REPUBLIC OF TURKEY
BARTIN UNIVERSITY
GRADUATE SCHOOL
DEPARTMENT OF MECHANICAL ENGINEERING

MASTER'S THESIS

THE DESIGN AND VERIFICATION OF A ROCKET LAUNCHER SUBFRAME

BY
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SUPERVISOR
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BARTIN-2020

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BARTIN-2020

ACCEPTANCE AND APPROVAL

DECLARATION

I hereby declare that, this master's thesis prepared in accordance with Bartın University Graduate School thesis writing manual, conducted under the supervision of Prof. Dr. M. Sabri GÖK and titled "THE DESIGN AND VERIFICATION OF A ROCKET LAUNCHER SUBFRAME" is a unique study, all information has been obtained in accordance with academic rule and ethical conduct. I have fully cited and referenced all material and results that are not original to this work and that I will accept any legal sanctions if found otherwise.

10/08/2020

Rıfat ÜNAL

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Rıfat ÜNAL

ABSTRACT

Master's Thesis

THE DESIGN AND VERIFICATION OF A ROCKET LAUNCHER SUBFRAME

Rıfat ÜNAL

Bartin University
Graduate School
Department of Mechanical Engineering

Thesis Advisor: Prof. Dr. Mustafa Sabri GÖK

Bartın-2020, pp: 45

This thesis evaluates the structural suitability of the rocket launcher subframe under static and dynamic conditions with the help of finite element method. Rocket launchers generally fires rockets at stabilization position to have good rocket accuracy and dispersion performance so that the dynamic behaviour of subframe during firing will be examined. The subframe is also under various loads on off-road condition as a part of mission. In this thesis, the reliability of subframe and its components will be examined during firing and off-road conditions.

The purpose of this thesis is to give tips for designing subframe, to analyse a finite element model and to verify the finite element model by taking the measurement in real test. Hence, to obtain a optimized rocket launcher subframe that can be integrated to tactical wheeled vehicle chassis is the key point of designing rocket launcher.

Keywords: Rocket launcher; subframe, finite element method, structural analysis, dynamic analysis

Scientific Field Code: 91432

ÖZET

Yüksek Lisans Tezi

ROKETATAR YARDIMCI ŞASE TASARIMI VE DOĞRULANMASI

Rıfat ÜNAL

Bartın Üniversitesi
Lisansüstü Eğitim Enstitüsü
Makine Mühendisliği Anabilim Dalı

Tez Danışmanı: Prof. Dr. Mustafa Sabri GÖK

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Bu tez, statik ve dinamik koşullar altında roketatar yardımcı şasesinin yapısal uygunluğunu sonlu elemanlar yöntemi yardımı ile değerlendirmektedir. Roketatarlar, iyi dağılım ve doğruluk performasına sahip olabilmek için genellikle stabilizasyon durumunda roketleri fırlatır bu nedenle yardımcı şasenin fırlatma anında dinamik davranışı incelenecektir. Yardımcı şase ayrıca arazi koşullarında çeşitli yüklere maruz kalmaktadır. Tez içerisinde fırlatma anında ve arazi koşullarında yardımcı şase ve parçalarının güvenilirliği incelenecektir.

Bu tezin amacı, yardımcı şase tasarımı ile ilgili tavsiyelerde bulunmak, yardımcı şasenin analizini yapmak ve gerçek testlerden alınan ölçümlerle analiz modelini doğrulamaktır. Sonuç olarak taktik tekerlekli bir araca entegre optimize bir yardımcı şase elde etmek roketatar tasarımının anahtar noktasıdır.

Anahtar Kelimeler: Roketatar; yardımcı şase; sonlu elemanlar yöntemi; yapısal analiz; dinamik analiz

Bilim Alanı Kodu:91432

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LIST OF NOTATIONS AND ABBREVATIONS

FE	:	Finite Element
FEM	:	Finite Element Method
LPT	:	Linear Position Transducer
MLRS	:	Multiple Launcher Rocket System
PEEQ	:	Equivalent Plastic Strain (Abaqus)
PTO	:	Power Take Off
WMS	:	Weapon Management System
μ	:	Friction co-efficient

SECTION 1

INTRODUCTION

1.1 General Information

The Multiple Launch Rocket Launcher System (MLRS) is used to carry more than one rockets on on-off road conditions and to fire/send rockets from defined place to specific area or region. Rocket launchers are generally used to destroy a certain area with heavy artillery fire instead of a single correct fire due to launching free-flight unguided rockets. For this reason, it is very important to launch more than one rocket within a short time from the rocket launcher and to reach the target with precise accuracy and range rates. In addition, the rocket launchers are placed on the tactical truck to quickly fire rockets and move away from their location. A Multiple Launcher Rocket System has been demonstrated in Figure 1.

Figure 1. An example of MLRS

The main sub-systems of Multiple Launch Rocket Launcher are tactical truck, subframe, cradle, ammunition canisters, ammunitions, weapon management system, hydraulic system, power system and communication system.

Tactical Truck is a vehicle that carries all the system. The selection of tactical truck shall be based on the payload capacity, useful chassis length behind the cab, power take off (PTO) availability, cab space etc. The truck will be used to transport the Launcher superstructure on road and off road terrain. And the driver's cab of the truck houses the crew and control & communication equipment to command the Launcher. If available it will back-up the power required by the electrical & electronic systems used in the Launcher through a PTO coupled alternator. The truck will also generate the hydraulic power required for stabilizing/supporting legs through a second PTO.

Subframe is integrated to truck chassis with brackets. The subframe consists of a subframe, equipment & accessory cabinets, platform and mounting interfaces for the cradle, hydraulic system together with stabilizing/supporting legs. It will bear the firing loads in horizontal and vertical directions during the rocket launch due to the fact that subframe enhances the stability of Multiple Launch Rocket System.

The Cradle System is mounted on subframe and composes an elevating platform, a turn table, a holder and related electromechanical/hydraulic actuator systems to aim and launch ammunitions. The cradle aimed on target in azimuth and elevation for a fire mission, after the stabilization platform is deployed and stabilized.

The Weapon Management System (WMS) components are located in driver's cab or cradle and on Stabilization/launching platform. The system manages mission related orders that include navigation and fire control related functions. The WMS commands automatic aiming process of cradle according to the given target coordinates, conducts safety checks and executes the fire mission.

The hydraulic system is mounted on subframe platform and it consists of stabilizers and outriggers and hydraulic pumps, Onestabilizer consists of vertical direction hydraulic cylinder and case. One outrigger consists of horizontal direction cylinder and case.

The power system supplies the electrical energy needed for electronic equipment and cradle motor drive system. Power System components such as generator, alternators are mounted on stabilization and launching platform.

Communication system provides data and voice Communication with the other MLRS realized through either a Radio located inside the driver's cab or a cable connected between each vehicle.

Ammunition canisters are placed on the elevation platform of cradle and houses the ammunitions. Precise positioning of ammunition in ammunition canisters and price placement of ammunition canister on to elevation platform is crucial for rockets to hit targets with high accuracy.

1.2 Scope of the Thesis

The scope of thesis is the design principle of Rocket Launcher subframe and the verification of the finite element model with real test results. Hence, the finite element model is created. The results of FEM are verified with the real test results to correlate the model.

The FEM of Rocket Launcher Subframe that includes brackets of chassis and subframe, stabilizers case and outrigger case and hydraulic cylinder mechanical connections are examined to understand the static and dynamics behavior of the system. Cradle, ammunition canister and ammunition, interactions between elevation table and ammunition canister, misalignment of thrust/plume force are not taken into account.

