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A DESİGN OF 3 PİECE RUN FLAT MOBİLE TİRE CHANGER FOR 22.5” RİMS

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Keywords

Rim, run flat, static structural analysis, solidworks

Abstract

As the usage of the Run Flat tires has prevailed in automotive industry, it has become a necessity to design a machine to mount-demount Run Flat tire safely. The reasons of that necessity can be explained as: unsafe and inefficient methods, immobile changer machines. In this study, it was aimed to design a mobile Run Flat tire changer for (3) piece Run Flat of the tires of Anti Riot Vehicle Solidworks, one of the CAD applications was used to analyze. Analysis processes were performed multiple times and the stress on the components of the design were checked. According to results, the last cross-sectional areas and dimensions were determined. At the first stage of study, rigid models of the equipment were set up. At the second stage, statistical analyses were executed. At the final stage, Von Mises Stress (MPa) and Ures Displacement (mm) values were calculated and the results were examined. Von Mises Stress (MPa) value of the arm mechanism was calculated as 222,4 MPa; Ures Displacement (mm) value of that was calculated as 0,407 mm; Coefficient of Safety was calculated as 1,57. As the size of the arm mechanism were increased, ergonomics of the model was affected negatively but Von Mises Stress (MPa) and Ures Displacement (mm) values were decreased. Maximum stresses and deformations were occurred on the surface of the tip. The design which provided workplace safety was achieved by maintaining the Coefficient of Safety high.

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22,5 İNCH JANTLAR İÇİN 3 PARÇA RUN FLAT MOBİL SÖKME TAKMA MAKİNESİ TASARIMI

Anahtar kelimeler

Jant, run flat, statik yapısal analiz, solidworks

Öz

Otomotiv sektöründe, Run Flat lastik kullanımının artması; Run Flat'in verimli ve emniyetli bir şekilde sökülüp takılmasına yönelik uygun bir makine tasarımını ihtiyaç haline getirmiştir. Söz konusu ihtiyacın nedenleri olarak: mevcut yöntemlerin emniyetsiz ve verimsiz olması, değiştirme makinelerinin mobil olmaması sayılabilir.

Bu çalışmada Toplumsal Olaylara Müdahale Aracı (TOMA) lastiklerindeki (3) parçalı Run Flat'in değişmesi için mobil Run Flat sökme takma makinesinin tasarlanması amaçlanmıştır. Bilgisayar Destekli Tasarım (CAD) uygulaması olan Solidworks programı kullanılmıştır. Analiz işlemleri birçok defa tekrarlanmış ve tasarım elemanları üzerinde oluşan gerilmeler kontrol edilmiştir. Elde edilen sonuçlara göre ekipmana ait en son boyut ve kesit alanları belirlenmiştir. Çalışmanın ilk aşamasında ekipmanların katı modelleri oluşturulmuş, ikinci aşamasında statik analiz yapılmıştır. Son aşamada ise Von Mises Stress (MPa) ve Ures Displacement (mm) değerleri bulunmuş ve sonuçlar incelenmiştir. Kol mekanizması Von Mises Stress (MPa) değeri 222,4 MPa; Kol mekanizması Ures Displacement (mm) değeri 0,407 mm; Emniyet katsayısı 1,57 olarak bulunmuştur. Kol mekanizmasının boyutları artırıldıkça ergonomik yapı olumsuz etkilenmiş ancak Von Mises Stress (MPa) ile Ures Displacement (mm) değerleri azalmıştır. Maksimum gerilmeler ve deformasyon, kol mekanizması tırnak yüzeyinde meydana gelmiştir. Emniyet katsayısı yüksek tutularak iş güvenliği sağlayan bir tasarım elde edilmiştir.

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1. Introduction

One of those precautions is Road holding. Road holding in the different conditions such as rainy, snowy roads has great importance for the traffic safety. There is a very close relation between road holding and the tire. The tire is composed of rubber, cord, steel wires and it is the only component which contacts with the ground (Geredelioğlu, 2012).

A tire can be subjected to external-internal impacts such as crashing into hard surfaces, overheating etc. which bring into punctures. All the companies in the market have focused on the problem of puncture. Those focuses have brought about to make new designs called Run Flat.

