 kg lighter than the chassis where the steel structure is used.

It has also been noted that they can expect around a 6.5% reduction in fuel consumption from reducing trailer unladen mass by 25% (**Odhams et al., 2010**. Measures to achieve the greenhouse gas reduction target in 2050 may include initiatives such as lightweighting the trailer, improving aerodynamics, choosing alternative fuels (**Léonardi and Baumgartner ,2004).**

In our study, we have gain %3 fuel consumption per 100 km after %9 reduction from trailer chassis weight. This rate of fuel reducing will significantly effect to total consumption on a year when we consider that per trailer 200.000 km distance traveled.

In addition that, In MIT's study, it was stated that 300 kg of lightening in the truck chassis provided 3000 liters of fuel savings at a distance of 200,000 km per year. These values are in parallel with the gain values obtained in our study. With 200 kg lightweighting, 1600 liters of fuel savings were achieved in trailers that travel 200,000 km per year. Considering a 300 kg lightening, the fuel saving would be calculated as 2400 liters per year.

3. MATERIAL AND METHOD

In this study , the effects of S355 steel and DP 1180 steel on the chassis have been investigated. Also, static and natural frequency (modal) analyses were conducted on the modular chassis produced by KOLUMAN under 30 tonnes loading conditions

3.1. S355 Material

S355 is a designation for structural steel that meets specific mechanical properties and chemical compositions. It's part of the EN 10025 European standard for hot-rolled structural steel, indicating a minimum yield strength of 355 megapascals (MPa). This steel grade is commonly used in construction, engineering, and various industrial applications due to its excellent strength, weldability, and durability.

S355 steel offers several advantages:

- **High Strength**: It provides good strength, allowing structures to bear significant loads while maintaining structural integrity.
- **Good Weldability:** S355 steel is easily weldable, making it suitable for various fabrication processes.
- **Durability**:It has good durability and can withstand harsh environmental conditions, making it suitable for outdoor and heavy-duty applications.
- **Versatility**: S355 steel is used in a wide range of applications, from building structures like bridges and buildings to machinery and equipment.

The mechanical properties of S355 steel, which is commonly used for structural purposes, typically include the following:

- The minimum yield strength of S355 steel is 355 megapascals (MPa). This is the point where the steel begins to deform plastically.
- The ultimate tensile strength of S355 steel typically ranges between 470 and 630 MPa. This is the maximum stress a material can withstand while being stretched or pulled before it fails.
- S355 steel generally exhibits a good level of elongation at break, often around 20% to 25%. This refers to the ability of the material to deform before fracturing.
- The modulus of elasticity (also known as Young's modulus) for S355 steel is around 205 GPa. This measures the stiffness of the material and its ability to return to its original shape after deformation.

- The hardness of S355 steel can vary based on processing and heat treatment, but it's generally within a moderate range.

These mechanical properties make S355 steel suitable for various structural applications, offering a balance between strength, toughness, and weldability. It's important to note that these properties may vary slightly depending on the specific grade, heat treatment, manufacturing process, and other factors. Always refer to the relevant standards or specifications for precise mechanical property values.

3.2. Dual Phase 1180 Steel

Dual Phase (DP) 1180 is a type of advanced high-strength steel (AHSS) that is specifically engineered to offer exceptional strength along with good formability. Here are some key characteristics and details about DP 1180 steel:

- **High Strength**: DP 1180 steel is known for its high tensile strength, typically exceeding 1180 megapascals (MPa). This high strength makes it suitable for applications requiring structural integrity and load-bearing capacity while reducing the weight of components.
- **Dual Phase Microstructure** :The name "Dual Phase" refers to its microstructure, consisting of two distinct phases—soft ferrite and hard martensite. This dual-phase structure is achieved through a specific heat treatment process, contributing to the steel's excellent combination of strength and ductility.
- **Formability**: Despite its high strength, DP 1180 steel retains good formability, allowing it to be shaped and formed into complex parts without sacrificing its mechanical properties significantly. This formability is crucial for manufacturing components with intricate designs.
- **Applications**: DP 1180 steel is commonly used in the automotive industry for producing components that require both high strength and formability. It's utilized in various structural parts of vehicles, including safety components, reinforcements, chassis components, and body panels, helping enhance vehicle safety and performance while reducing weight.
- **Weldability**: While DP 1180 steel offers good weldability, proper welding techniques and procedures are necessary to ensure the integrity of welded joints and maintain the material's properties.
- **Lightweighting**: Its high strength-to-weight ratio makes DP 1180 steel suitable for applications where reducing weight is essential while maintaining structural integrity, contributing to overall lightweighting efforts in industries like automotive manufacturing.

DP 1180 steel, as part of the AHSS family, addresses the need for materials that can meet stringent performance requirements in various industries, especially in the automotive sector, where lightweight materials with high strength and formability are increasingly sought after for improved fuel efficiency and safety. Mechanical properties of Dual Phase Steel was shown on the Figure 8. When martensite content is increase, strength will increase also.

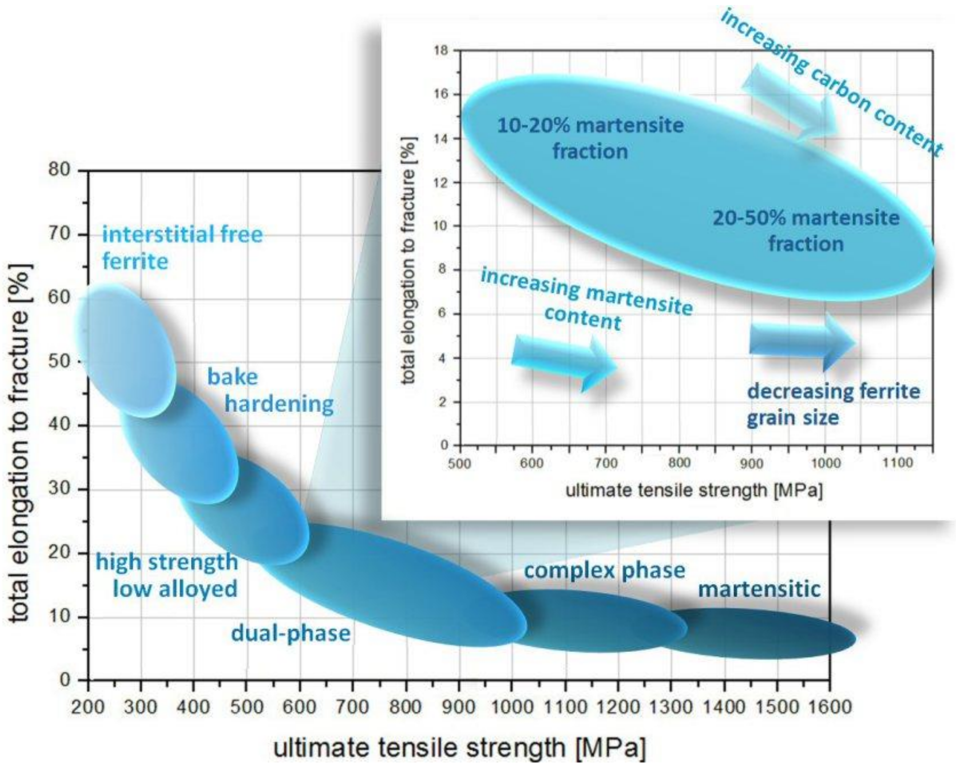

Figure 8. Steel-Elongation UTS Diagram

3.3. Differences Between S355 and DP 1180 Materials

S355 and Dual Phase 1180+ are different types of steel with distinct compositions and properties:

Chemical Composition:

- S355 is a structural steel grade defined by its minimum yield strength of 355 megapascals. It contains carbon, manganese, silicon, sulfur, and phosphorus as major elements.
- Dual Phase 1180 refers to a type of advanced high-strength steel (AHSS) that's heat-treated to achieve high strength. It typically contains low carbon with additional alloying elements like manganese, silicon, chromium, and possibly other elements to create the dual-phase microstructure.

Mechanical Properties:

- S355 is known for its good strength, weldability, and toughness. Its yield strength typically ranges around 355 MPa, with variations in tensile strength and elongation depending on the specific grade and treatment.
- Dual Phase 1180+ is an AHSS designed for exceptionally high strength. It achieves significantly higher tensile strengths, often surpassing 1180 MPa, while maintaining good formability and ductility due to its dual-phase microstructure. This type of steel is used in applications where high strength with good formability is required, such as in automotive components.

Microstructure

- S355 steel typically has a ferritic-pearlitic microstructure, common in structural steels.
- The "dual-phase" designation indicates a microstructure consisting of two phases—soft ferrite and hard martensite. This dual-phase structure contributes to its high strength and good formability.

Applications:

- S355 steel is widely used in various structural applications, construction, and engineering due to its strength, weldability, and versatility.
- Dual Phase 1180 is often utilized in industries such as automotive manufacturing for components requiring high strength with good formability, like structural parts in vehicle bodies.

Mechanical properties of S355J2 and DP1180 materials are shown in the Table 1. DP1180 steel has better mechanical properties compare than S355J2.

Table 3.1. Mechanical Properties of Materials (**Murata T, et al , 2017**)

	Mechanical Properties		
Materials	**Yield Strength**	**Tensile Strength**	**Elongation**
S355J2	355 MPa	470-630 MPa	%22
DP1180	910 MPa	1185 MPa	%10

In summary, while both S355 and Dual Phase 1180+ are steel grades with their own strengths, they cater to different applications and offer distinct combinations of strength, formability, and mechanical properties. Dual Phase 1180+ is specifically engineered to provide exceptionally high strength while maintaining formability, especially suitable for demanding applications like automotive manufacturing.

3.4. Methods

3.4.1. Analyses Method

In all analyses conducted, the materials were ideally modeled. Ideal material assumes a homogeneous material where any internal crack, gas pocket, or other defects resulting from the material's production, either through rolling or casting processes, are not present.

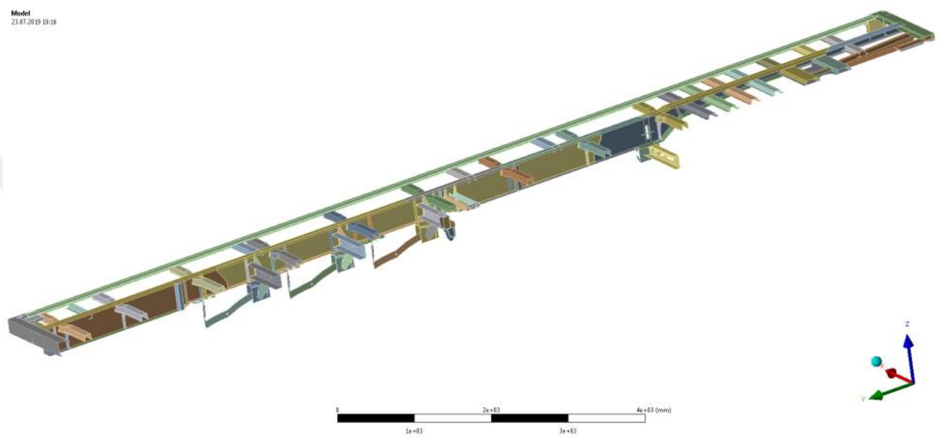

Figure 9. General Drawing of Analyse Model

The simplified and prepared analysis model was equipped with a finite element mesh to enable the numerical solution using the finite element method. These elements consist of first-order (linear) hexagonal structural solution elements placed over components modeled as shells. The visual representation and details of these solution elements are provided in this section. They are illustrated in Figure 9,10,11 and 12.