1.3 Aim of the Thesis

The tests and their verification processes of launching system are very challenging that consumes more time and more money. Because, price of a one rocket or missile and test area renting price and the observation rocket or missile trajectory and the behavior of launching platform by using a lot of radars. To decrease the number of experimental test, to be sure that tactical vehicle can carry this rocket launcher system off-on road conditions and to be sure that accuracy and dispersion values of rocket/ammunition meets the requirement of the system are the main purposes of this thesis. The dynamic movement of the subframe until the missile leaves the canister shall be minimum since it directly affects the dispersion and accuracy values of free flight rockets. Therefore, weight optimized and minimized dynamic deviation subframe analyses is very crucial by using this finite element model.

The first aim of this thesis is give some tips about how to design a Rocket Launcher subframe. The second aim is to obtain a FEM to verify it with real test results. If any other rockets are fired on the same rocket launcher, there will be no need an experimental test for verification due to detailed finite element model which is mentioned in this thesis.

Therefore; effort, costs and the number of real test descend by creating the finite element model.

1.4 Sections of the Thesis

The sections are arranged as follows:

- In Section 2, literature research about multiple launcher rocket system are introduced.
- In Section 3, design work of Rocket Launcher subframe and analysis of the finite element model are mentioned.
- In Section 4, test study and confirmations of the finite models are given.
- In Section 5, summary is given.

SECTION 2

LITERATURE SEARCH

The first aim of this thesis is give some tips about how to design a Rocket Launcher subframe. The second aim is to obtain a FEM to verify it with real test results.

The design and analyse of subframe is common issue. However, the design of subframe differs from vehicle to vehicle. The method of analysis subframe changes according to the vehicle working conditions such as off-road, on road etc.

Chen and Zhu (2011) worked on the YJ3128-type dump truck’s subframe. The cracks based on fatigue were observed and load features, working conditions of truck were examined in detail. After the finite element analysis, improvement and optimization on subframe were made. The improved subframe is revealed in Figure 2.

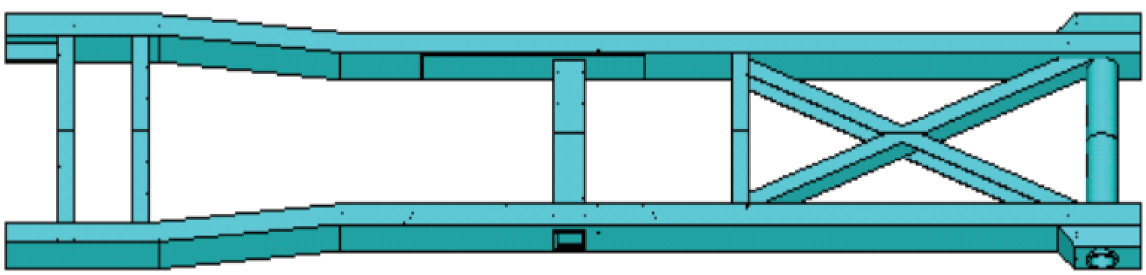

Figure 2. The Improved Subframe Model by Chen and Zhu (2011)

Sandip and Patel (2013) worked on the load analysis within statical balance of the chassis of TATA ace ex using ANSYS workbench to determine crucial characteristics of a chassis. The location of high stress area were defined. By using reinforcement technique of optimization the load carrying performance of the vehicle has been enhanced successfully. The meshed model of chassis is shared in Figure 3.

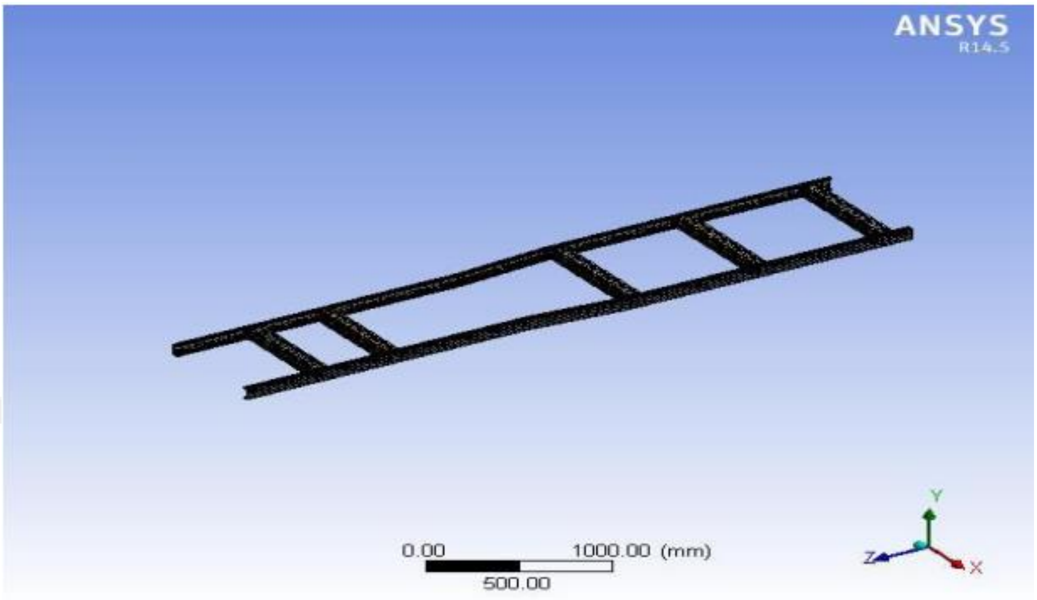

Figure 3. The meshed model of chassis by Sandip and Patel (2013)

Sairem and Gopinath (2013),worked on finite element model of the TATRA chassis by using ANSYS. For a plain road and bump conditions static analysis is done and the stress and deflection plots are determined. The plots of stress is shown in Figure 4.

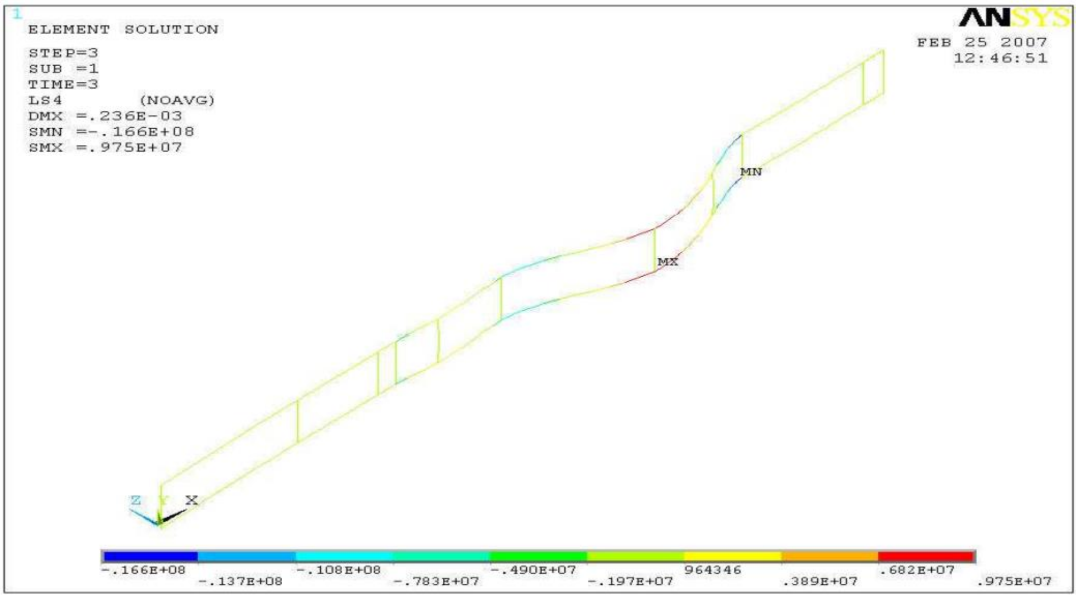

Figure 4. Stress developed on Chassis by Sairem and Gopinath (2013)

Liu (2011), worked on Aerial Work Truck Subframe with UG alternative development framework. He developed a rapid design system to improve the design efficiency and parametric modeling process was proposed. The efficiency of the system were verified by an application. 3D model of proposed subframe system is demonstrated in Figure 5.