A run-flat tire is a pneumatic vehicle tire that is designed to resist the effects of deflation when punctured, and to enable the vehicle to continue to be driven at reduced speeds (under 80 km/h), and for limited distances (up to 80 km), depending on the type of tire (Mohamed Ali, Seng, Din, Hakim, & Mohamed, 2016).

Driving without inflation pressure leads to high increase of rolling resistance (up to 500%) thus also to very high increase of tire temperature. The wheels with Run-Flat inserts provide safe vehicle driving after tire depressurization, but only for very limited distance and time. It is also difficult for driver to control the tire condition and assess distance that may be driven without total tire destruction (Ejsmont, Jackowski, Luty, Motrycz, Stryjek, & Zurek, 2014).

It is recommended that rubber Run Flat be inserted inside the tire for the strength and resistance improvement of the wheel in terms of blast loading (Baranowski and Malachowski, 2015).

One of the oldest companies which produce Run Flat is Hutchinson Industries Inc. It has provided runflat systems to the military and security markets since 1926 (Hutchinson Defense and Mobility Systems, 2023).

Even though the structural composition as well as the type of run-flat tire is different for different tire makers, nowadays the run-flat tire with the sidewall reinforced rubbers is a mainstream thanks to its superior riding comfort and durability (Cho, Lee, Jeong, Kim, 2011).

In 2001, the 4th generation of the BMW 7 Series launched the market, and was the first model of mass-produced vehicles to be equipped with run-flat tires, which represents that the run-flat tire has officially entered the original market (Liu, Pan, Bian, Wang, 2021).

Run Flat system has some advantages such as:

- enhanced passenger safety and comfort
- prevention of a system shutdown in the event of a tire deflation and allowing

the vehicle to continue operation at a reduced speed (Grimaldi, 1998).

There are some extra requirements (bulletproof etc.) especially for military vehicles on which Run Flat tires are used.

The bulletproof function is achieved generally by providing the runflat structure inside the tire, and the runflat structure is expected to support the vehicle to continue to move when the tire is shot or burst. To avoid the extra attacks, the tire should sustain a distance of 50 km at the speed of 30~40 km/h on various road conditions. Therefore, the design of the runflat structure has a crucial impact on the performance of the bulletproof tire (Zhou, Ma, Cheng, Li, & Huang, 2014).

As the usage of the Run Flat tires has prevailed in automotive industry, it has become a necessity to design a machine to mount-demount Run Flat tire safely. The reasons of that necessity can be explained as,

- Lack of standard operation procedures,
- Unsafe and inefficient methods,
- Heavy changer machines,
- Immobility of changer machines.

When the studies have been researched to date, it is very common to see the Run Flat tire changer especially in the Defense Industry.

The first study in Türkiye about Run Flat was carried out by Dr.Nihat GEMALMAYAN in 1998. His study was about changer machine of one-piece Run Flat tires.

Figure 1. Changer Machine of One-Piece Run Flat Tires

It was presented in Traffic and Road Safety Congress held by Faculty of Engineering and Architecture of Gazi University in 2001.

In a study about Run Flat systems, Kestamid (PA06) was used to analyze. According to the results:

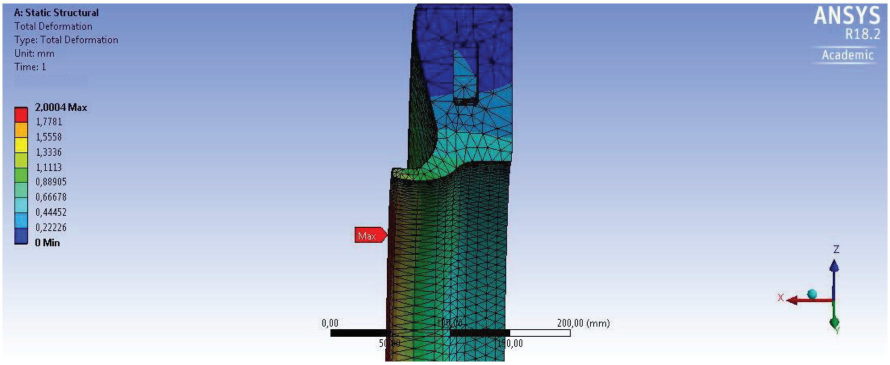

Figure 2. Total Deformation on the Thin Side

- Total Maximum Deformation was observed on the thin side of the Run Flat.
- Fishbolt and screw holes decreased the Coefficient of Safety.
- Durability and reliability of Run Flat system were supported by the finite element method (Pamuk 2018).