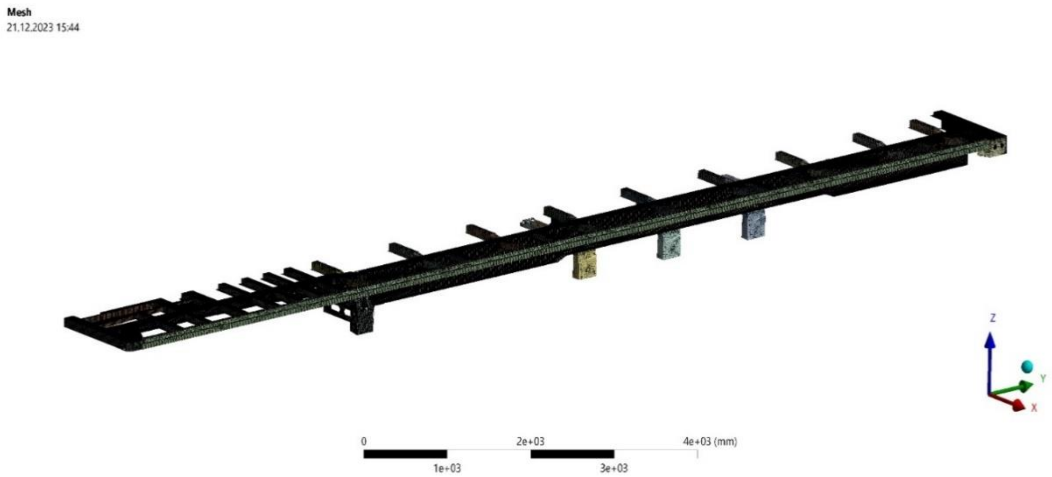

Figure 10. Finite Elements Mesh Model

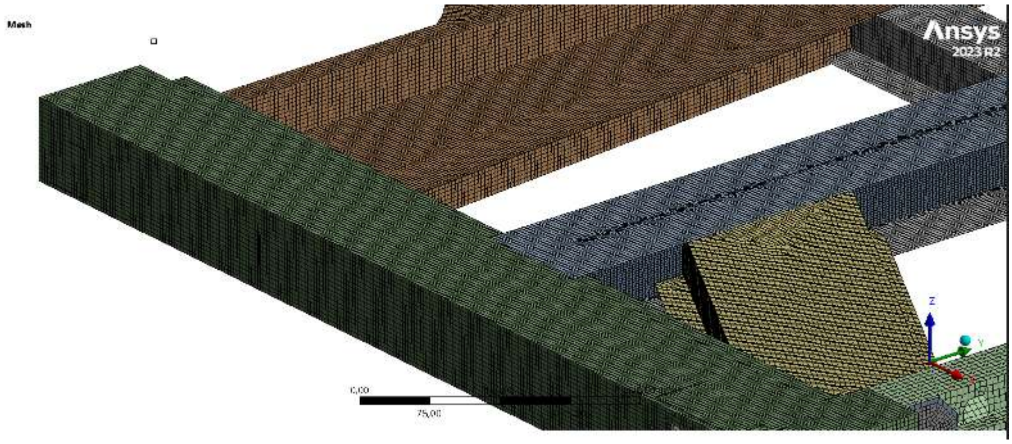

Figure 11. Finite Elements Mesh Model-1

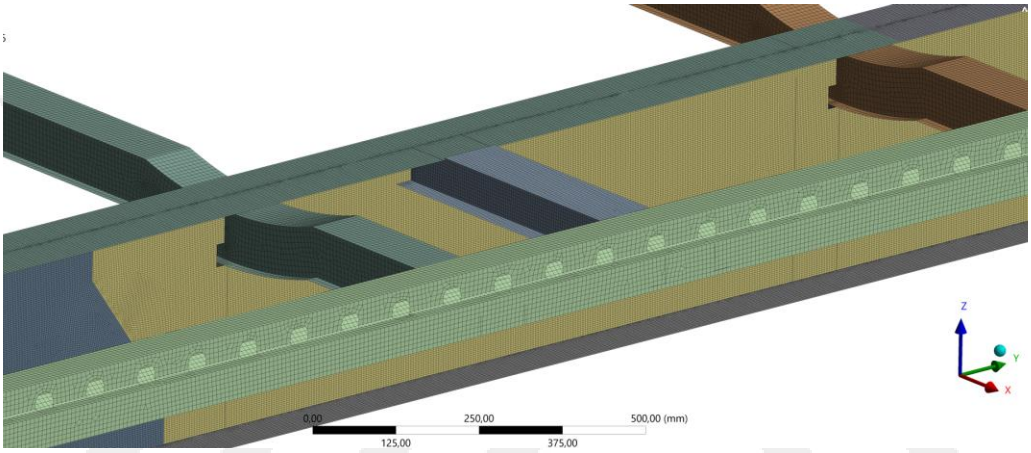

Figure 12. Finite Elements Mesh Model-1

In the created solution mesh, a total of 1,199,753 node points and 1,175,570 elements were utilized as shown in the Figure 13.Also average skewness value is 0.57; acceptable.

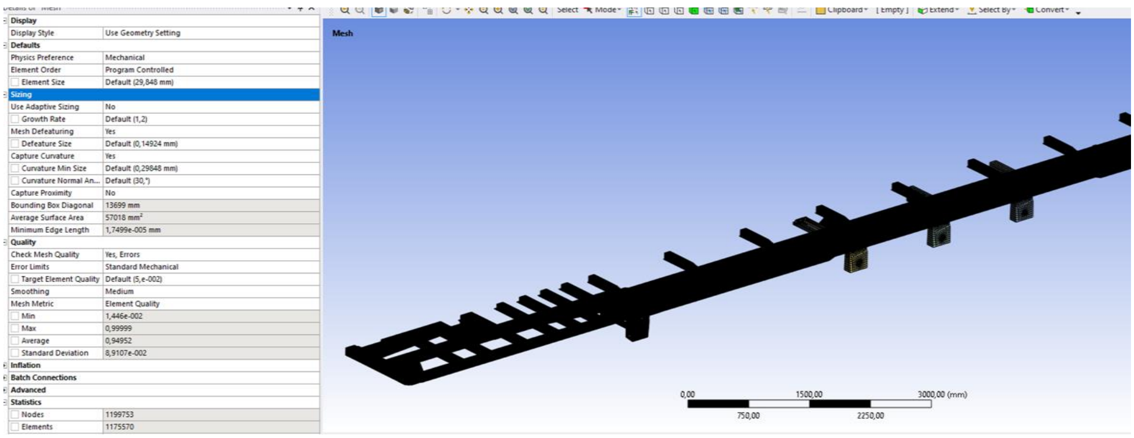

Figure 13. Finite Elements Mesh Properties

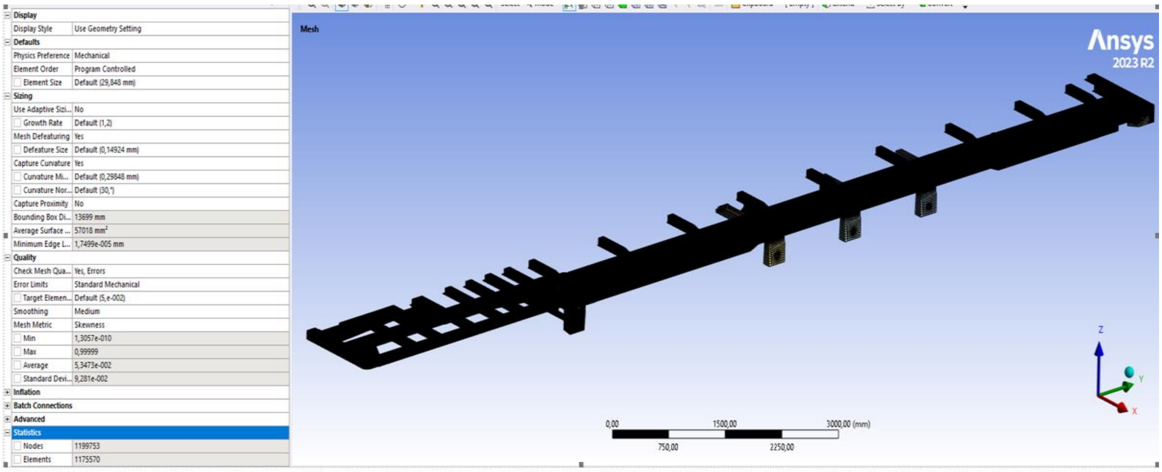

Figure 14. Mesh Properties

3-D solid models in step format were simplified with Space Claim Direct Modeler (SCDM) in ANSYS software and an analysis model was prepared. The same geometry was used in all analyses.

The purpose of the simplification process is to obtain fast solutions by deleting parts that have no or negligible effect on the analysis, deleting sharp corner chamfers and relatively small roundings (fillets) and fasteners such as bolts and nuts, and converting sheet metal parts that are so thin that the stresses will not change throughout their thickness into 2-D surface elements (shell) containing thickness, and creating easier and fewer numerical solution elements.

The payload that the trailer can carry is 30 tons, and since the chassis has a symmetrical structure, half of the chassis was modeled and 15 tons of distributed force, which is half of the payload, was applied on the chassis. Force graph was shown on the Figure 15.

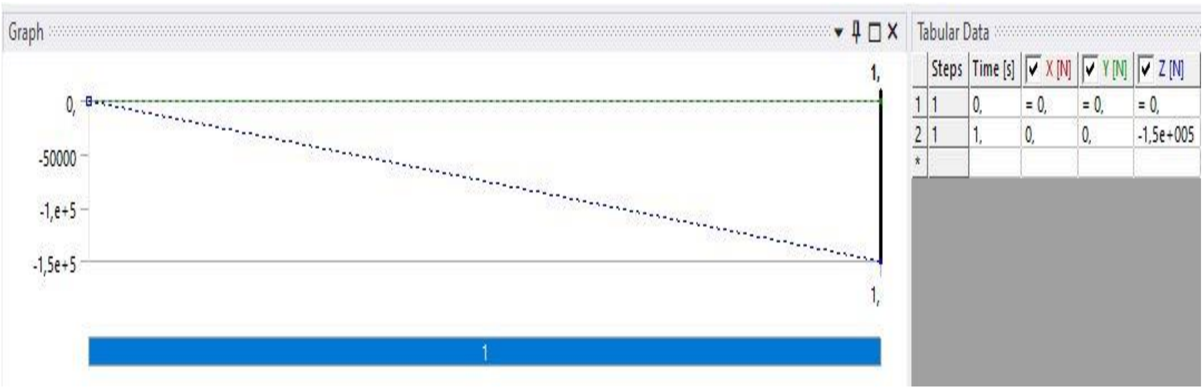

Figure 15. Force Graph

3 different analyses were performed and these are;

- Chassis material S355
- Chassis material Dp1180
- Chassis material Dp1180, longitudinal carrier and reduced section thickness.

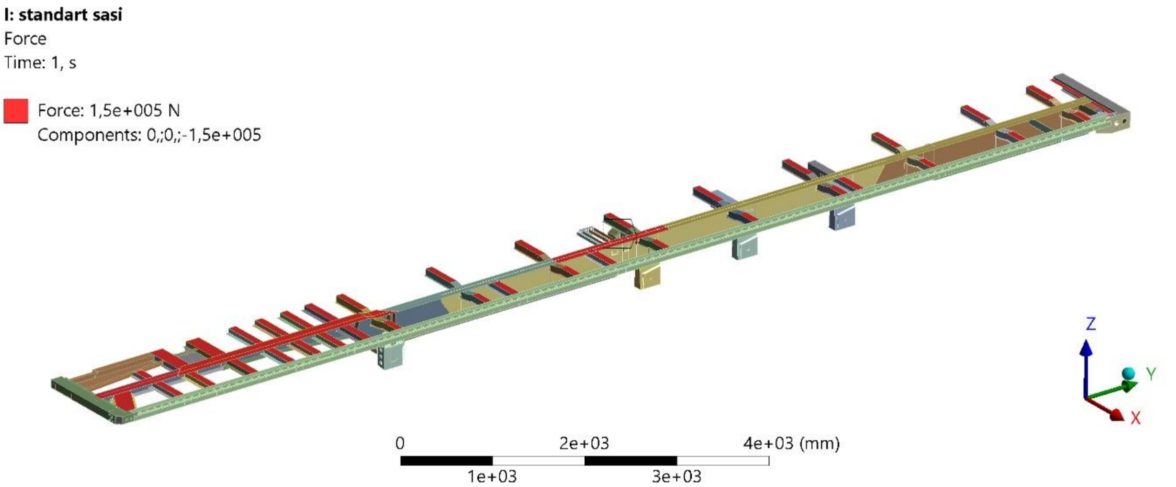

Figure 16. 15 tons of chassis boundary condition to which the distributed load will be applied

The chassis is fixed at 4 points as shown in the Figure 17,18 and 19. These are; 1st, 2nd and 3rd axle boots and the kingpim plate.