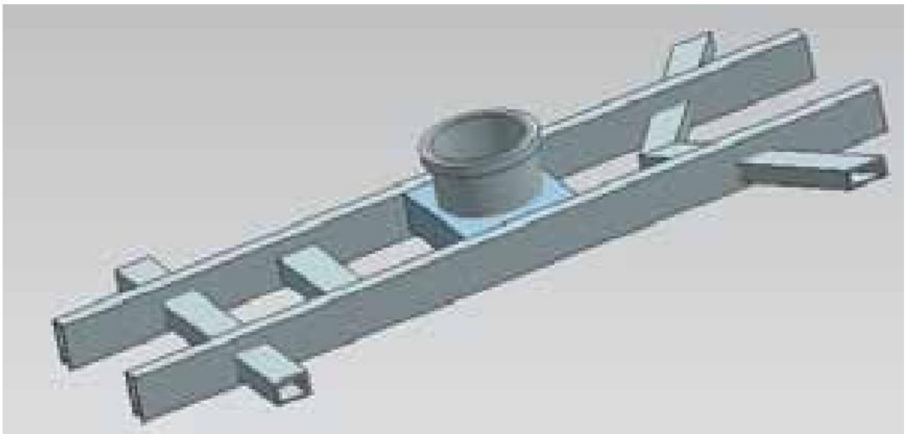

Figure 5. 3D model of proposed subframe system by Liu (2011)

In the literature research, it was observed that there is limited open source about rocket and missile launch. The studies may not have been distributed or kept in secret status.

Çiçek (2014) examined the dynamic characteristics of rocket launcher and obtained a simplified FE model not to waste too much time using the detailed FE model in his study. Under static and dynamic load conditions, the detailed FEM results, simplified FEM results were obtained and compared with the real test outputs. Finite element model of Çicek (2014) is revealed in Figure 6.

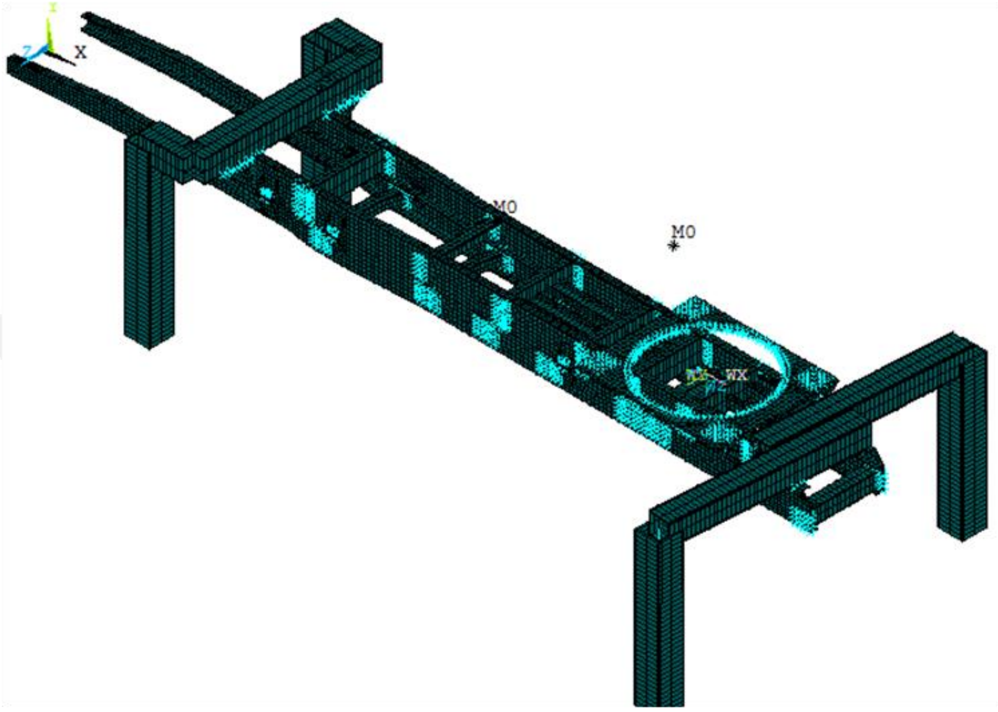

Figure 6. Detailed FEM by Çicek (2014)

Işık (2012) worked on the dynamic characteristics of rocket launcher. In the study, only cradle and ammunition canister which are the sub system of launching systems were examined by creating simple mathematical model, FEM and flexible multi-body model. Under dynamic load conditions, the results were obtained and compared with the real test outputs. FEM approach of Işık (2012) is given in Figure 7.

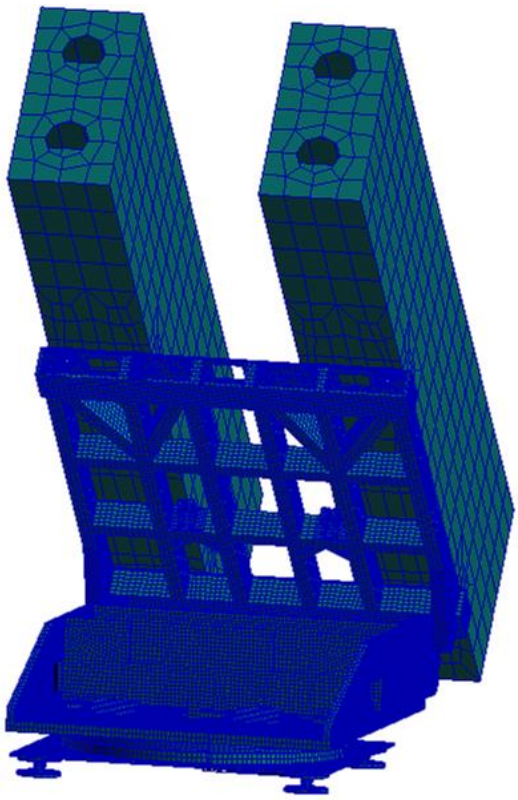

Figure 7. Detailed FEM by Işık (2012)

Selmic vd. (2004) worked on a model that consists ofchassis, suspension, stabilizers and pneumatics. While stabilizers and pneumatics are shown as inflexible, lunching tube is shown as flexible body. While ground is shown as elastic, vehicle and cradle connections are shown as unbending. The model of Selmic vd. (2004) is indicated in Figure 8.