Figure 3. Run Flat Tire in the Event of Loss of Pressure

Figure 4. Non Run Flat Tire in the Event of Loss of Pressure

Every company produces Run Flat with materials it develops. The aim is to design new products which can go farther, slow down warming up and become more durable against the outside effects.

Run Flat generally is produced from polymer and composite materials. Thanks to those materials which lead to maximum output, high-tech products can be designed. Those designs are used especially in the space and defense industry increasingly.

1.1 Run Flat Mounting

- Firstly, deflate the tire.
- Separate the one side of the tire from the rim.
- Center the mobile Run Flat changer in the rim hole.
- Screw the top flange nut so that foot mechanism of the Run Flat grasps the tire.
- Use hydraulic jack, to set up an optimum working space between the tire and the rim.
- Insert the Run Flat into the tire piece by piece.
- After inserting the 3 piece Run Flat, tighten the first two pieces by screw.

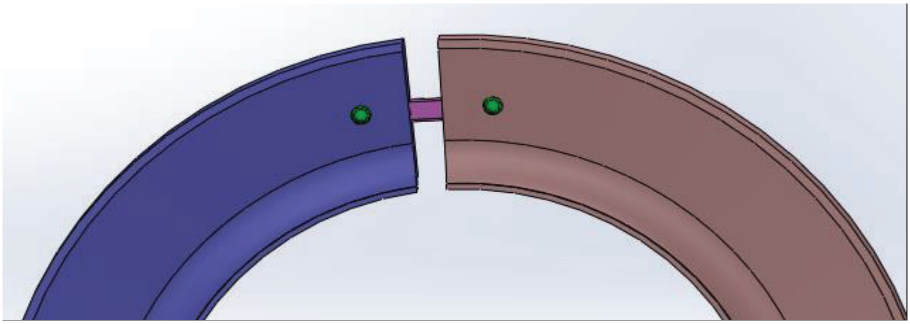

Figure 5. 3 Piece Run Flat Fishbolt

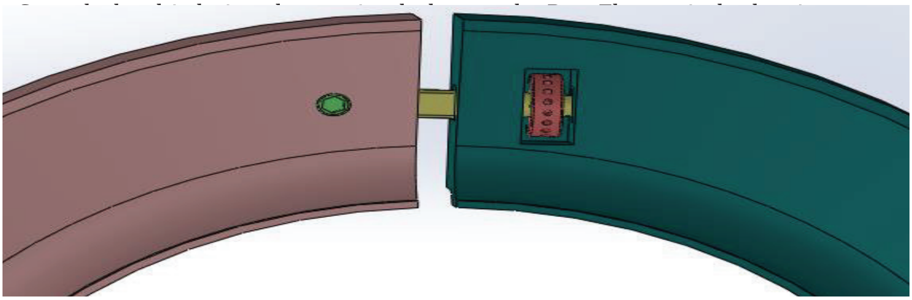

Figure 6. 3 Piece Run Flat Tension Bolt

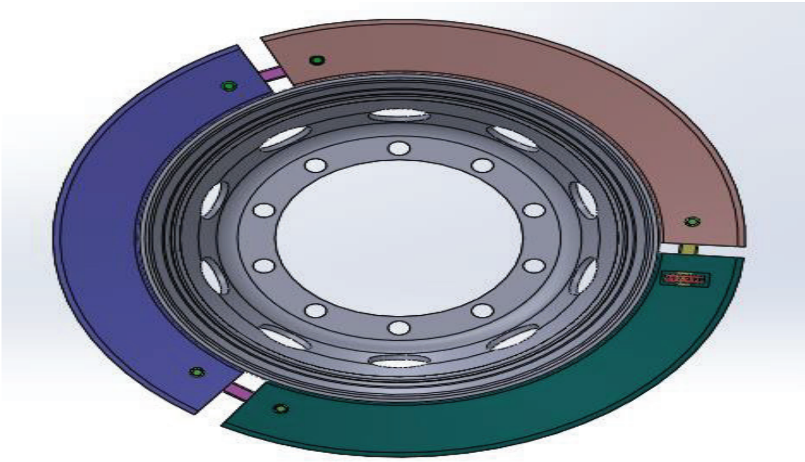

Figure 7. Mounting of 3 Piece Run Flat on the Rim

- Lastly, unscrew the top flange nut and remove Run Flat changer from the rim. Inflate the tire and complete the mounting process.