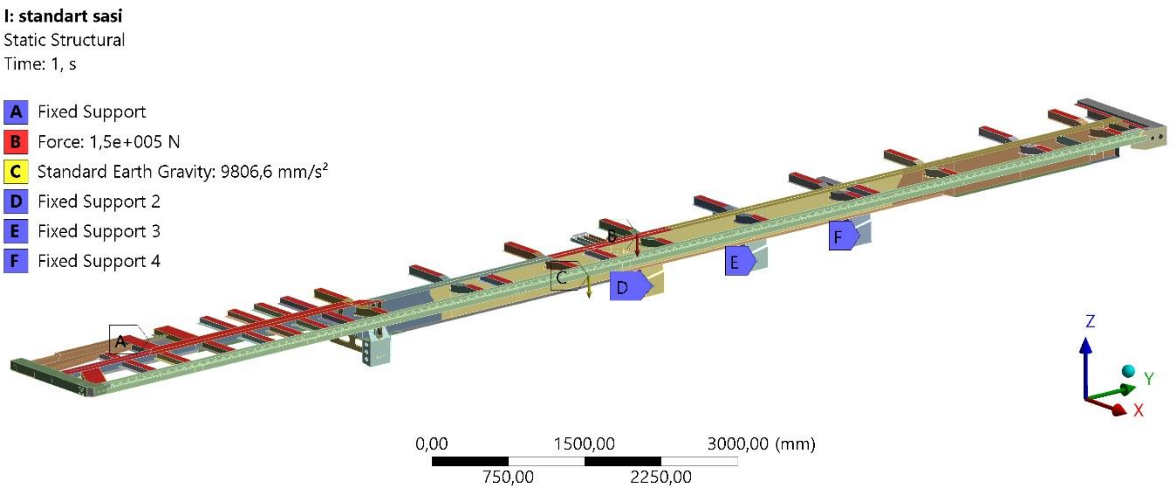

Figure 17. Fixed Supports-1

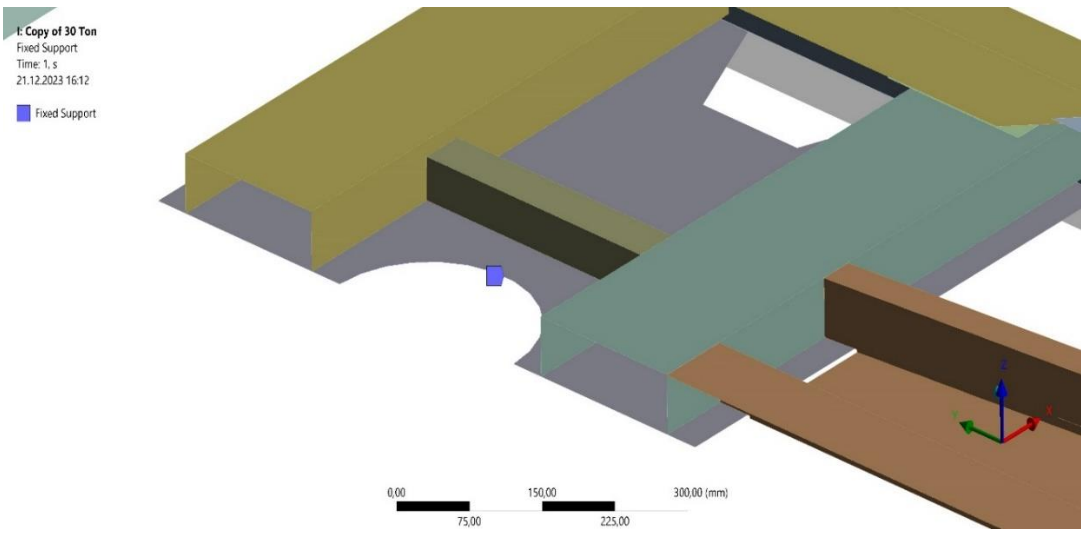

Figure 18.*Fixe*d Supports- King pim plate

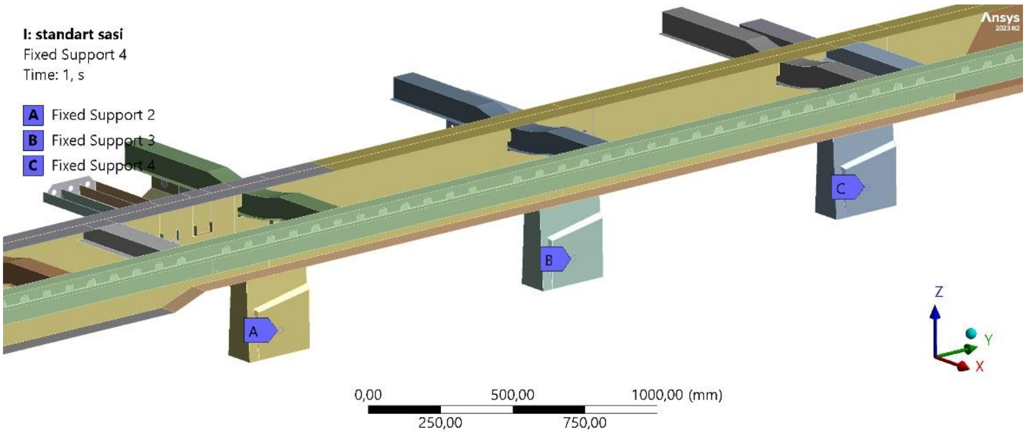

Figure 19. Fixed Supports- Axle Bracket

Mechanical properties of 2 different materials that used on the analyses (ANSYS) shown on the Figure 20 and Figure 21.

Properties of Outline Row 3: S355J2

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7850	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's Modulus and Poisson...			
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	355	MPa		
25	Compressive Yield Strength	355	MPa		
26	Tensile Ultimate Strength	520	MPa		
27	Compressive Ultimate Strength	0	Pa		

Figure 20. Mechnaical Properties of S355J2 on the ANSYS

Properties of Outline Row 3: dp1180

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7850	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's ...			
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	980	MPa		
25	Compressive Yield Strength	980	MPa		
26	Tensile Ultimate Strength	1380	MPa		
27	Compressive Ultimate Strength	0	Pa		

Figure 21. Mechanical Propertis of DP1180 on the ANSYS

In order to perform the finite element numerical solution, a finite element mesh was created on the simplified analysis model. These elements, hexagonal (hex) first order (linear) elements, which are structural solution elements, were formed on the components modelled as shells. The visualisation and details of the solution elements are given in this section.

3.4.2. Longitudinal Carrier Cross Section

The chassis longitudinal carrier consists of 3 welded parts. The section thicknesses of the longitudinal carriers called "I section" are given in the Figure 22 and 23;

- Thicknesses in zone 1; upper slat 8 mm, intermediate slat 6 mm, lower slat 8mm
- Thicknesses in zone 2; upper slat 18 mm, intermediate slat 6 mm, lower slat 18 mm.
- Thicknesses in the 3rd region; upper slat 12 mm, intermediate slat 4 mm, lower slat 13 mm.

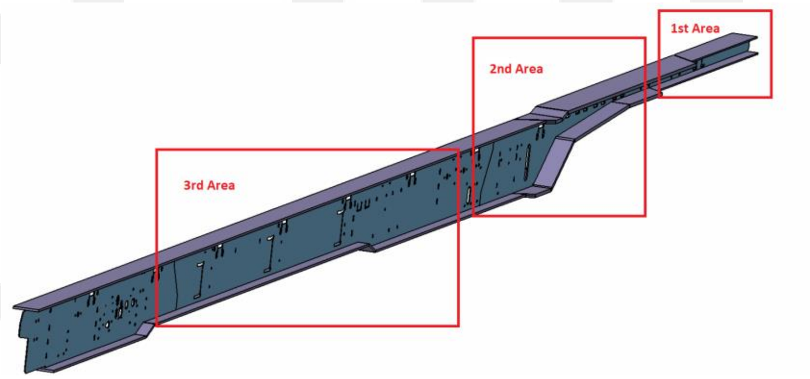

Figure 22. Longitudinal Carrier

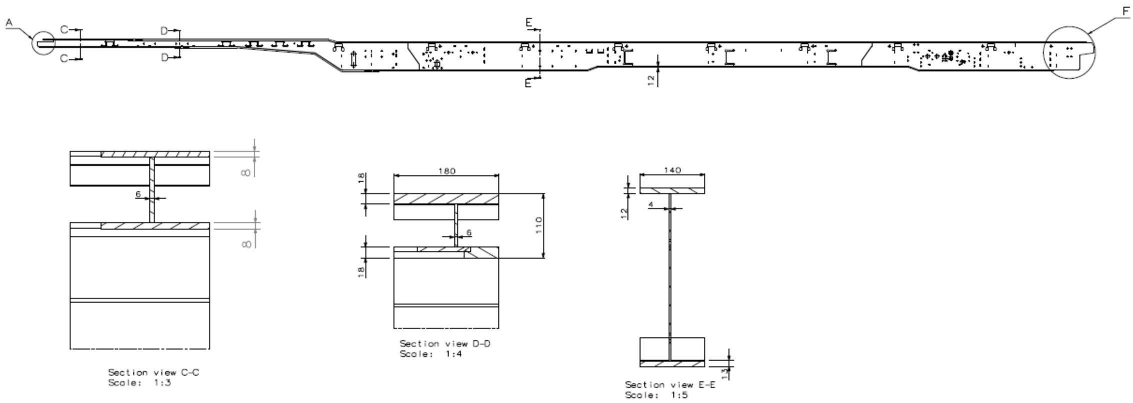

Figure 23. Longitudinal Carrier Cross Sections

As a result of the analyses in which DP1180 steel and S355J2 were specified as chassis materials, a new analysis was carried out in which the longitudinal beam thicknesses were reduced by 1 mm in the chassis where DP1180 steel was used.

- Thicknesses in zone 1; upper slat 7 mm, intermediate slat 5 mm, lower slat 7 mm

- Thicknesses in the 2nd zone; upper slat 17 mm, intermediate slat 5 mm, lower slat 17 mm.
- Thicknesses in the 3rd region; upper slat 11 mm, intermediate slat 3 mm, lower slat 12 mm.

4. RESULTS and DISCUSSIONS

4.1. Results

4.1.1. Chassis Material-S355

Total Stress

15 tonnes applied to the chassis and maximum stress occurred on the kingpim plate point as a 1459 MPa . When the morphological structure of the region where high stress occurs is examined, it is determined that no stress occurs in the internal structure of the material and the stress occurs superficially. Detail results were shown on the Figure 24-25-26 .

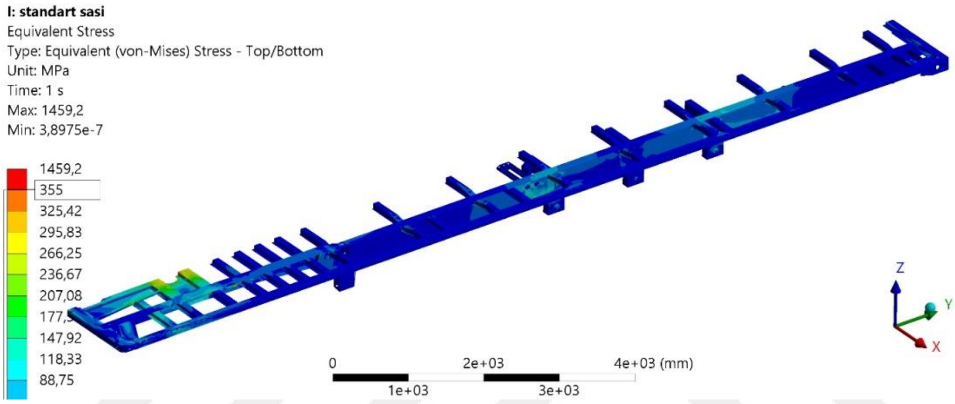

Figure 24. Stress Values of S355 Chassis

The maximum stresses were occurred on the King-pim plate below the yield point of S355 material. Detail stress distribution was shown on the Figure 25 and 26.