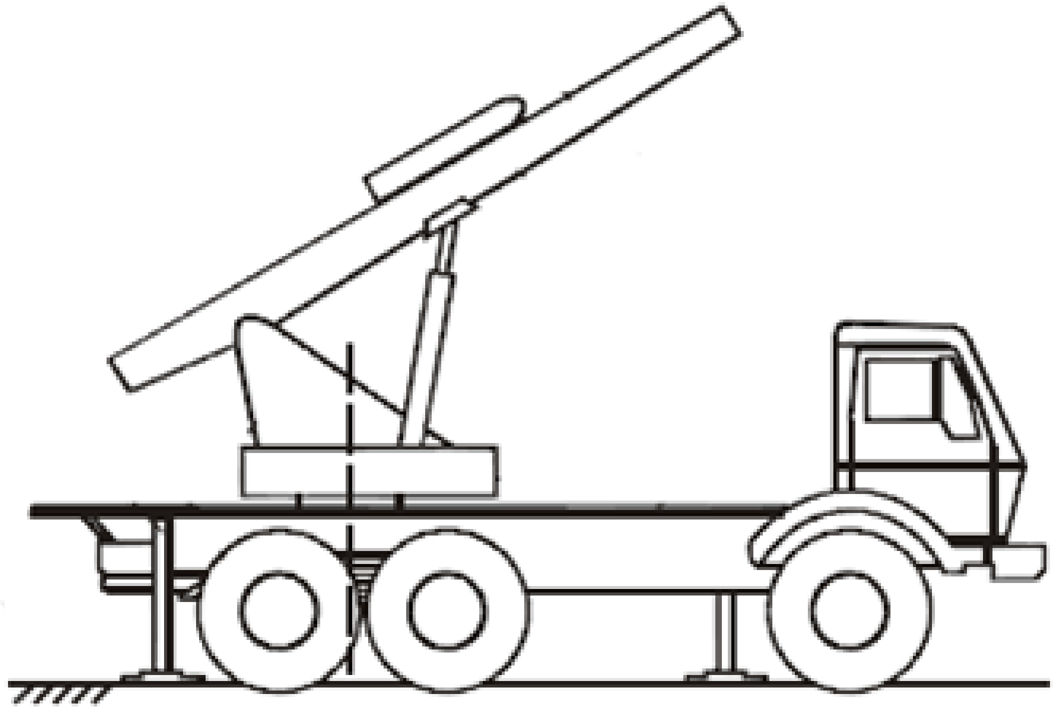

Figure 8. The model created by Selmic vd. (2004)

Hadipour vd. (2011) worked on a FEM to show the enhancement in rigidity of the chassis by adding a subframe. Also the change on vibration behavior of the chassis was shown by using ANSYS software. Finite element model formed by Hadipour vd. (2011) is revealed in Figure 9.

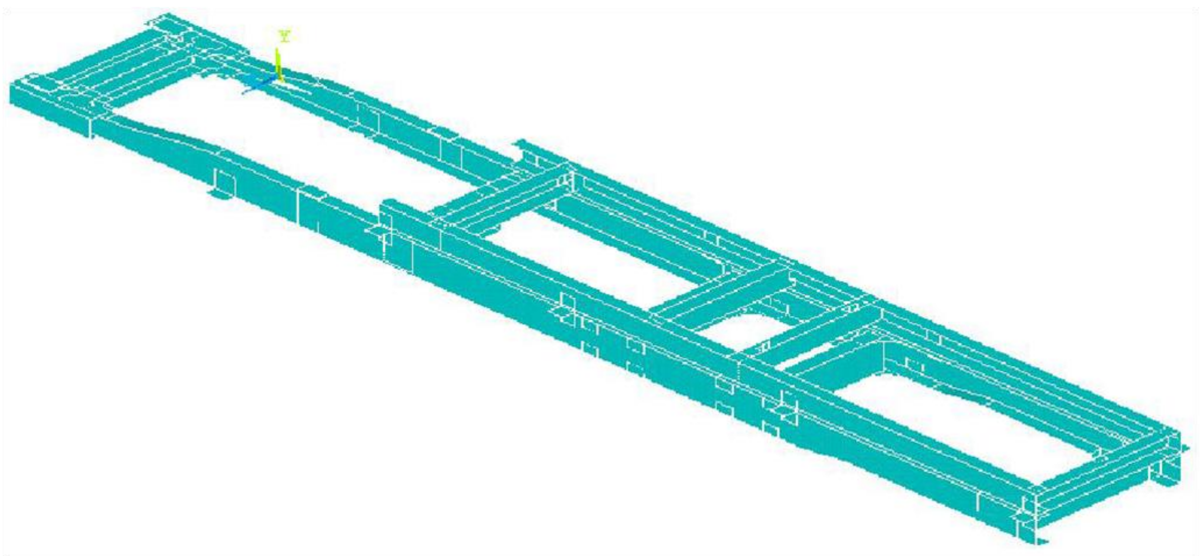

Figure 9. FEM by Hadipour vd. (2011)

Cömert (2000) worked on the dynamics of rocket launcher. By examining the connections ammunition and elevation table he showed the dominant flexibility effects on the system. He obtained the roll, pitch and yaw angles, the rotational velocity and accelerations due to time thanks to rotational equational motion.

Zhang and Xiao (2005) worked on a rocket launcher model that includes vehicle, yaw-pitch body, launch tube and rocket. As shown in Figure 10, elastic connection with springs and dampers is used between the vehicle and ground. Also, torsion spring and dampers are used between yaw body and vehicle. Pitch body is attributed to the yaw body with flexible and rigid connections are used between pitch body and yaw body. System behavior is examined with this boundary conditions.

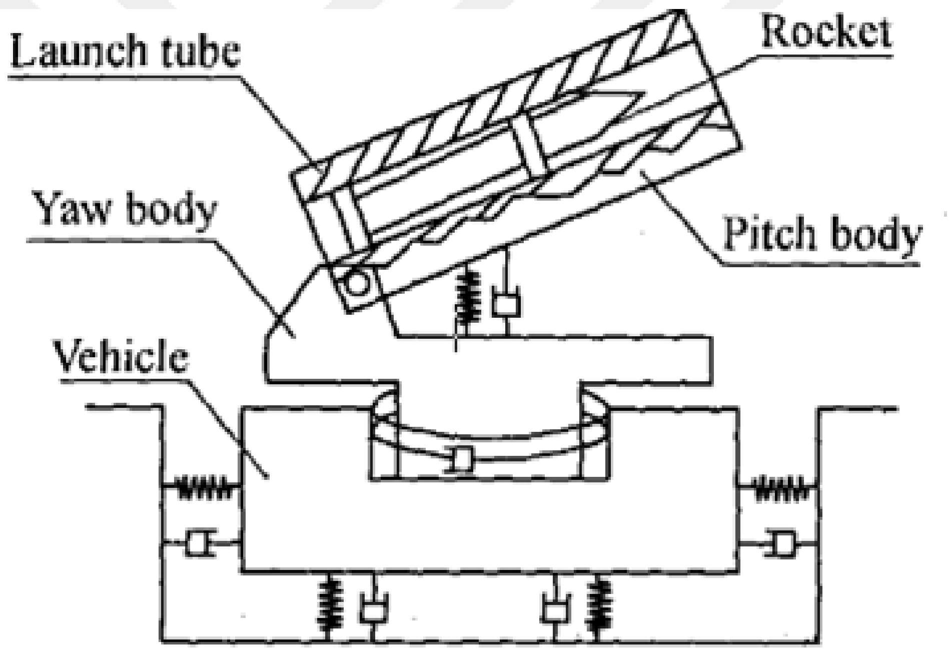

Figure 10. The model by Zhang and Xiao (2005)

Roslan vd. (2009) worked on the basic characteristics of a truck chassis. By obtaining a finite element model that includes cross members, brackets etc. model analysis were performed. The dynamic characteristics of vehicle were defined due to experimental modal analysis and model updates. The flow chart of chassis development which is formed by Roslan vd. (2009) is revealed in Figure 11.