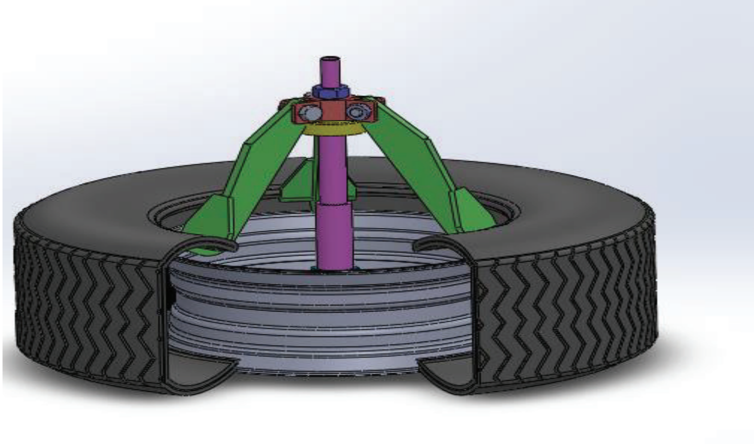

Figure 8. Non Run Flat Tire on the Rim

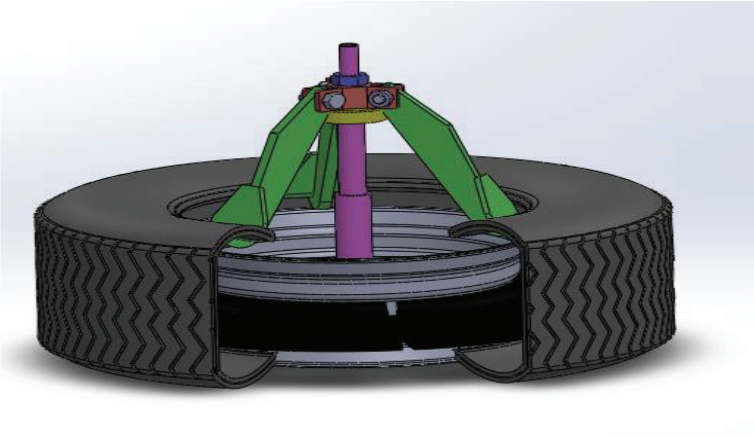

Figure 9. 3 Piece Run Flat on the Rim

1.2 Scope of Run Flat

Run Flat is used in police and military vehicles, engineering vehicles, ambulances, fire-fighter vehicles, armored money transport trucks, armored escort vehicles.

Figure 10. Panzer

Figure 11. Anti Riot Vehicle

2. Methodology

2.1 Types of Run Flat

Run Flat systems are generally named according to the number of the pieces they are composed of. There are 3 types of Run Flat.

1 piece Run Flat: It is used generally for the Panzer vehicles which have 20 inch rims. It is preferred for cleavable rims because it is easy to mount for separated parts. Neverthless, it is not suitable and efficient for single piece rims, since the weight of the mounting machine is too heavy and its size is too large.

Figure 12. 1 Piece Run Flat

2 piece Run Flat: Generally it is preferred for Shortland type vehicles which have 16 inch rims because it is easy to mount.