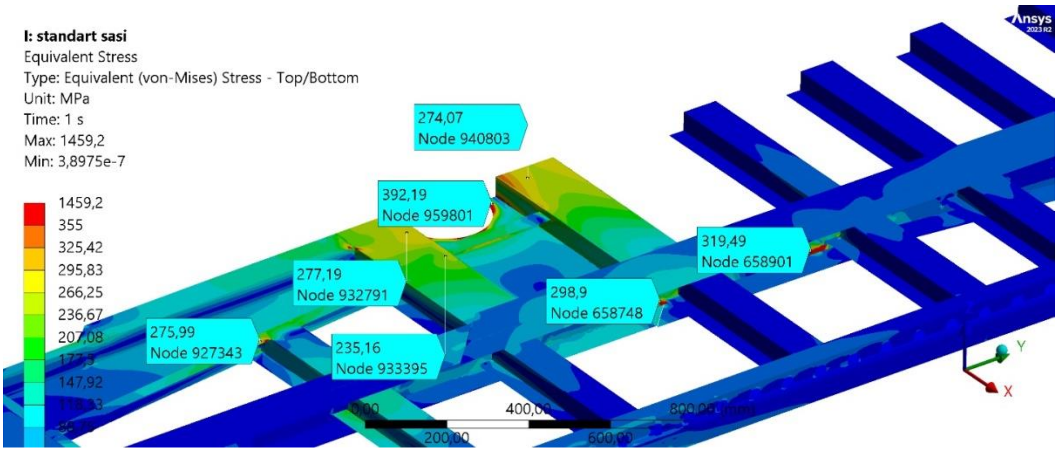

Figure 25. Stress Values of S355 Chassis-2

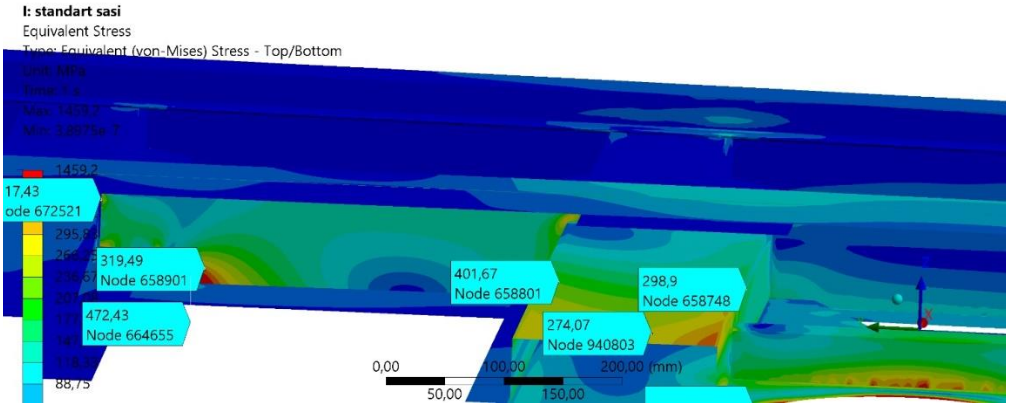

Figure 26. Stress Values of S355 Chassis-3

The stresses in the region of the fixing points are shown in Figure 27. The stresses at these points are in the range of 53-147 Mpa and are negligibly small.

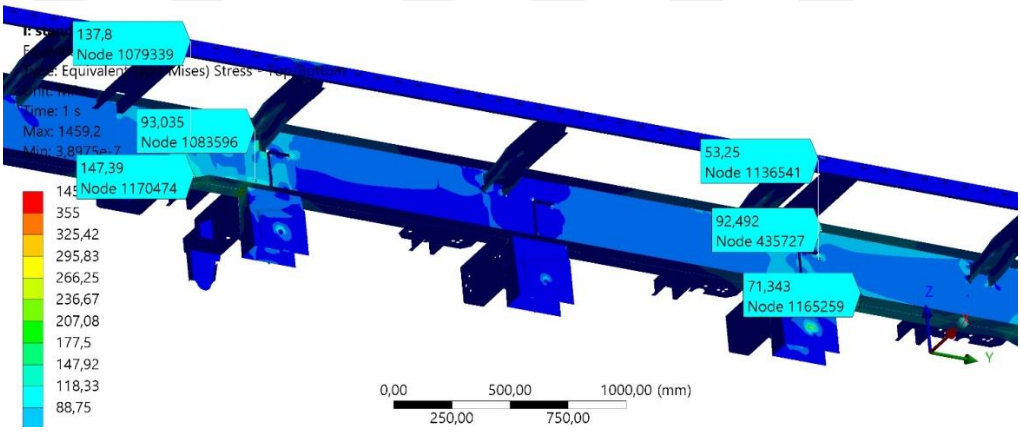

Figure 27. Stress Values of S355 Chassis-4

The stresses occurring on the longitudinal carrier are in the range of 102-154 MPa and are very low. The detail picture is shown in Figure 28.

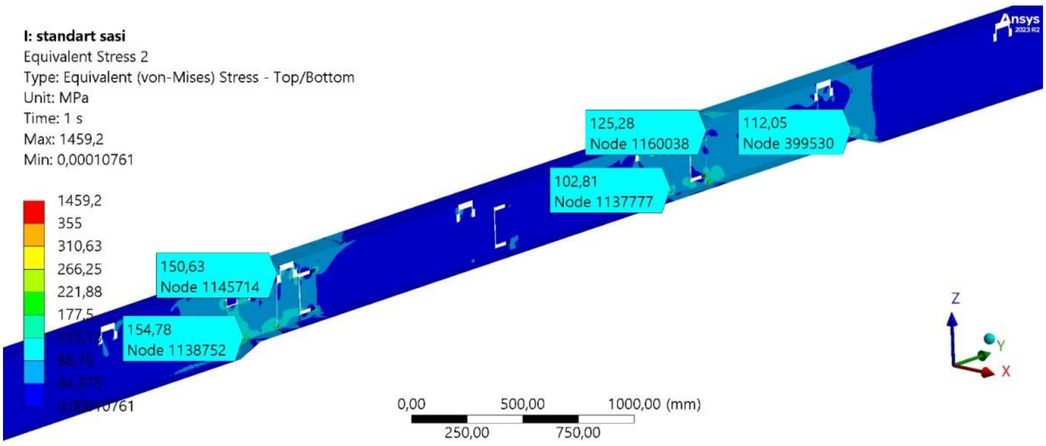

Figure 28. Stress Values of S355 Chassis Longitudinal Carrier

Total Deformation

The maximum elastic deformation on the longitudinal carrier is 14 mm and the elastic deformation on the chassis is measured as 28 mm on the front cover. Detail analyse results were shown on the Figure 29 and Figure 30.

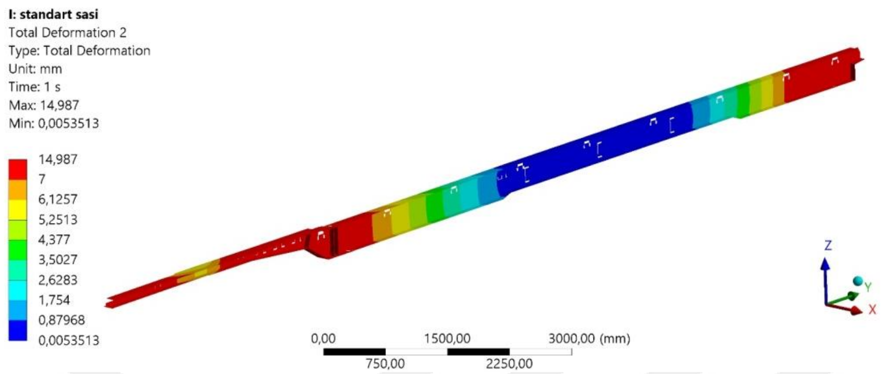

Figure 29. Deformation Values of Longitudinal Carrier

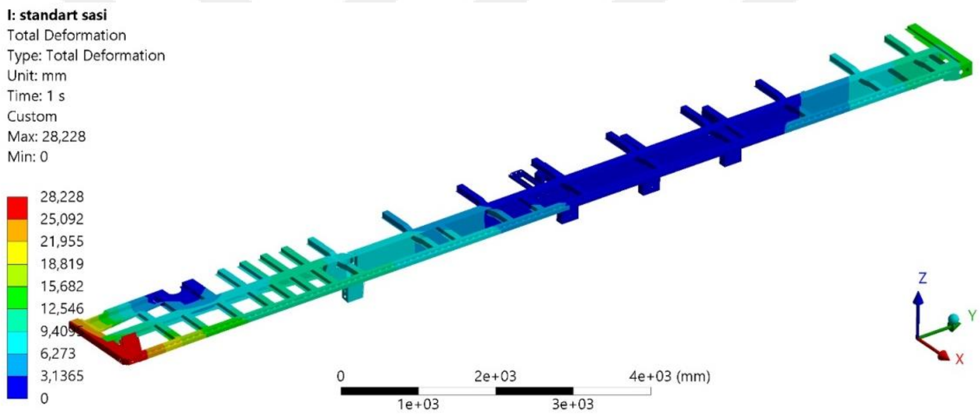

Figure 30. Deformation Values of Chassis

4.1.2. Chassis Material-DP1180

Total Stress

Under the same conditions, 15 tonnes were applied to the chassis using Dp1180 steel and the maximum stress at the kingpim plate point was 1275 MPa. When the morphological structure of the region where the high stress occurred was examined, it was determined that no stress occurred in the internal structure of the material and the stress occurred superficially. Detail results are shown in Figures 31,32,33 and 33.

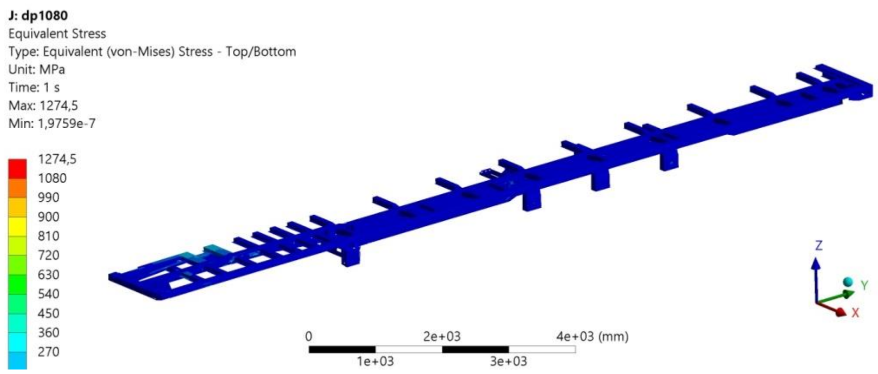

Figure 31. Stress Values of DP1180 Chassis

The stresses on the transverse supports in the King pin area were observed as a maximum of 572 MPa pointwise in the sheet bending area. When the stress distribution is examined, there is no change in the form of the material when the mechanical properties of DP 1180 steel are taken into consideration. Detail stresses distribution were shown in the Figure 32 and Figure 33

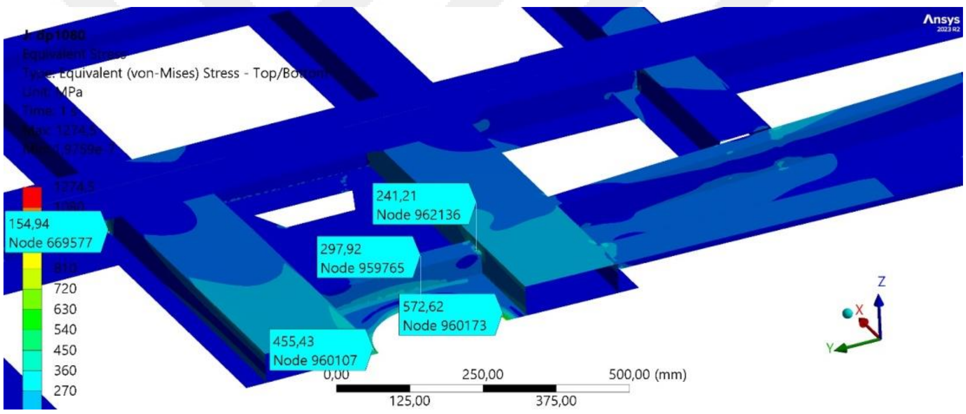

Figure 32. Detail Stress Values of DP1180 Chassis-2

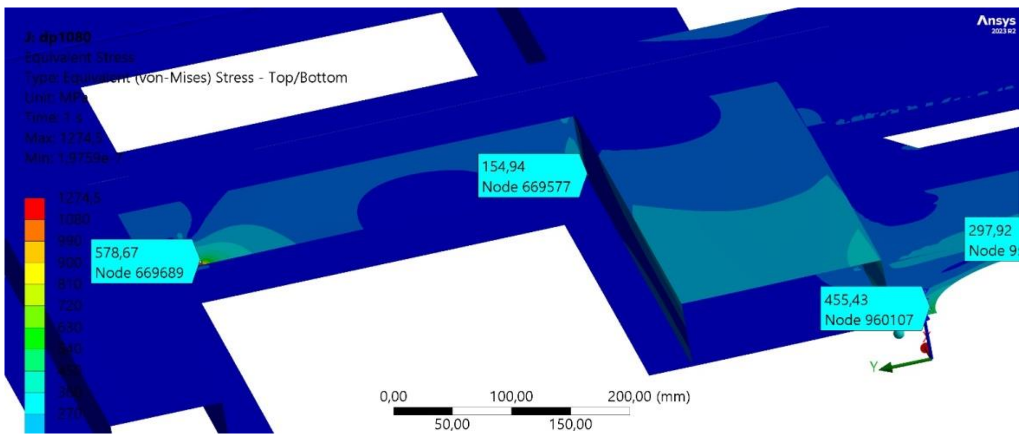

Figure 33. Detail Stress Values of DP1180 Chassis-3

The stresses in the region of the fixing points are shown in Figure 34. The stresses at these points are in the range of 85-123 Mpa and are negligibly small. These stresses are lower than S355 chassis.