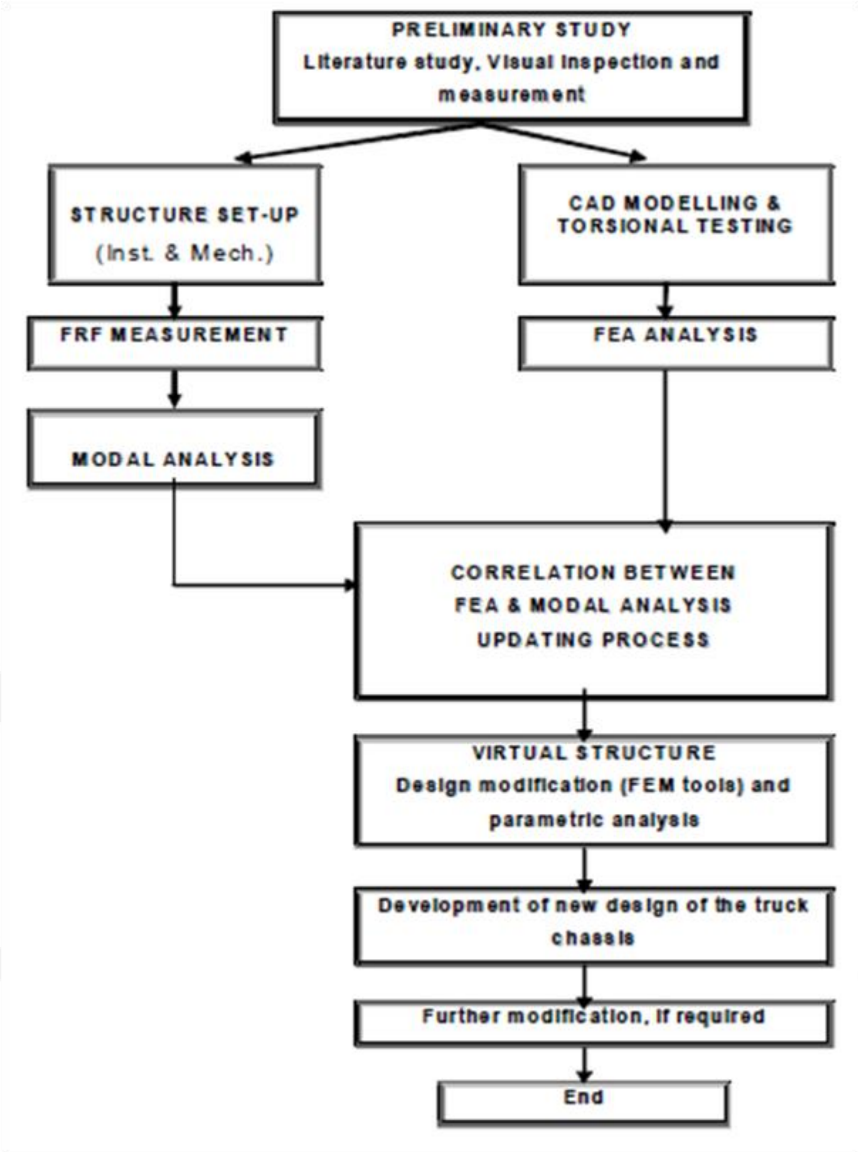

Figure 11. Detail flow chart by Roslan vd. (2009)

SECTION 3

DESIGN WORK OF ROCKET LAUNCHER SUBFRAME AND ANALYSIS OF THE FE MODEL

3.1 Design Work of Rocket Launcher Subframe

With the help of my personal experience, URL-1 (2020) and URL-2 (2020); the design tips about subframe is given in this section.

Subframe provides the connection between the truck and upper structure. Subframe model can be observed in Figure 12.

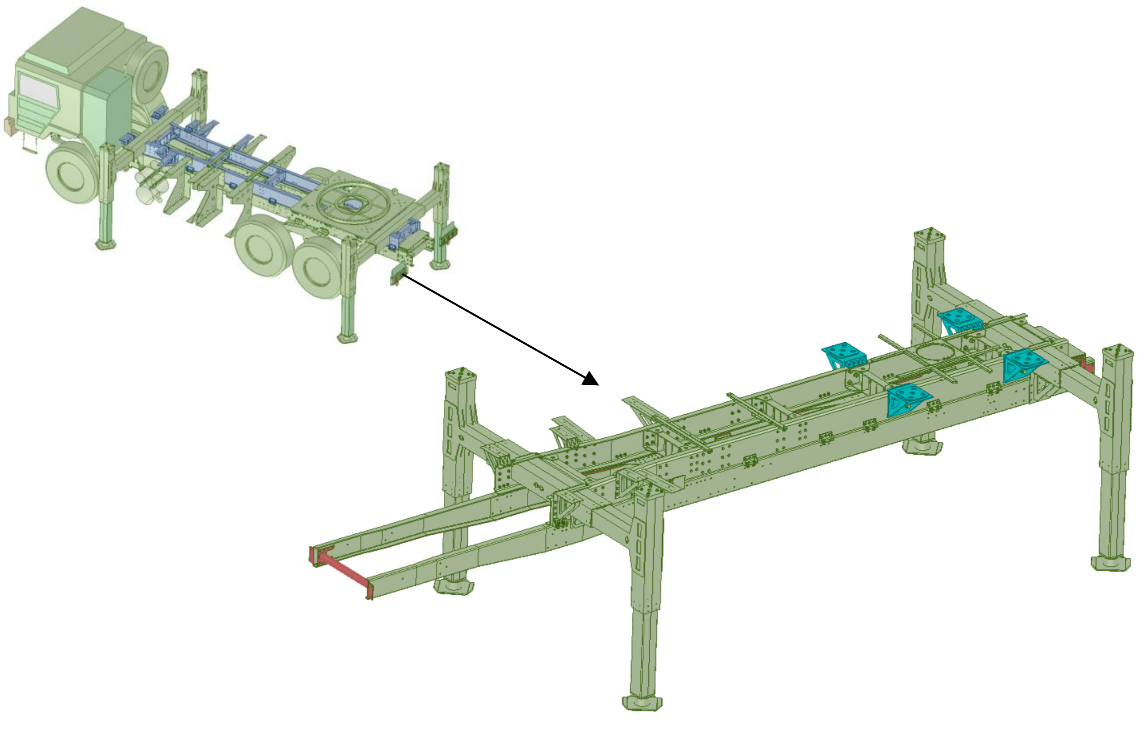

Figure 12. General view of subframe

Subframe composes two C shaped frames and six cross members. (Figure 13)

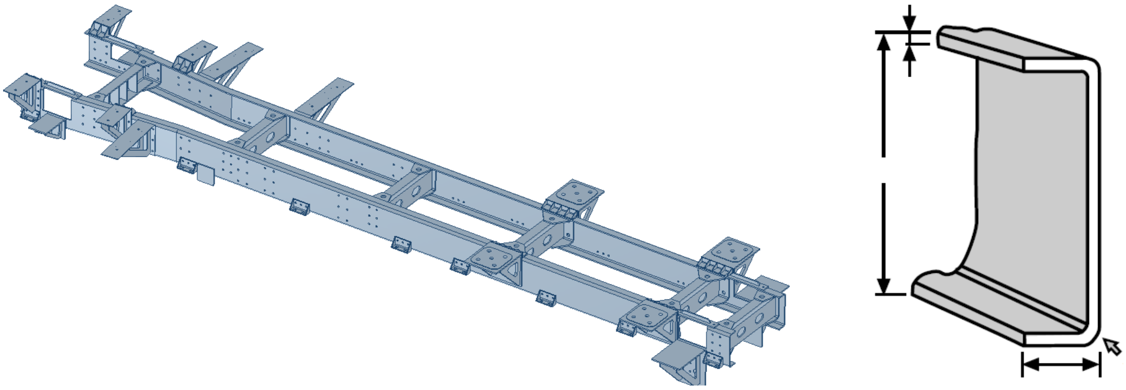

Figure 13. C shaped frames and Cross members

Hydraulic outrigger cases welded to subframe from to appropriate positions at front and rear (Figure 14). To prevent high stress at sharp edges, undercut application is preferred.