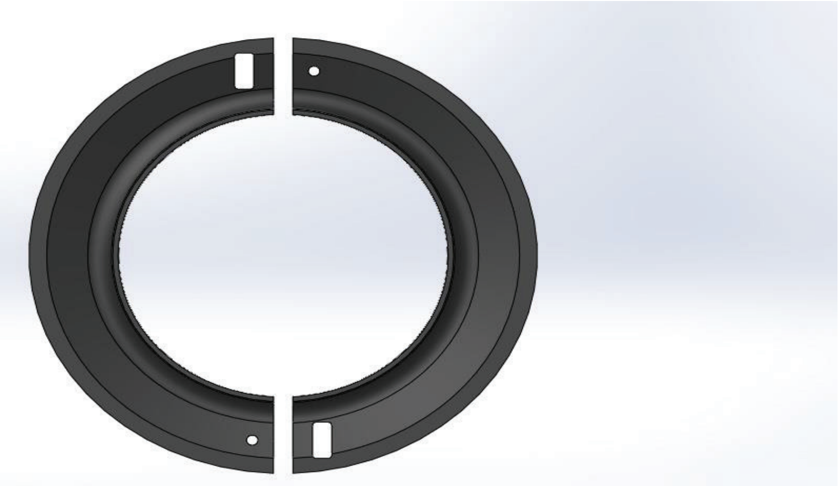

Figure 13. 2 Piece Run Flat

3 piece Run Flat: Generally it is preferred for Anti Riot Vehicles which have 20+ inch rims. It is easy to mount for single piece rims that is why it is commonly favored.

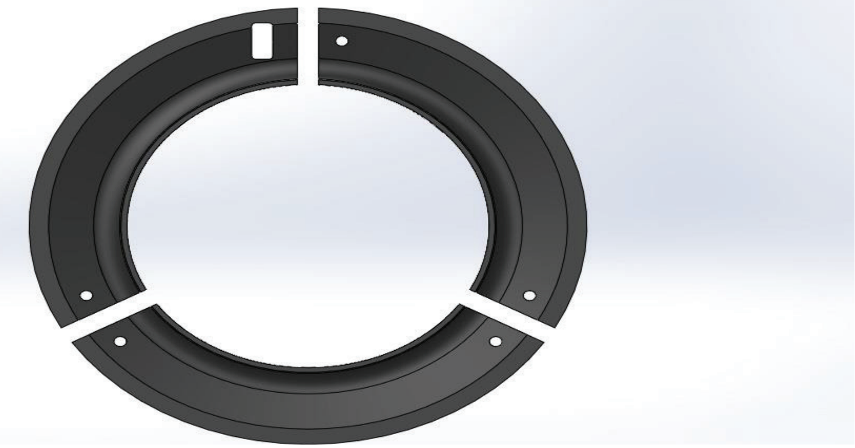

Figure 14. 3 Piece Run Flat

2.2 Material Selection

Material selection is very important for every product. Therefore, ideal material selection and design make the product safe, comfortable and cost-effective. Modern technology and applications help engineers and producers on that issue.

There are some factors in order to select ideal material. They are:

- Malleability
- Durability
- Strength
- Compatibility
- Cost-effectiveness
- Ductility
- Corrosion resistance
- Environment conditions.

Taking into consideration those factors, AISI 1020 steel was preferred in this study. That steel is generally used in the producing machines.

The technical specification of AISI 1020 is presented in Table 1 (Materials Informations Research, 2023).

Table 1. AISI 1020 Steel Mechanical Properties

Material	AISI 1020 Steel, Cold Rolled
Ultimate Strength	420 MPa
Yield Strength	350 MPa
Modulus of Elasticity	186 GPa
Poissons Ratio	0.29

2.3 Mobile Run Flat Tire Changer

Designed Run Flat Tire Changer is composed of;

- 3 Arm mechanism
- 1 Disc
- 1 Disc shaft
- 1 Arm equipment
- 1 Top flange nut
- Hydraulic jack 10 ton
- Jacking bed