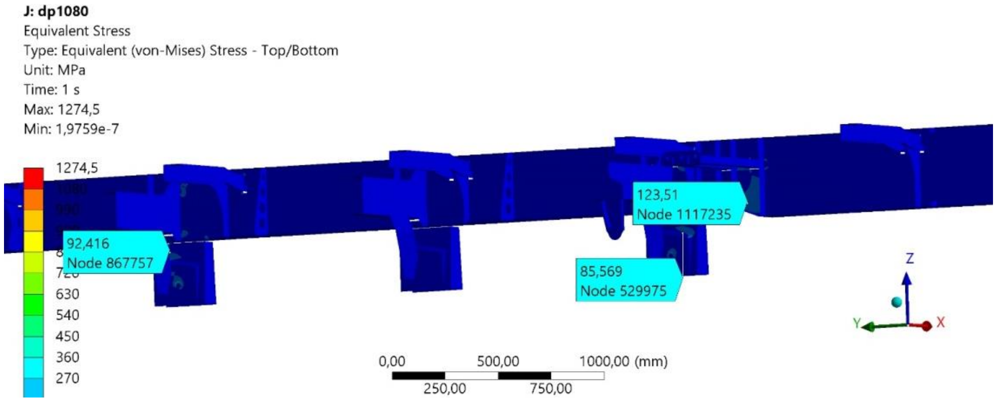

Figure 34. Detail Stress Values of DP1180 Chassis-4

The stresses occurring on the longitudinal carrier are in the range of 100-173 MPa and are very low. The detail picture is shown in Figure 35.

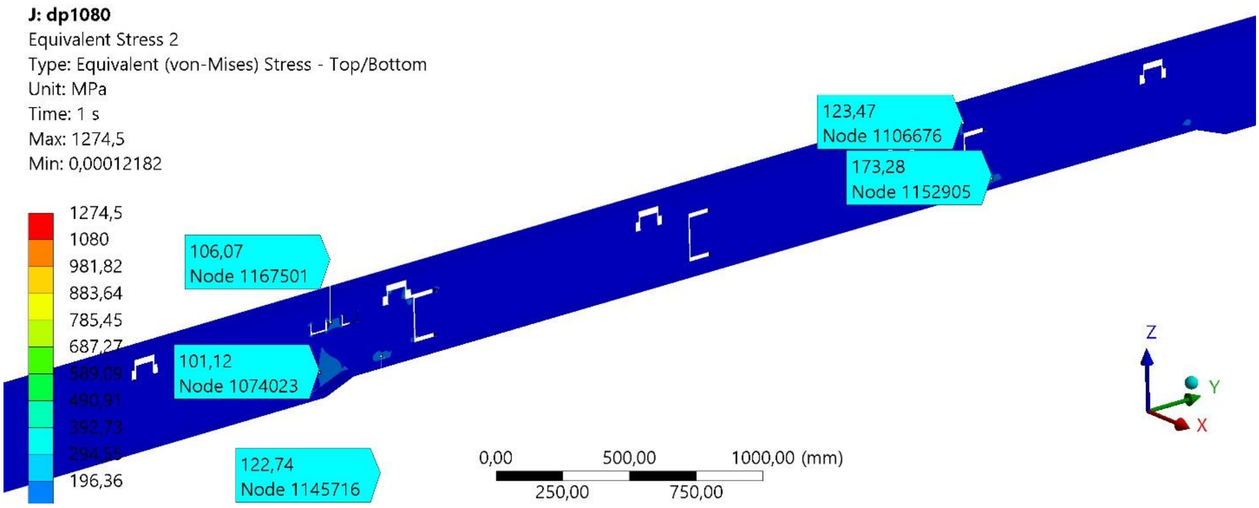

Figure 35. Longitudinal Carrier Stress Values

Total Deformation

The maximum elastic deformation was measured 24 mm on the longitudinal carrier at the front cover. Detail analyse results were shown on the Figure 36.

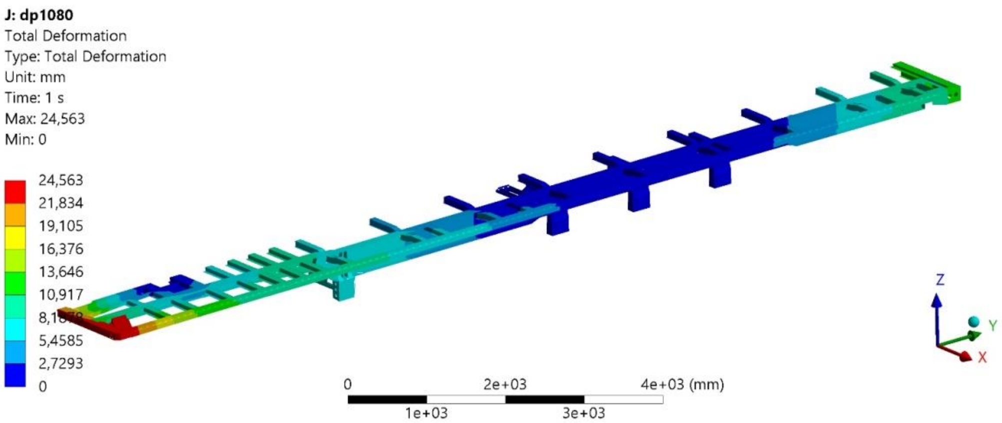

Figure 36. Longitudinal Carrier Total Deformation

4.1.3. Chassis Material DP 1180-New Thickness

Total Stress

The analysis results of DP1180 steel with S355 chassis in the same conditions were compared and close values were obtained by reducing the thickness of the chassis I section. Again, 15 tonnes were applied to the chassis and the maximum stress at the kingpim plate point was 1720 MPa. When the morphological structure of the region where high stress occurred was examined, it was determined that no stress occurred in the internal structure of the material and the stress occurred superficially. Detail results are shown in Figures 37,38 and 39.

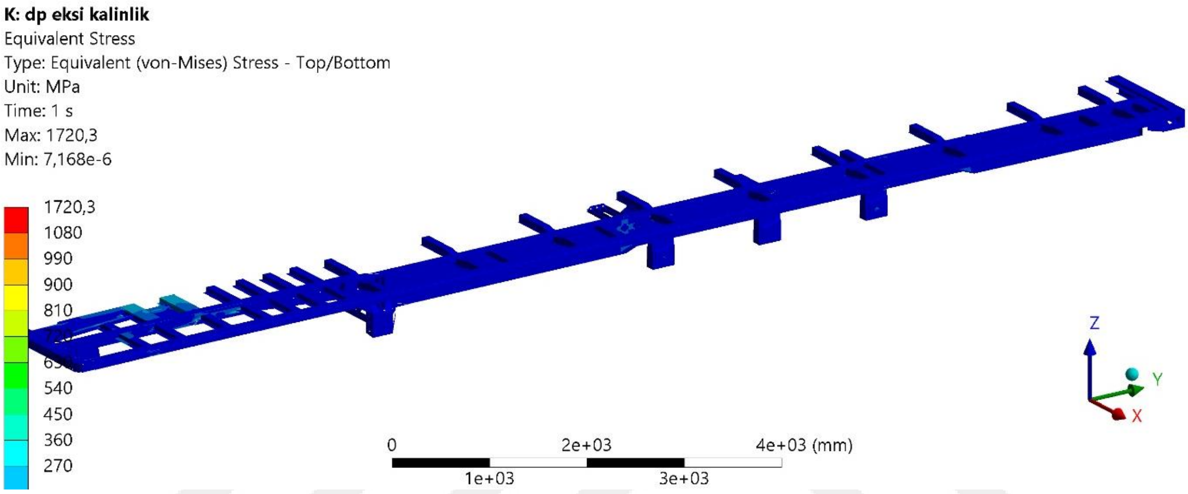

Figure 37. Stress Values DP1180-New Thickness

The stresses in the region of the fixing points are shown in Figure 38 and 39. The stresses at the king pim points are in the range of 248-575 Mpa while stresses at the axle beam connection points are in the range of 100-136 Mpa and are negligibly small considering the mechanical properties of DP1180 steel.

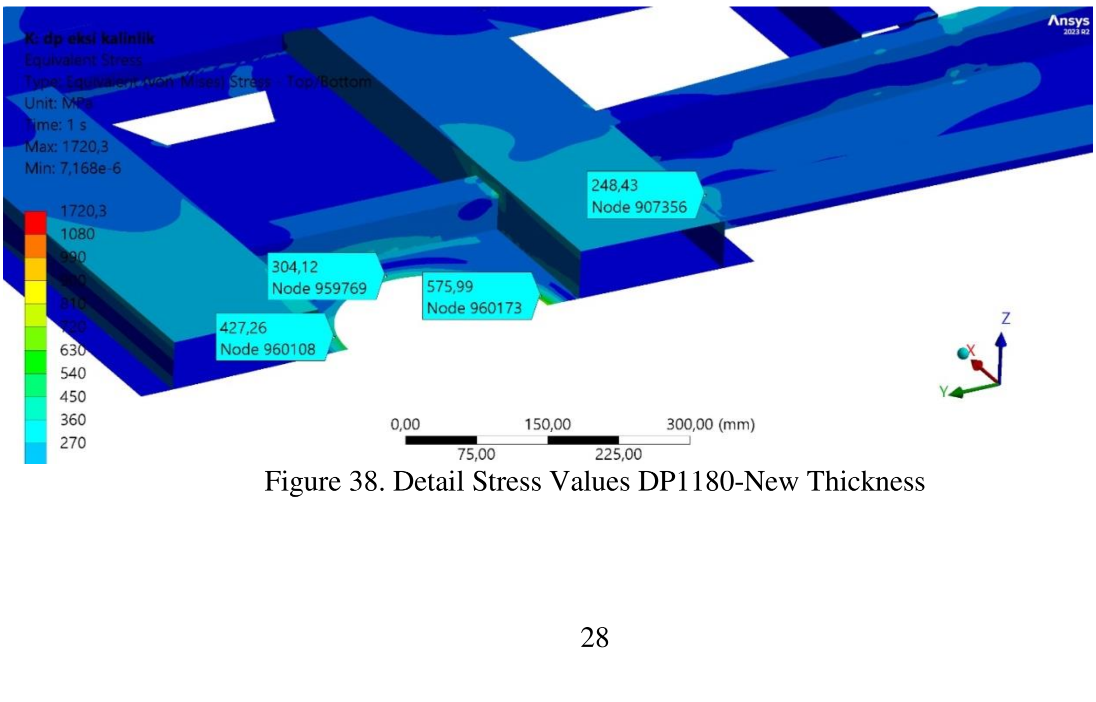

Figure 38. Detail Stress Values DP1180-New Thickness

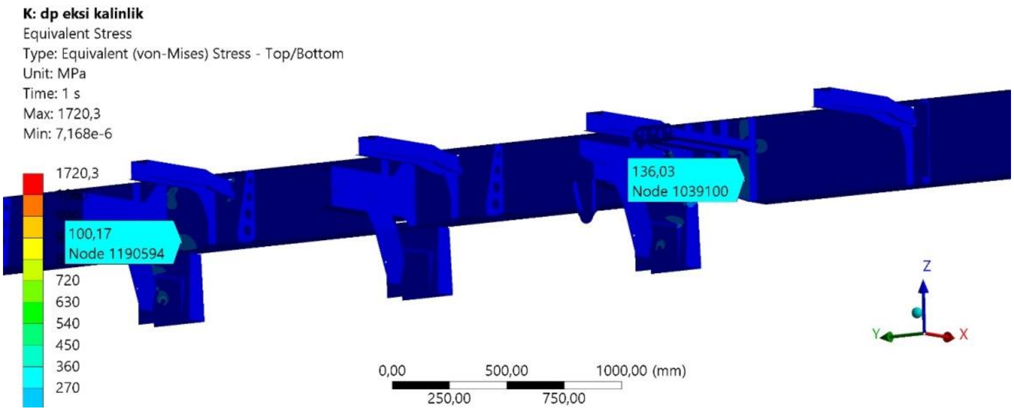

Figure 39. Maximum Stress Values DP1180-New Thickness

Total Deformation

The maximum elastic deformation was measured as 24 mm on the chassis and 13 mm on the longitudinal carrier in the front cover. The result of the analysis is similar to the analysis run without reducing the thickness. Detail analysis results are shown in Figure 40 and 41