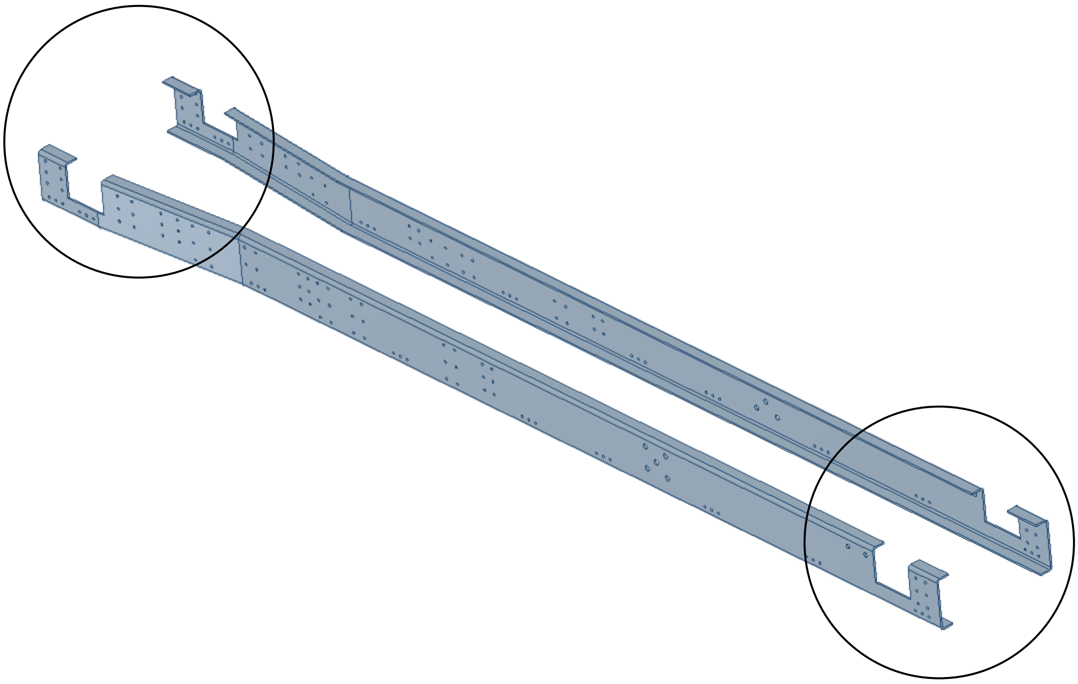

Figure 14. Outtriger Welding Points

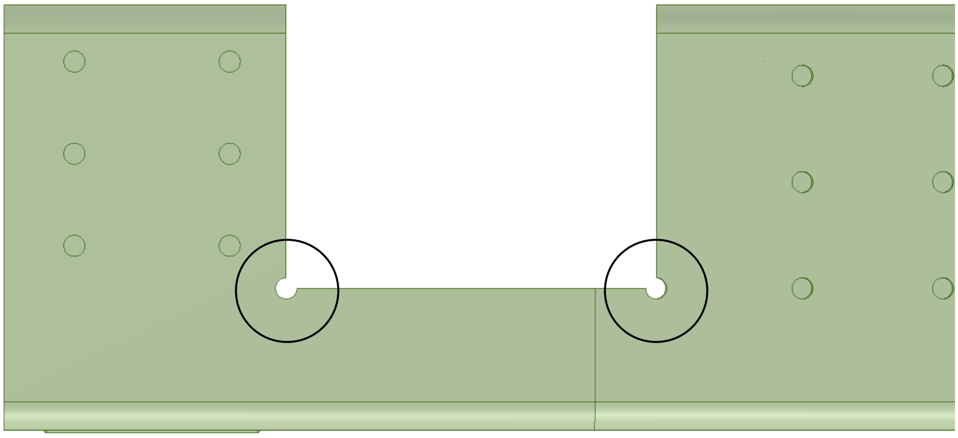

Figure 15. Undercut Application

8 brackets between the truck chassis and the subframe are shown in Figure 16. For off road conditions, the first and second brackets are flexible upwards/downwards with lateral control to avoid torsional stresses.

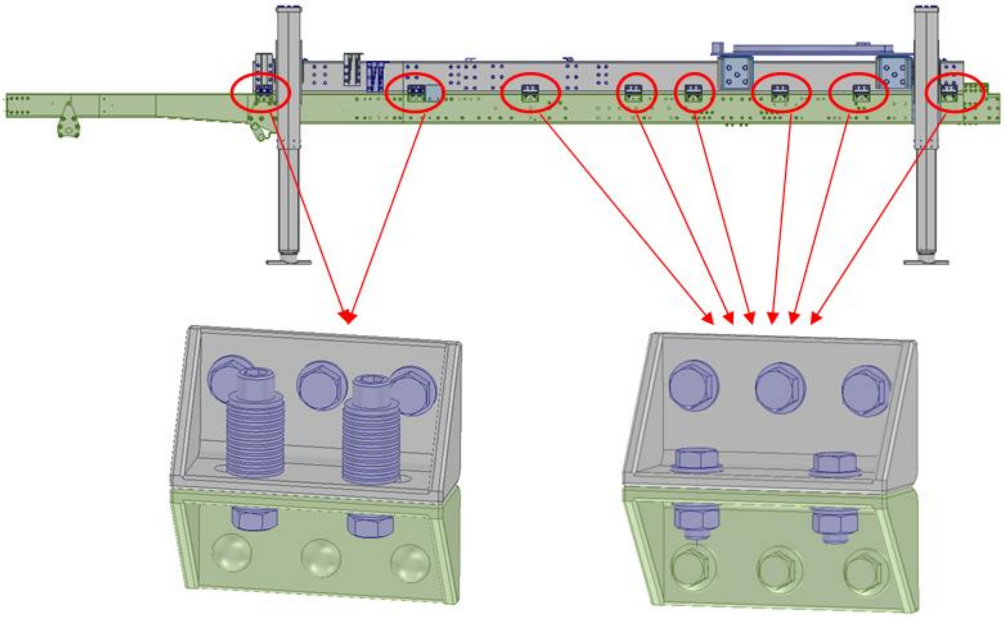

Figure 16. Flexible and Rigid Brackets

Shims are preferred as compensators to absorb tolerances between upper and lower brackets (Figure 17). Also shim application decreases high manufacturing costs.

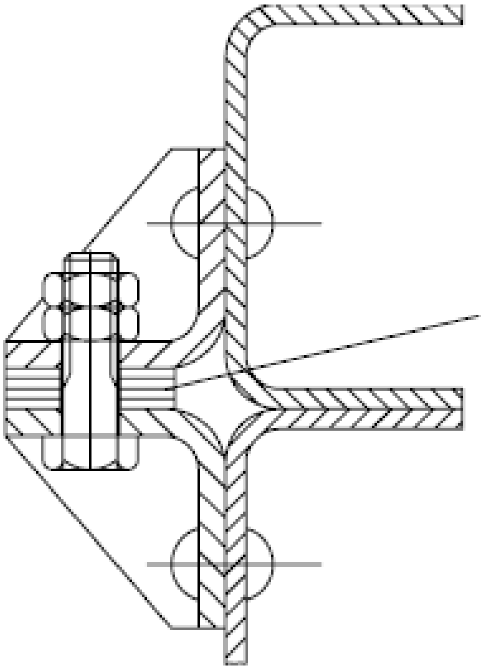

Figure 17. Shim application on brackets

Shear bolt or hexagon flange bolt is preferred on brackets because of shear forces on vertical and longitudinal directions (Figure 18).