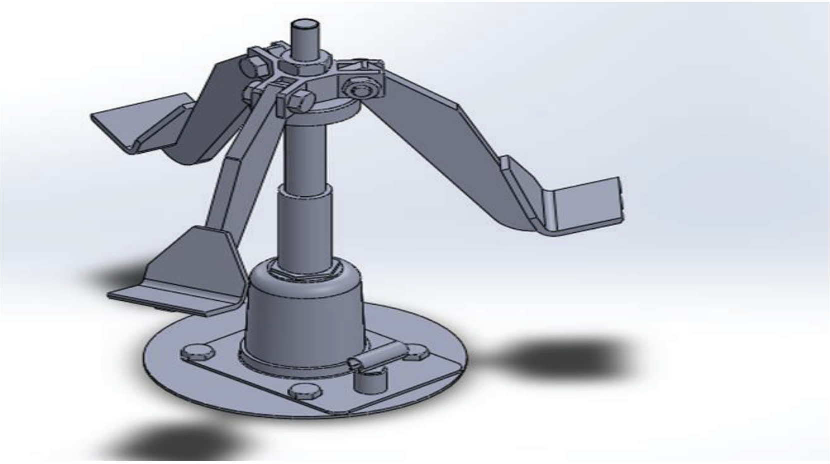

Figure 15. A Design of 3 Piece Run Flat Mobile Tire Changer for 22.5” Rims

2.4 Parts Coloring

Nowadays it has been an important issue to present the design of products properly. With regard to presenting the designed product, visual of 3 piece Run Flat mobile changers is of great importance. According to that necessity, visual enrichment and parts coloring were carried out in the computing environment.

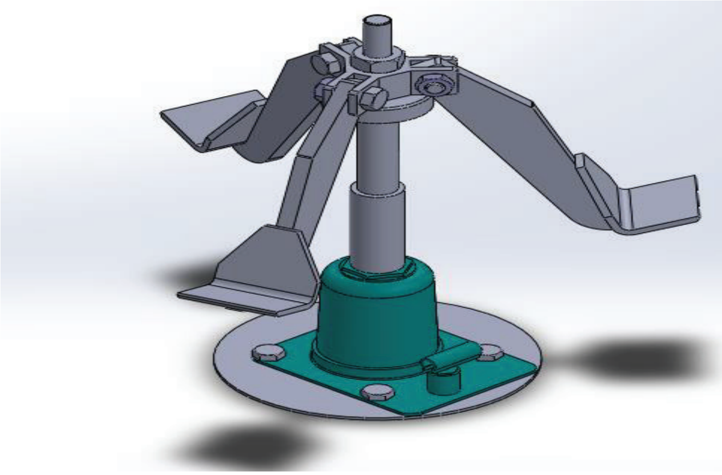

Figure 16.Coloring Parts Rigid Model-1

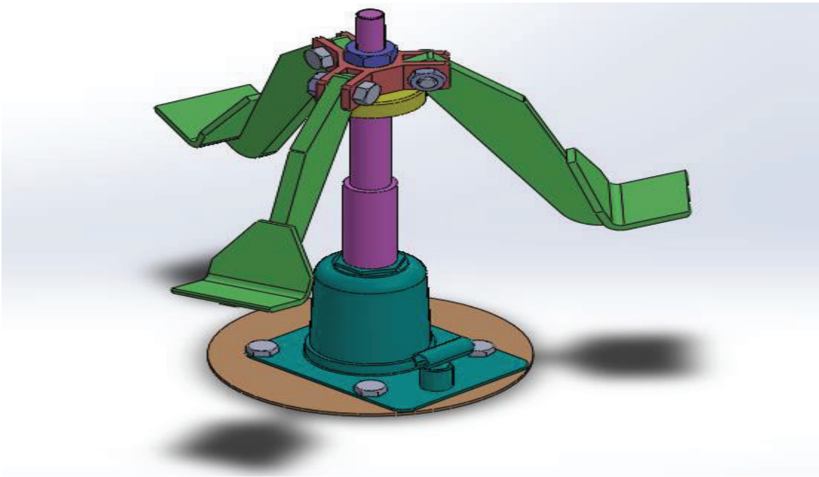

Figure 17. Coloring Parts Rigid Model-2

3. Results

3.1 Estimated Cost Calculation

Design of 3 piece Run flat mobile changer for 22,5 inch rims was done according to meeting the necessities of Turkish National Police. The necessities are to have high operating speed on every environment but to need less space, to be portable and light, to place workplace safety to forefront.

To decrease the costs, parts of the system were designed as simple as possible. The system didn't include any complex or unnecessary parts. To meet the expectations of the market in a short time in case of too many demands, the easily producible and providable materials were chosen.