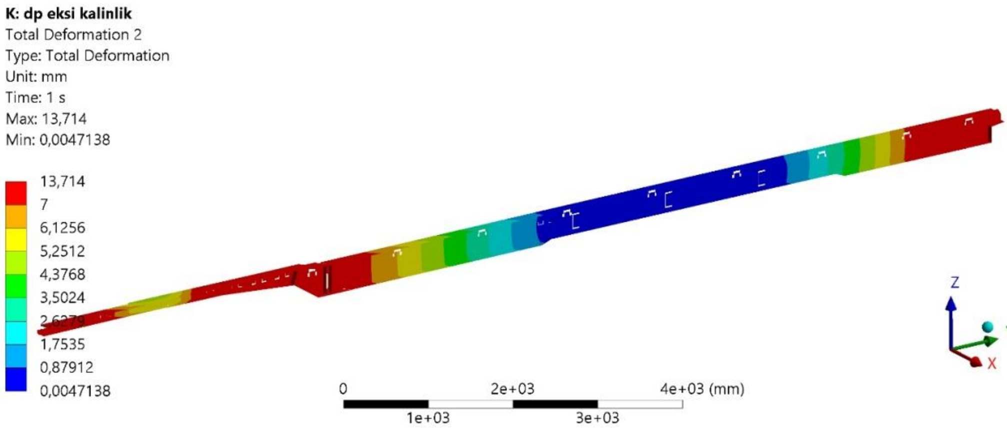

Figure 40. Total Deformation of Longitudinal Carrier-DP1180

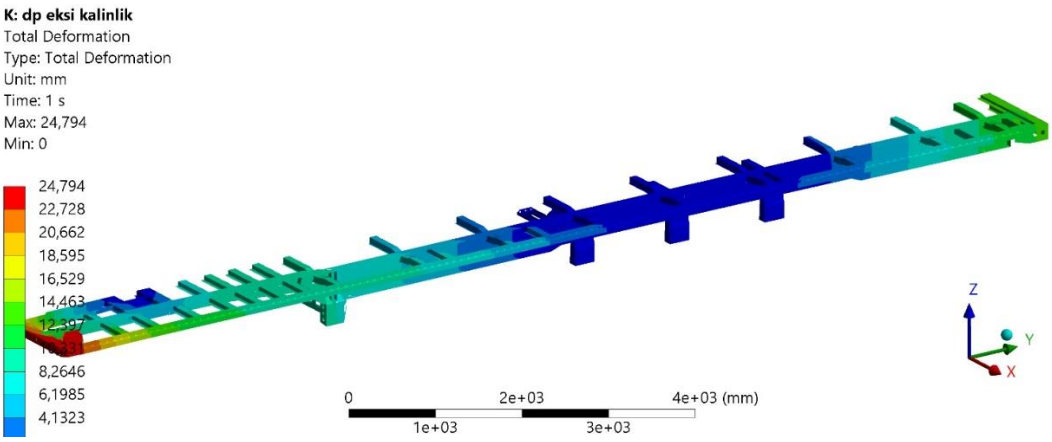

Figure 41. Total Deformation of Chassis-DP1180

4.2. Discussions

4.2.1. Analyses Results of S355J2 Chassis Material

In the design where the chassis material is specified as S355J2, the maximum stress was measured as 1459 MPa according to the results of the analysis values, the maximum value in question occurred pointwise at the bending point of the kingpin plate and there is no stress formation in the morphological structure.

When the stresses in the transverse sleeper parts supporting the chassis were analysed, it was observed that the stresses were around 235 MPa, 310 MPa, 470 MPa

The stresses in the chassis longitudinal carriers, which are the main carriers, are 100-150 MPa.

Total elastic deformation was measured as 28 mm in the front closure area.

4.2.2. Analyses Results of DP1180 Chassis Material

In the design where the chassis material was specified as Dp1180, the maximum stress was measured as 1274.5 MPa according to the results of the analysis values, the maximum value in question occurred pointwise at the bending point of the kingpin table and there is no stress formation in the morphological structure.

When the stresses occurring in the transverse sleeper parts supporting the chassis were examined, it was observed that the stresses were around 150 MPa, 240 MPa and 455 MPa and DP1180 material gave better values according to the analysis results.

The stresses in the chassis longitudinal carriers, which are the main carriers, are 85-120 MPa.

The total transient deformation was measured as 24.5 mm in the front closure area.

4.2.3. Analyses Results of DP1180 Chassis Material-New Thickness

In the design where the chassis material was specified as DP1180 and the longitudinal carrier section thicknesses were reduced by 1 mm, the maximum stress was measured as 1720.3 MPa according to the results of the analysis values, the maximum value in question was again pointwise at the bending point of the kingpin table, and there was no stress formation in the morphological structure.

When the stresses occurring in the transverse sleeper parts supporting the chassis were examined, it was observed that the stresses were around 250-450-590 MPa and according to the previous analysis result, even if the stresses were little bit high, these stresses occurred on the surface of the parts and no stress occurred above the yield value of the material.

The stresses in the chassis longitudinal carriers, which are the main carriers, are 100-140 MPa.

The total transient deformation was measured as 24.5 mm in the front closure area.

Considering all these stress and deformation values, it seems appropriate to reduce the thickness of the longitudinal carrier sections by 1 mm.

4.3. Cost Calculations

Average Cost of St52 (S355J2) steel plate is 680 $/ per ton while average cost of DP1180 coil steel is 840 $/per ton as shown in the figure 42 and 43

In this study total weight reduce 182 kg

Chassis weight when used S355J2 material:1981 kg

Chassis weight when used DP1180 material: 1789 kg

Total cost when used of S355J2: ($680 x 1.98) = **$1346**

Total cost when used of DP1180: ($840 x 1.79)= **$1503**

flattening of the coil sheet should be consider by making cost calculation **$ 50 per ton** ,

Cost differences between DP1180 and S355J2: **$157+$50 =$207**

Fuel saving rate per year: 0.8 lt x 2000 x (42.69 / 32.27 USD) **= $2116** (While making the calculation, it was taken into consideration that 1 trailer travels 200000 km per year and the price of 1 liter of diesel on 13.05.2024.)

Although DP1180 steel is $207 more expensive when used instead of S355J2, it saves 0.8 liters of fuel per 100 km due to the lighter weight of the vehicle and considering that 1 trailer travels 200,000 km per year, an annual fuel saving of $2116 is achieved. The monthly fuel consumption gain is 176 dollars, which almost compensates for the increase in production costs in 1 month.

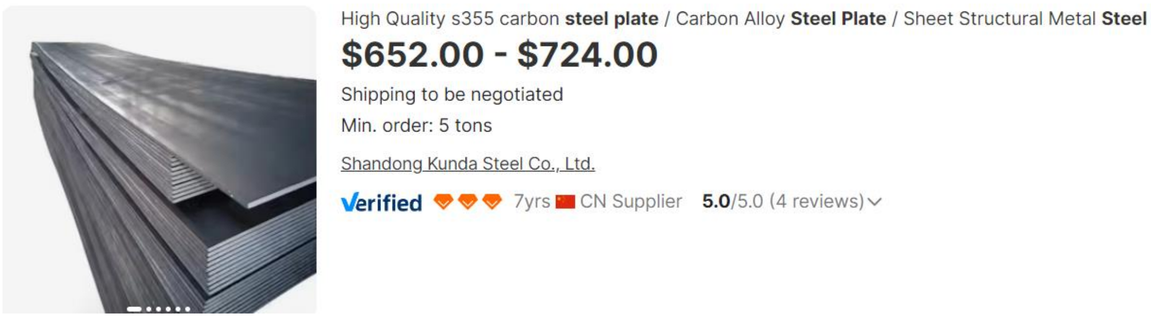

Figure 42. Cost of S355J2 (St52)

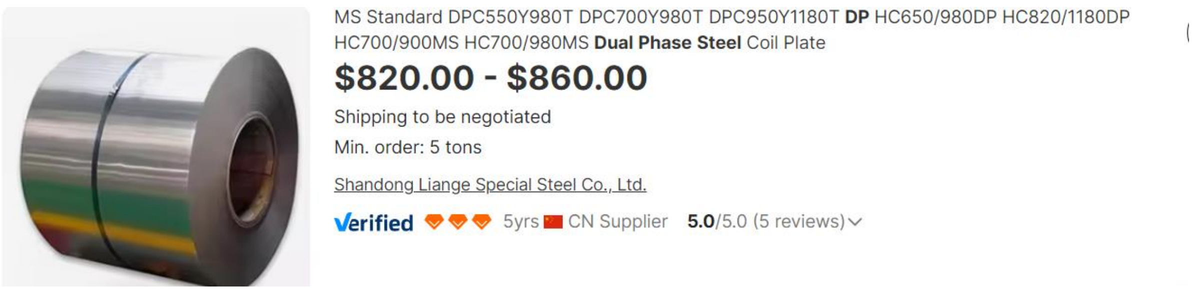

Figure 43. Cost of DP1180

4.4. Weight Calculations

Weigh of empty chassis: 1981 kg and 1799 kg

Weight of the axle group : 1150 kg

Weight of the upperbody: 4070 kg

Weight of the payload: 30000 kg

Distance of empty chassis to RA(kingpim): 4840 mm

Distance of empty chassis to RB (Rear axle group) : 2860 mm

Distance of payload and upperbody to RA: 5440 mm

Distance of payload and upperbody to RB: 2260 mm

$7700\ x\ RB = (1981\ kg\ x\ 4840\ mm) + (34070\ kg\ x\ 5440\ mm) + (1150\ kg\ x\ 7700\ mm)$

$RB = 26464\ kg < 27000\ kg$ (when empty chassis weight is 1799 kg, RB is equal to 26351kg)

$7700\ x\ RA = (1980\ kg\ x\ 2860\ mm) + (34070\ kg\ x2260\ mm)$

$RA = 10580\ kg < 12000\ kg$ (when empty chassis weight is 1799 kg, RA is equal to 10667kg)

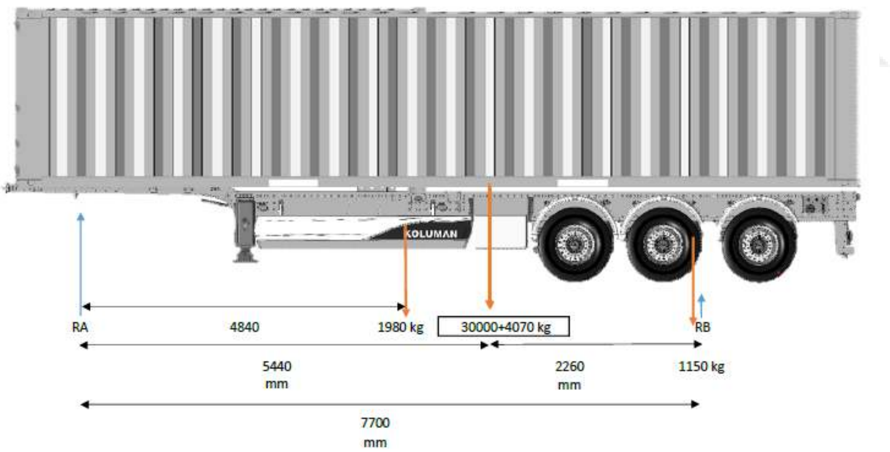

Figure 44. Dimension for Weight Calculations

5. CONCLUSION

When the previous studies on lightweighting of vehicles are examined, it is seen that the Automotive Applications Council of AISI's Steel Market Development Institute, SMDI, stated that if the use of AHSS in passenger car chassis is in the range of 10-15%, 70 kg of lightweighting can be achieved, and in the research conducted by TATA Group in 2008, it was stated that this weight gain could reach 100 kg.

In the article titled "Topology Optimization of Truck Chassis Under Multi Loading Conditions" written by Mehmet Hanifi Dogru, as a result of the analysis made with the von Misses method in the truck chassis, it was seen that a 14% gain was achieved by decreasing from 2685 kg to 2316 kg.

In the report written by the Massacahusetts Institute, it is stated that a 300 kg lightening in the truck chassis will save 4500 liters of fuel per year.