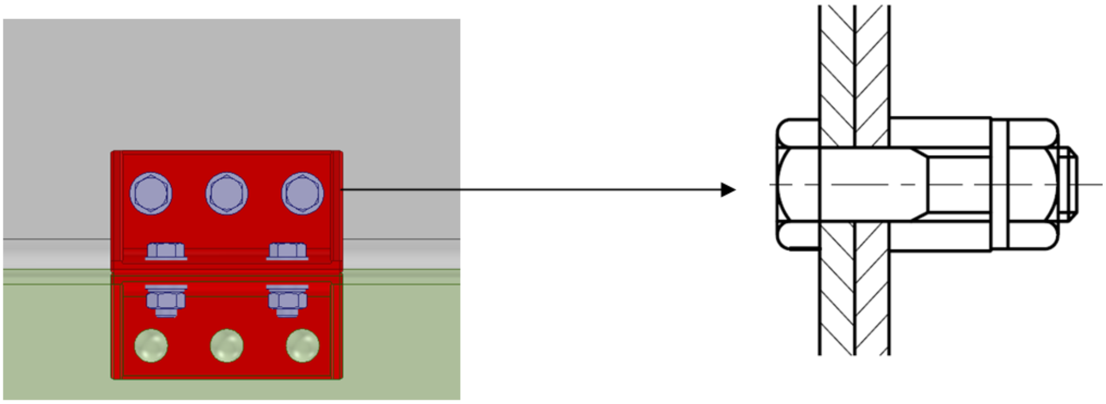

Figure 18. Shear Bolts on Bracket

To make the assembly much easier and to correct the error of truck chassis or subframe, brackets on subframe shall have lateral direction slots and brackets on truck chassis shall have longitudinal slots (Figure 19).

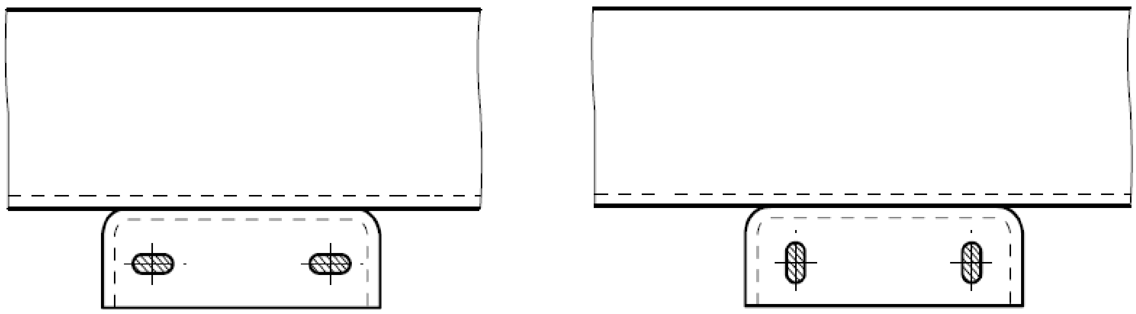

Figure 19. Slots on Truck Chassis and Subframe Brackets

Hydraulic stabilizer and outrigger cylinders are placed in steel cases due to the fact that high longitudinal and lateral forces can create leakage and permanent defect on cylinder. Steel cases contact with each other with bearings and the lateral longitudinal forces transfer along that bearings through steel cases and subframe (Figure 20).

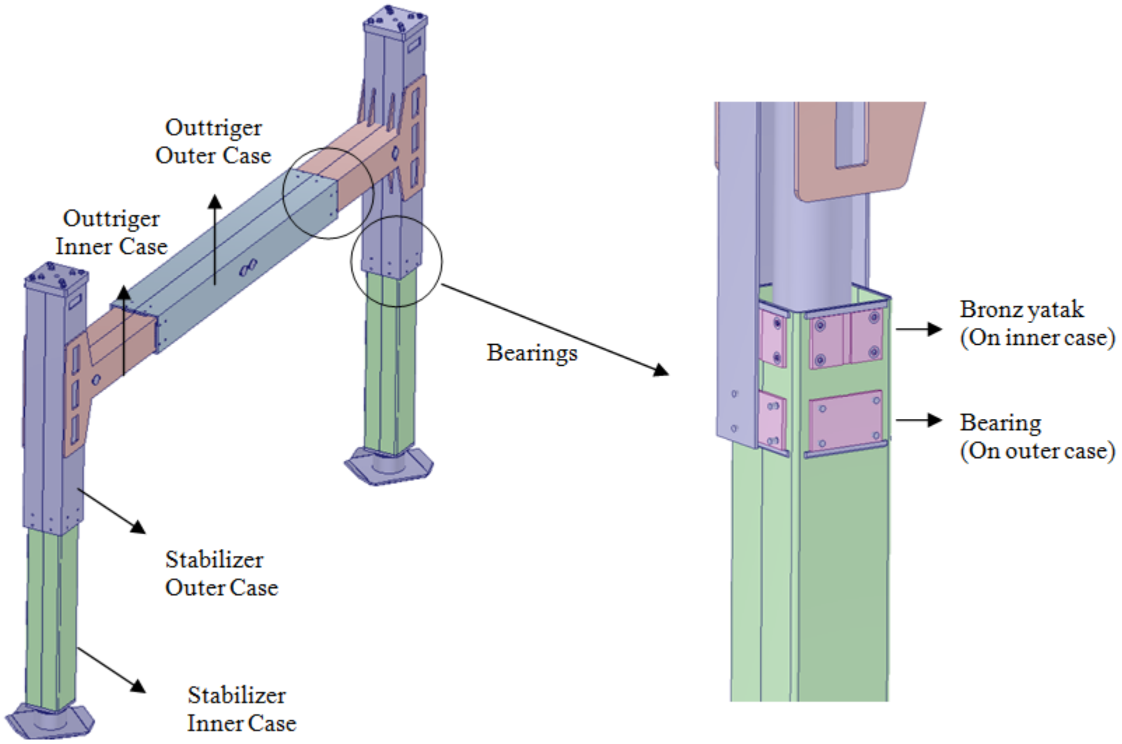

Figure 20. Outtriger/Stabilizer Cases and Bearings

To reinforce the stabilizer and outrigger cases additional steel brackets can be added the structure or the thickness of cases can be increased (Figure 21, Figure 22).