Estimated cost calculation was done according to dollar exchange rate at the end of May 2023 (1 USD = 19,25 TL)

Table 2. Estimated Cost Table

Part	Number	Unit Price	Total Amount
Hydraulic Jack 10 Ton	1	1.000 TL	1.000 TL
Arm Mechanism	3	500 TL	1.500 TL
Disc	1	300 TL	300 TL
Disc Shaft	1	250 TL	250 TL
Arm Equipment	1	500 TL	500 TL
Jacking Bed	1	300 TL	300 TL
Top Flange Nut	1	75 TL	75 TL
Joint Bolt	3	25 TL	75 TL
TOTAL			4.000 TL

There are approximately 150 tires which need to be repaired by this machine in a year. Since the cost of mounting and demounting Run Flat is 500 TL for each tire, average total cost will be 75.000 TL. According to Estimated Cost Table it is very clearly observed that the production cost of a machine equals to mounting cost of 8 Run Flat tires. As a consequence, it is obvious that designed machine is cost-effective. Besides, it is much cheaper to produce it in Türkiye.

3.2 Determining Analysis Modules

How to carry out force analyses by using Solidworks will be described in this section. There are different modules for different conditions. In this study, the most important part of the system, arm mechanism, was analyzed. The basic step of the analysis is to set up the rigid model.

3.3 Defining the Materials

Firstly, the arm mechanism is opened in the Static analysis module and a name is given to the part. Then, apply material is clicked and AISI 1020 steel is chosen. Hence, defining material gets finished.

3.4 Configuration of Analyses

Critical position is chosen for the arm mechanism. Getting the arm mechanism in the right angel, the mechanism is fixed by one of its components. To apply those fixtures, fixed geometry is chosen in the fixtures module. To select the size and directions of the force against the surface, external loads is clicked. Then surface of the tip is chosen and the force value (16537,5 N) is defined.

Create mesh is clicked in the mesh module and standard mesh structure is chosen. Clicking the run this study on the screen, calculations are made. After completion of the process, the results can be viewed.

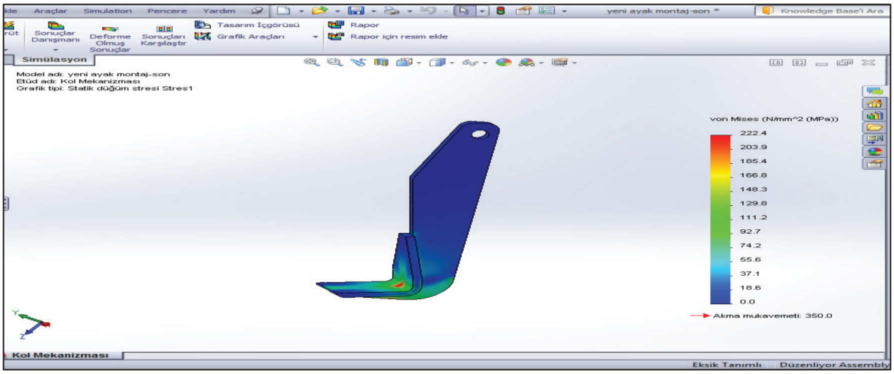

Figure 18. Result Screen of Von Mises Stress (MPa)-1

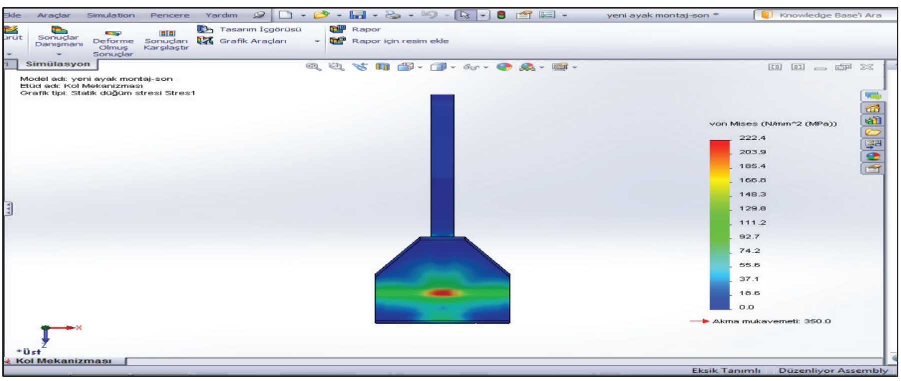

Figure 19. Result Screen of Von Mises Stress (MPa)-2

3.5 Arm Mechanism Von Mises Stress (MPa)

Maximum stresses were occurred on the surface of the tip as expected. Maximum Von Mises Stress (MPa) value was calculated as 222,4 MPa. Yield Strength of the selected material was 350 MPa. In this case, coefficient of Safety was calculated as 1,57. Those values were viable for the model.