In 13.60 mt and 16.5 mt long trailer vehicles, lightweighting studies on composite materials were intensified and it was stated that a mass gain of 30% was achieved as a result of the composite materials used in the superstructure and floorboards, but it was stated that the unit price of the composite material was not applied because it was 2 times more expensive than the trailers to be made of steel n the same dimensions.

For this reason, in this study by selecting dual phase steel, which contains high strength and has high formability due to its ferrite structure; As a result of reducing the thickness of the chassis I section by 1 mm, the chassis weight decreased from 1981 kg to 1799 kg;gain of 9 percent from chassis weight (%9).The walking mass of the curtained vehicle decreased from 7200 kg to 7018 kg ;2.7 percent (%2.7) from total mass was achieved.

As a result of 182 kg of weight reduction, 1600 liters of fuel is saved in 1 trailer vehicle that travels 200,000 km per year. These gains and fuel saving rates show same rates with previous studies.

The analyses run in the VECTO program and the obtained consumption and energy gain values are shown below.

In the analyses made in the VECTO Trailer program, the fuel consumption of the trailer with a walking mass of 7200 kg was 27.6 lt/100 km, while the fuel consumption of the 7018 kg trailer decreased to 26.8 lt/100 km.

At the same time, carbon emission has decreased from 722 g/km to 702 g/km.

Figure 45 and 46 show the information of the weight of chassis by using S355J2 and DP1180.

The results of the analyses performed in the VECTO Trailer Program and the fuel consumption and emission rates are shown in the figure from 47 to 54

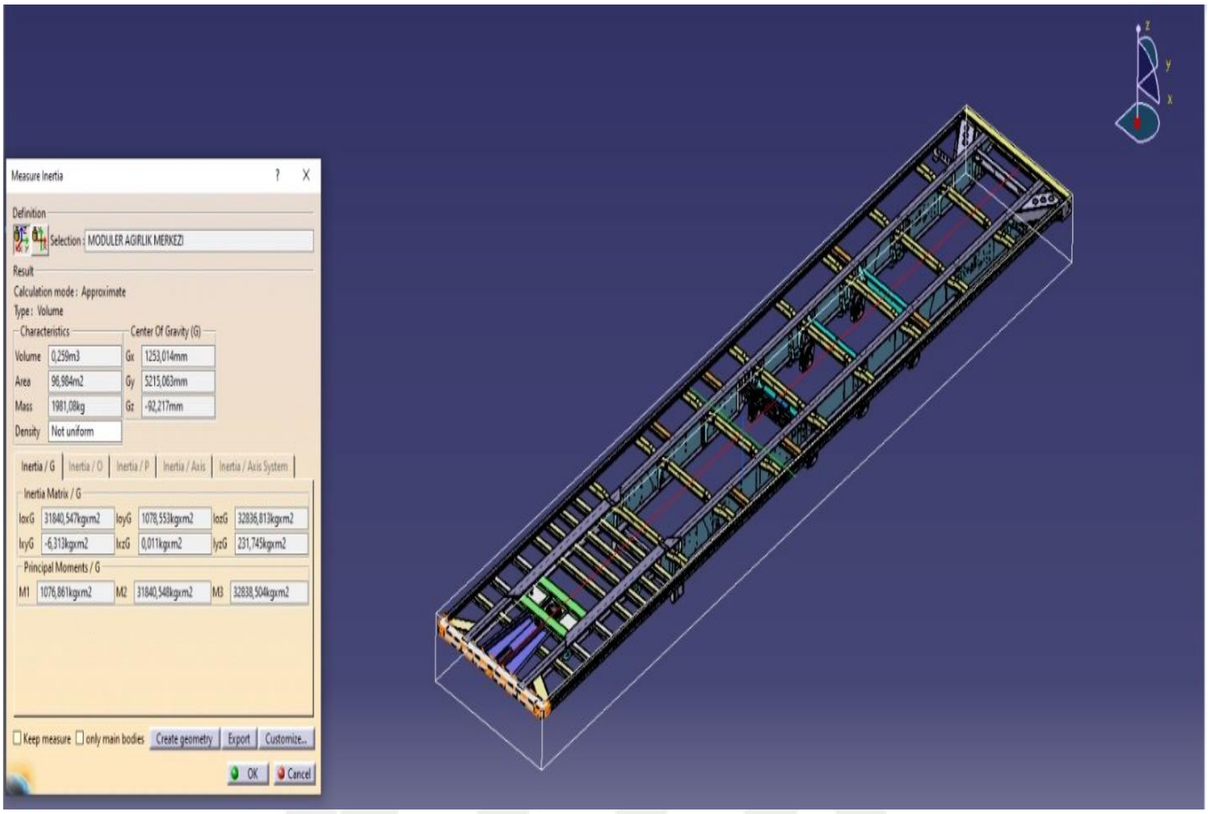

Figure 45. S355J2 Chassis Weight

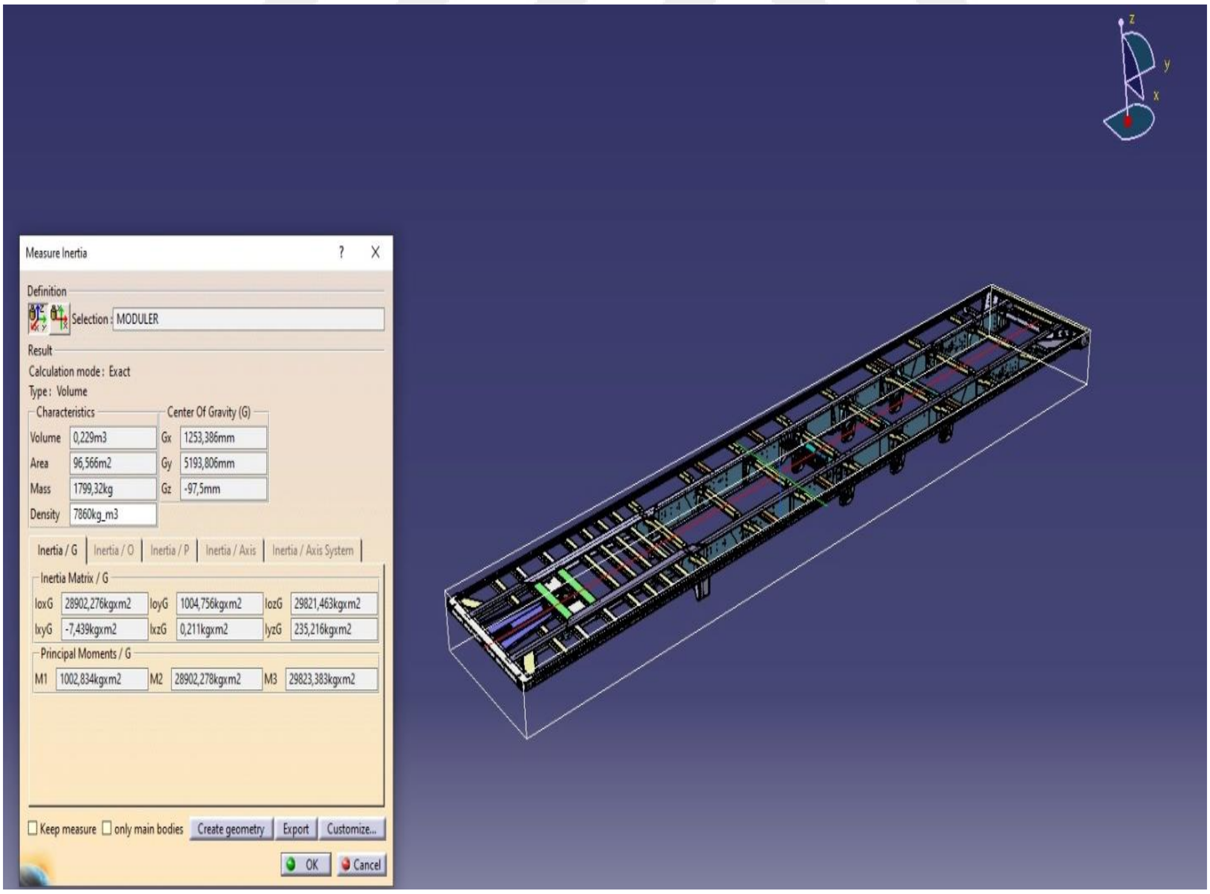

Figure 46. DP1180 Chassis Weight

European Commission

VECTO Trailer Tool - Customer Information File

Vehicle Configuration

Manufacturer:	KOLUMAN
Manufacturer address:	Şahin Mah.
Model / Commercial name:	SBPR27
VIN:	NLFS3010000012345
Date:	2023-12-22T07:49:29.149353Z
Legislative category:	O4
Axle count:	3
Trailer type:	DA
Bodywork type:	drop-side tarpaulin body
Trailer coupling point	n/a

Masses

Corrected mass in running order:	7200	kg
TPMLM trailer:	39000	kg
TPMLM axle assembly:	27000	kg

Vehicle group Annex I:	131
Vehicle group tool internal:	31501

Dimensions

External length of the body:	13.850	m
External width of the body:	2.550	m
External height of the body:	2.770	m
Total height of the trailer:	4.000	m
Cargo volume:	94.3	m³
Volume orientation	false	

Figure 47. VECTO Trailer Results Masses and Dimensions 1-7200 kg.

2/22/23, 10:42 AM

Axle and Tyre Features

Axle 1

Steered	false
Liftable	true
Twin tyres	false

Tyre

Certification Nr.:	e2*2017/2400*2022/1379*T*10002*00
Dimension:	385/55 R22.5
Fuel efficiency class	A

Axle 2

Steered	false
Liftable	false
Twin tyres	false

Tyre

Certification Nr.:	e2*2017/2400*2022/1379*T*10002*00
Dimension:	385/55 R22.5
Fuel efficiency class	A

Axle 3

Steered	false
Liftable	false
Twin tyres	false

Tyre

Certification Nr.:	e2*2017/2400*2022/1379*T*10002*00
Dimension:	385/55 R22.5
Fuel efficiency class	A

Results

Towing Vehicle

Generic group 5 (4x2 tractor), MY2019/20, 325kW

Figure 48. VECTO Trailer Results Axle and Tyre type-7200 kg.

12/22/23, 11:01 AM

Long Haul

Simulation Parameters

Payload:	2600	kg
Total vehicle mass:	17347	kg
CdxAyawAngle0:	5.641	m²
CdxAyawAngle3:	5.832	m²
CdxAyawAngle6:	6.505	m²
CdxAyawAngle9:	7.350	m²
Average speed:	79.7	km/h

Fuel consumption:	22.3	l/100km
Fuel consumption:	0.0857	l/t-km
Fuel consumption:	0.00236	l/m³-km
Fuel consumption:	186	g/km
Fuel consumption:	71.6	g/t-km
Fuel consumption:	1.97	g/m³-km
CO2 emissions:	583	g/km
CO2 emissions:	224.2	g/t-km
CO2 emissions:	6.18	g/m³-km
Efficiency ratio:	0.983	km-based
Efficiency ratio:	0.983	t-km-based
Efficiency ratio:	0.948	m³-km-based

Long Haul

Simulation Parameters

Payload:	19300	kg
Total vehicle mass:	34047	kg
CdxAyawAngle0:	5.641	m²
CdxAyawAngle3:	5.832	m²
CdxAyawAngle6:	6.505	m²
CdxAyawAngle9:	7.350	m²
Average speed:	78.5	km/h

Fuel consumption:	29.8	l/100km
Fuel consumption:	0.0154	l/t-km
Fuel consumption:	0.00316	l/m³-km
Fuel consumption:	249	g/km
Fuel consumption:	12.9	g/t-km
Fuel consumption:	2.64	g/m³-km
CO2 emissions:	780	g/km
CO2 emissions:	40.4	g/t-km
CO2 emissions:	8.27	g/m³-km
Efficiency ratio:	0.980	km-based
Efficiency ratio:	0.980	t-km-based
Efficiency ratio:	0.946	m³-km-based

Regional Delivery

Simulation Parameters

Payload:	2600	kg
Total vehicle mass:	17347	kg
CdxAyawAngle0:	5.641	m²
CdxAyawAngle3:	5.832	m²
CdxAyawAngle6:	6.505	m²
CdxAyawAngle9:	7.350	m²
Average speed:	60.7	km/h

Fuel consumption:	23.4	l/100km
Fuel consumption:	0.0900	l/t-km
Fuel consumption:	0.00248	l/m³-km
Fuel consumption:	196	g/km
Fuel consumption:	75.3	g/t-km
Fuel consumption:	2.07	g/m³-km
CO2 emissions:	612	g/km
CO2 emissions:	235.6	g/t-km
CO2 emissions:	6.49	g/m³-km
Efficiency ratio:	0.957	km-based
Efficiency ratio:	0.957	t-km-based
Efficiency ratio:	0.923	m³-km-based

Regional Delivery

Simulation Parameters

Payload:	12900	kg
Total vehicle mass:	27647	kg
CdxAyawAngle0:	5.641	m²
CdxAyawAngle3:	5.832	m²
CdxAyawAngle6:	6.505	m²
CdxAyawAngle9:	7.350	m²
Average speed:	60.1	km/h

Fuel consumption:	30.0	l/100km
Fuel consumption:	0.0232	l/t-km
Fuel consumption:	0.00318	l/m³-km
Fuel consumption:	250	g/km
Fuel consumption:	19.4	g/t-km
Fuel consumption:	2.66	g/m³-km
CO2 emissions:	784	g/km
CO2 emissions:	60.8	g/t-km
CO2 emissions:	8.31	g/m³-km
Efficiency ratio:	0.966	km-based
Efficiency ratio:	0.966	t-km-based
Efficiency ratio:	0.932	m³-km-based

Figure 49. VECTO Trailer Results for Long Haul and Regional Delivery-7200 kg.