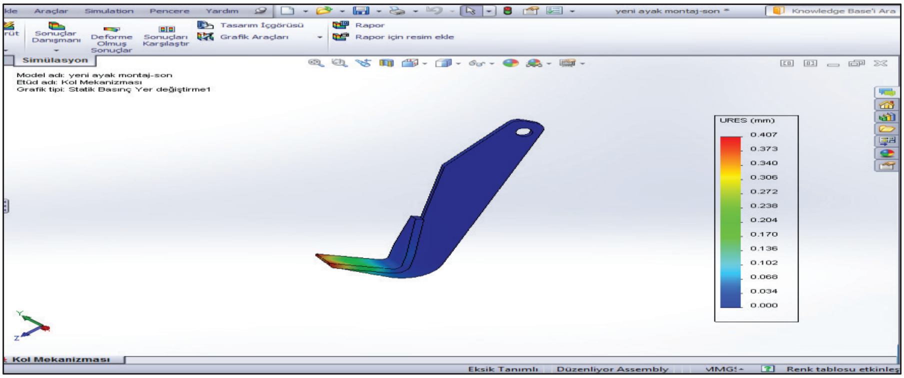

Figure 20. Result Screen of Ures Displacement (mm) -1

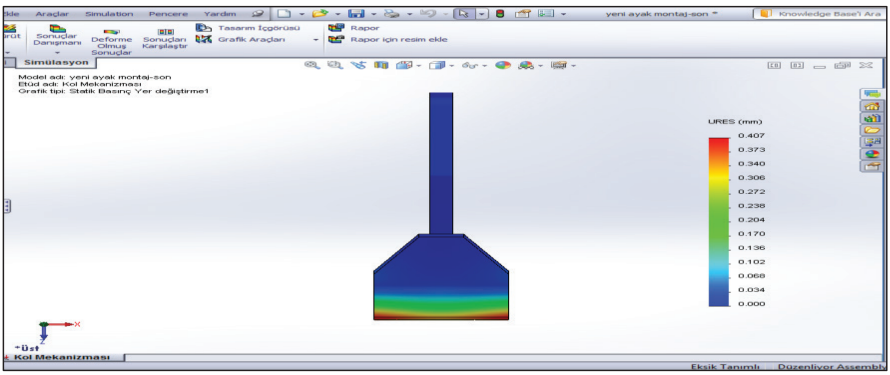

Figure 21. Result Screen of Ures Displacement (mm) -2

3.6 Arm Mechanism URES Displacement (mm)

Displacement values were increase on the surface of the tip as expected. Ures Displacement (mm) value was calculated as 0,407 mm.

4. Conclusıon and Suggestıons

In this study, a design of a 3 piece Run Flat tire changer which was used to make anti riot vehicles be ready to move in a shorter time in case of a puncture was made. When an anti riot vehicle is subjected to puncture because of any impact, the driver can bring it in a safe zone. In the safe zone, the puncture can be fixed very fast and efficiently thanks to new design which is mobile, light and small sized.

In the designing process, rigid model studies were performed by using Solidworks. Safety was foregrounded in those and it was observed that stresses were within the acceptable limits.

A great effort was put into making Run Flat tire changer user-friendly as well as ergonomic because it was intended to present that machine in some platforms. The materials were designed as compatible with the geometry.

In order to perform static analysis on the arm mechanism, analysis steps were studied, the model was prepared, materials were defined. Calculating the given values, results of the statistic analysis were obtained.

It was observed that maximum stresses and deformations occurred on the surface of the tip. The maximum values were observed as 222.4 MPa and 0,407 mm respectively. Stresses and deformations were given by the figures.

As a result;

- Knowledge and experience were gained by this study. In the study, necessary forces were determined, analysis steps were scrutinized and the system was strengthened against the stresses.
- Costs were decreased, changing of 3 piece Run Flat was eased and probable work accidents were minimized by featuring workplace safety.
- A new successful approach was introduced to mount-demount Run Flat tires which were getting used on a large scale gradually.

Within the context of suggestion; dimensions of the materials (disc, disc shaft etc.) can be changed to perform new studies about the Run Flats which have different rims.

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