Urban Delivery			Urban Delivery		
Simulation Parameters			**Simulation Parameters**		
Payload:	2600	kg	Payload:	12900	kg
Total vehicle mass:	17347	kg	Total vehicle mass:	27647	kg
CdxAyawAngle0:	5.641	m^2	CdxAyawAngle0:	5.641	m^2
CdxAyawAngle3:	5.832	m^2	CdxAyawAngle3:	5.832	m^2
CdxAyawAngle6:	6.505	m^2	CdxAyawAngle6:	6.505	m^2
CdxAyawAngle9:	7.350	m^2	CdxAyawAngle9:	7.350	m^2
Average speed:	26.2	km/h	Average speed:	25.7	km/h
Fuel consumption:	36.8	l/100km	Fuel consumption:	52.0	l/100km
Fuel consumption:	0.142	l/t-km	Fuel consumption:	0.0403	l/t-km
Fuel consumption:	0.00390	l/m³-km	Fuel consumption:	0.00551	l/m³-km
Fuel consumption:	308	g/km	Fuel consumption:	434	g/km
Fuel consumption:	118.3	g/t-km	Fuel consumption:	33.7	g/t-km
Fuel consumption:	3.26	g/m³-km	Fuel consumption:	4.61	g/m³-km
CO2 emissions:	963	g/km	CO2 emissions:	1360	g/km
CO2 emissions:	370.3	g/t-km	CO2 emissions:	105.4	g/t-km
CO2 emissions:	10.21	g/m³-km	CO2 emissions:	14.41	g/m³-km
Efficiency ratio:	0.948	km-based	Efficiency ratio:	0.962	km-based
Efficiency ratio:	0.948	t-km-based	Efficiency ratio:	0.962	t-km-based
Efficiency ratio:	0.914	m³-km-based	Efficiency ratio:	0.928	m³-km-based

Weighted Results

Payload:	13842	kg
Fuel consumption:	27.6	l/100km
Fuel consumption:	0.0199	l/t-km
Fuel consumption:	0.00292	l/m³-km
Fuel consumption:	230.6	g/km
Fuel consumption:	16.7	g/t-km
Fuel consumption:	2.45	g/m³-km
CO2 emissions:	722	g/km
CO2 emissions:	52.1	g/t-km
CO2 emissions:	7.65	g/m³-km
Efficiency ratio:	0.979	km-based
Efficiency ratio:	0.979	t-km-based
Efficiency ratio:	0.945	m³-km-based

VECTO Trailer Tool Version:

0.9.0.3168-RC !!NOT FOR CERTIFICATION!!

Date:

2023-12-22T08:01:04.8789236Z

Cryptographic hash manufacturer's records file:

jeMFehSCy1NG4gHMyVbYR5jAXCOV40S21VSZClr+0E8=

Figure 50. VECTO Trailer Overal Results Fuel Consumption and CO2 Emissions-7200 kg.

European Commission

VECTO Trailer Tool - Manufacturer Records File

Vehicle Configuration

Manufacturer:	KOLUMAN
Manufacturer address:	Şahin Mah.
Model / Commercial name:	SBPR27
VIN:	NLFS3010000012345
Date:	2023-12-21T13:41:05.7116324Z
Legislative category:	O4
Axle count:	3
Trailer type:	DA
Bodywork type:	drop-side tarpaulin body
Trailer coupling point	n/a

Masses

Corrected mass in running order:	7000	kg
TPMLM trailer:	39000	kg
TPMLM axle assembly:	27000	kg

Vehicle group Annex I:	131
Vehicle group tool internal:	31501

Dimensions

External length of the body:	13.850	m
External width of the body:	2.550	m
External height of the body:	2.770	m
Total height of the trailer:	4.000	m
Length from trailer front end to center of first axle:	8.140	m
Length between centres of axles:	2.620	m
Cargo volume:	94.3	m³
Volume orientation	false	

Figure 51. VECTO Trailer Results Masses and Dimensions-7018 kg.

2/22/23, 10:42 AM

Axle and Tyre Features

Axle 1

Steered	false
Liftable	true
Twin tyres	false

Tyre

Certification Nr.:	e2*2017/2400*2022/1379*T*10002*00
Dimension:	385/55 R22.5
Fuel efficiency class	A

Axle 2

Steered	false
Liftable	false
Twin tyres	false

Tyre

Certification Nr.:	e2*2017/2400*2022/1379*T*10002*00
Dimension:	385/55 R22.5
Fuel efficiency class	A

Axle 3

Steered	false
Liftable	false
Twin tyres	false

Tyre

Certification Nr.:	e2*2017/2400*2022/1379*T*10002*00
Dimension:	385/55 R22.5
Fuel efficiency class	A

Results

Towing Vehicle

Generic group 5 (4x2 tractor), MY2019/20, 325kW

Figure 52. VECTO Trailer Results Axle and Tyre Information

Long Haul

Simulation Parameters		
Payload:	2600	kg
Total vehicle mass:	17347	kg
Average speed:	79.7	km/h

Fuel consumption:	21.8	l/100km
Fuel consumption:	0.0837	l/t-km
Fuel consumption:	0.00231	l/m³-km
Fuel consumption:	182	g/km
Fuel consumption:	70.0	g/t-km
Fuel consumption:	1.93	g/m³-km
CO2 emissions:	569	g/km
CO2 emissions:	219.0	g/t-km
CO2 emissions:	6.04	g/m³-km
Efficiency ratio:	0.960	km-based
Efficiency ratio:	0.960	t-km-based
Efficiency ratio:	0.926	m³-km-based
Reference ratio:	0.977	km-based

Long Haul

Simulation Parameters		
Payload:	19300	kg
Total vehicle mass:	34047	kg
Average speed:	78.6	km/h

Fuel consumption:	28.9	l/100km
Fuel consumption:	0.0150	l/t-km
Fuel consumption:	0.00307	l/m³-km
Fuel consumption:	242	g/km
Fuel consumption:	12.5	g/t-km
Fuel consumption:	2.56	g/m³-km
CO2 emissions:	757	g/km
CO2 emissions:	39.2	g/t-km
CO2 emissions:	8.03	g/m³-km
Efficiency ratio:	0.952	km-based
Efficiency ratio:	0.952	t-km-based
Efficiency ratio:	0.918	m³-km-based
Reference ratio:	1.002	km-based

Regional Delivery

Simulation Parameters		
Payload:	2600	kg
Total vehicle mass:	17347	kg
Average speed:	60.7	km/h

Fuel consumption:	23.0	l/100km
Fuel consumption:	0.0884	l/t-km
Fuel consumption:	0.00244	l/m³-km
Fuel consumption:	192	g/km
Fuel consumption:	73.9	g/t-km
Fuel consumption:	2.04	g/m³-km
CO2 emissions:	601	g/km
CO2 emissions:	231.2	g/t-km
CO2 emissions:	6.37	g/m³-km
Efficiency ratio:	0.939	km-based
Efficiency ratio:	0.939	t-km-based
Efficiency ratio:	0.906	m³-km-based
Reference ratio:	0.980	km-based

Regional Delivery

Simulation Parameters		
Payload:	12900	kg
Total vehicle mass:	27647	kg
Average speed:	60.1	km/h

Fuel consumption:	29.3	l/100km
Fuel consumption:	0.0227	l/t-km
Fuel consumption:	0.00311	l/m³-km
Fuel consumption:	245	g/km
Fuel consumption:	19.0	g/t-km
Fuel consumption:	2.60	g/m³-km
CO2 emissions:	767	g/km
CO2 emissions:	59.4	g/t-km
CO2 emissions:	8.13	g/m³-km
Efficiency ratio:	0.944	km-based
Efficiency ratio:	0.944	t-km-based
Efficiency ratio:	0.911	m³-km-based
Reference ratio:	0.994	km-based

Figure 53. VECTO Trailer Results for Long Haul and Regional Delivery-7018 kg.

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Urban Delivery

Simulation Parameters

Payload:	2600	kg
Total vehicle mass:	17347	kg
Average speed:	26.2	km/h

Fuel consumption:	36.4	l/100km
Fuel consumption:	0.140	l/t-km
Fuel consumption:	0.00386	l/m^{3}-km
Fuel consumption:	304	g/km
Fuel consumption:	117.0	g/t-km
Fuel consumption:	3.23	g/m^{3}-km
CO2 emissions:	953	g/km
CO2 emissions:	366.3	g/t-km
CO2 emissions:	10.10	g/m^{3}-km
Efficiency ratio:	0.938	km-based
Efficiency ratio:	0.938	t-km-based
Efficiency ratio:	0.905	m^{3}-km-based
Reference ratio:	0.966	km-based

Urban Delivery

Simulation Parameters

Payload:	12900	kg
Total vehicle mass:	27647	kg
Average speed:	25.8	km/h

Fuel consumption:	51.5	l/100km
Fuel consumption:	0.0399	l/t-km
Fuel consumption:	0.00546	l/m^{3}-km
Fuel consumption:	430	g/km
Fuel consumption:	33.3	g/t-km
Fuel consumption:	4.56	g/m^{3}-km
CO2 emissions:	1347	g/km
CO2 emissions:	104.4	g/t-km
CO2 emissions:	14.28	g/m^{3}-km
Efficiency ratio:	0.953	km-based
Efficiency ratio:	0.953	t-km-based
Efficiency ratio:	0.919	m^{3}-km-based
Reference ratio:	0.977	km-based

Weighted Results

Payload:	13842	kg
Fuel consumption:	26.8	l/100km
Fuel consumption:	0.0194	l/t-km
Fuel consumption:	0.00285	l/m^{3}-km
Fuel consumption:	224.4	g/km
Fuel consumption:	16.2	g/t-km
Fuel consumption:	2.38	g/m^{3}-km
CO2 emissions:	702	g/km
CO2 emissions:	50.7	g/t-km
CO2 emissions:	7.45	g/m^{3}-km
Efficiency ratio:	0.953	km-based
Efficiency ratio:	0.953	t-km-based
Efficiency ratio:	0.919	m^{3}-km-based

VECTO Trailer Tool Version:
0.9.0.3168-RC !!NOT FOR CERTIFICATION!!

Date:
2023-12-22T07:42:08.3808875Z

Cryptographic hash manufacturer's records file:
YrCv8FWskEiM08/oqUlQn7CC4Sk2sSSuQUaZ+/kflF8=

Cryptographic hash customer information file:
TIHca7hRYPg8iEj0N0NAUqJU8zgs2ge7mVctTAIvUpI=

Figure 54. VECTO Trailer Overal Results Fuel Consumption and CO2 Emissions-7018 kg.

Since the impact of the logistics sector on greenhouse gas emissions is 25% and 70% of this is related to road transport, the annual fuel savings of 1600 litres and 4400 kg carbon emission savings from 1 vehicle are of great importance.

According to TUIK data, a total of 32,153 semi-trailers were registered until December 2023. 16,288 of these vehicles are curtained, closed body and refrigerated superstructure vehicles that fall into the aerodynamic vehicle categories specified in the EU 2022/1362 regulation.

When 16.288 vehicles x 1600 lt/vehicle is calculated, 26.060.080 lt of fuel will be saved from heavy vehicle trailer vehicles registered to traffic in Turkey in 2023, and when 16.288 vehicles x 4400 kg is calculated, 71.667.200 kg of carbon emission emissions will be saved.

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