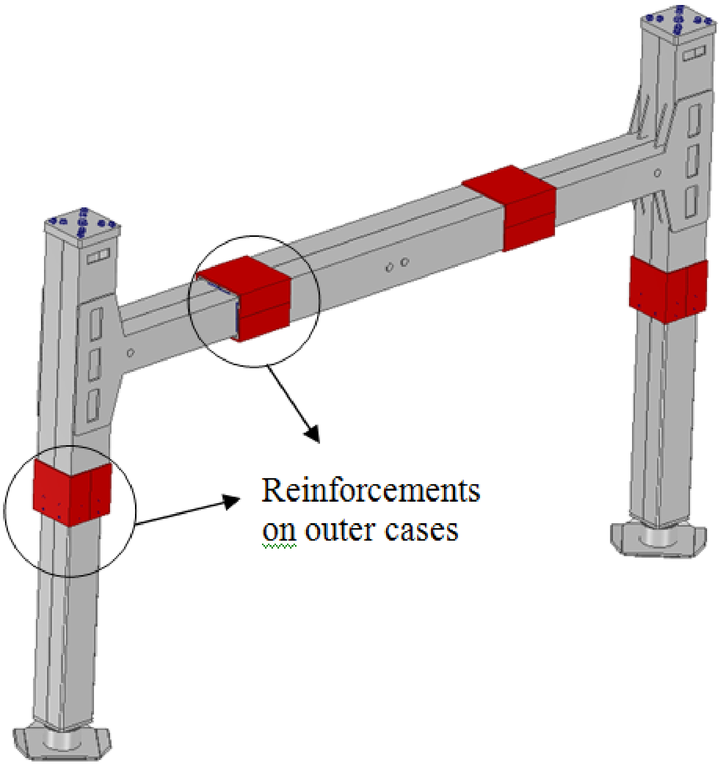

Figure 21. Reinforcements I

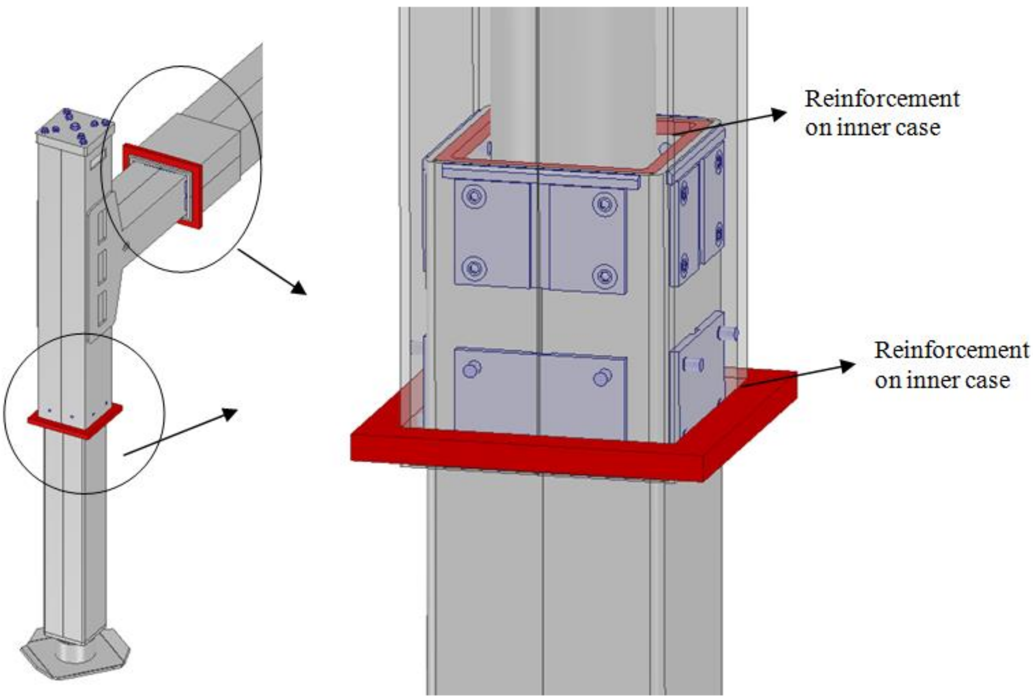

Figure 22. Reinforcements II

3.2 FEM Analysis of the Rocket Launcher

The FE model of the rocket launcher includes truck chassis, subframe, cradle and ammunition canisters. Subframe composes C shaped frames, cross members, brackets, stabilizers, outriggers. The truck and other parts of the system are constructed as lumped mass with inertia. The FE Model does not include any rocket/missile. However, the effects of the ammunition defined as a plume force.

Structural Analysis Department created the detailed FE model.

As a general rule, when the ratios l/t (length/thickness) of the elements is over 20, 2D shell elements could be used. Also, at some portion, some revisions and simplifications are made, such as filling small holes and wiping grooves. The detailed FEM of rocket launcher is shown in Figure 23.

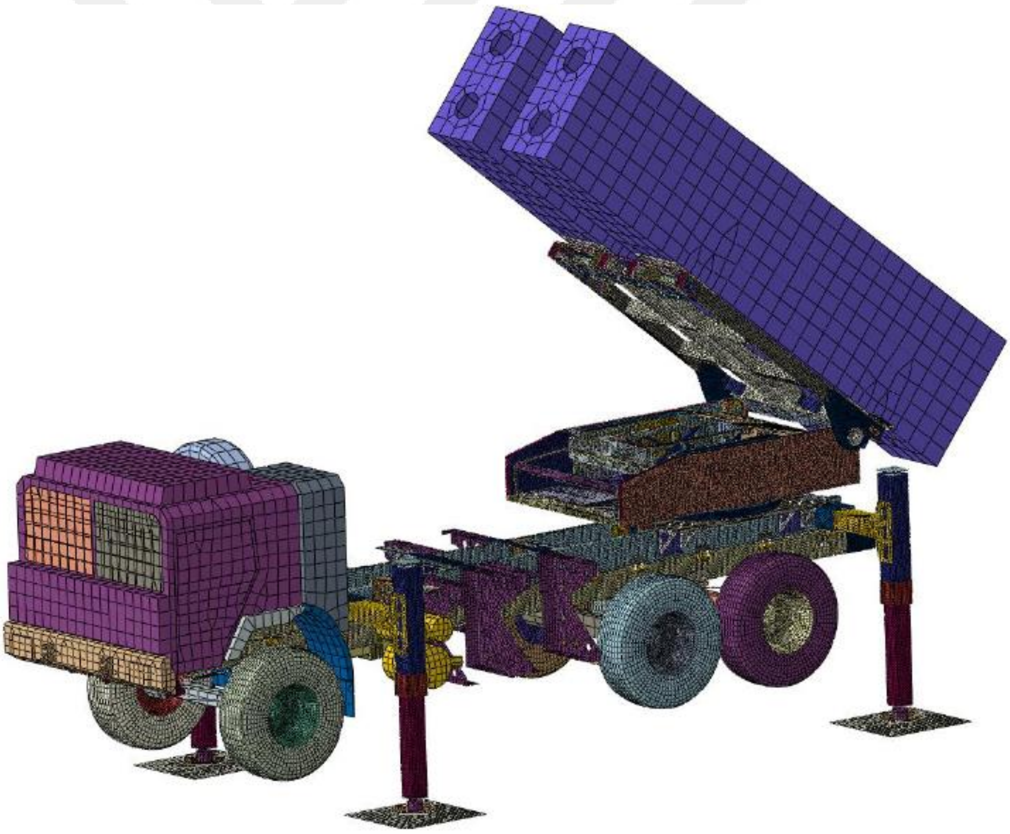

Figure 23. The Detailed FEM of Rocket Launcher

Stabilizers and outriggers are constructed as deployed since the rocket is fired at stabilized position. The hydraulic based system in the system is formed as truss elements by presenting rigidity.

The brackets between the truck chassis and the subframe are designed. Beam elements could be assessed instead of bolts between the upper and lower sections of the brackets. The contact is illustrated between the subframe and the bottom of the bracket. The connection enables flexibility to the vehicle on and off-road conditions. The system involves 8 supports in the rocket launcher system. The number of brackets is attributed to on and off-road conditions. If the number of brackets is raised, the rigidity of the link between the truck chassis and the subframe increases. As a conclusion, damage will occur during off-road conditions. If the number of brackets decreases, the stiffness of the connection between the chassis and subframe decreases. As a result, the rigidity of the rocket launcher system will decrease and the thus the subframe will be lost.

In addition to that, contact is occurred between the chassis and the subframe to sustain the stiffness of both truck chassis and the subframe into account. The friction coefficient was evaluated as 0.1 under static and dynamic operations. Lumped masses based inertial impact are related with the mass and inertia of non-structural parts.

3.3 Material Properties and Boundary Conditions for FEM Analysis

For the rocket launcher subframe, generally St-37 or St-52 steel material are used. St-37 and St-52 steel material properties is given in Table 1.

Table 1. St-37 and St-52 Material Properties

	Yield Strength	Elastic Modulus	Poisson's Ratio	Density	μ
St-37	235 MPa	210 GPa	0.3	7800 kg/m^3	0.1
St-52	355 MPa				

For boundary conditions, the contact point between stabilizers and ground is defined as fixed point that have zero displacement in three axes. However, Spherical joint at the bottom of stabilizers are taken into consideration in the FEM .

3.4 Structural Analysis of the FE Model During Firing

The plume force of rocket/missile is applied to FE Model along firing direction (Figure 24) and the results are noted. (Figure 25, Figure 26, Figure 27, Figure 28, Figure 29)

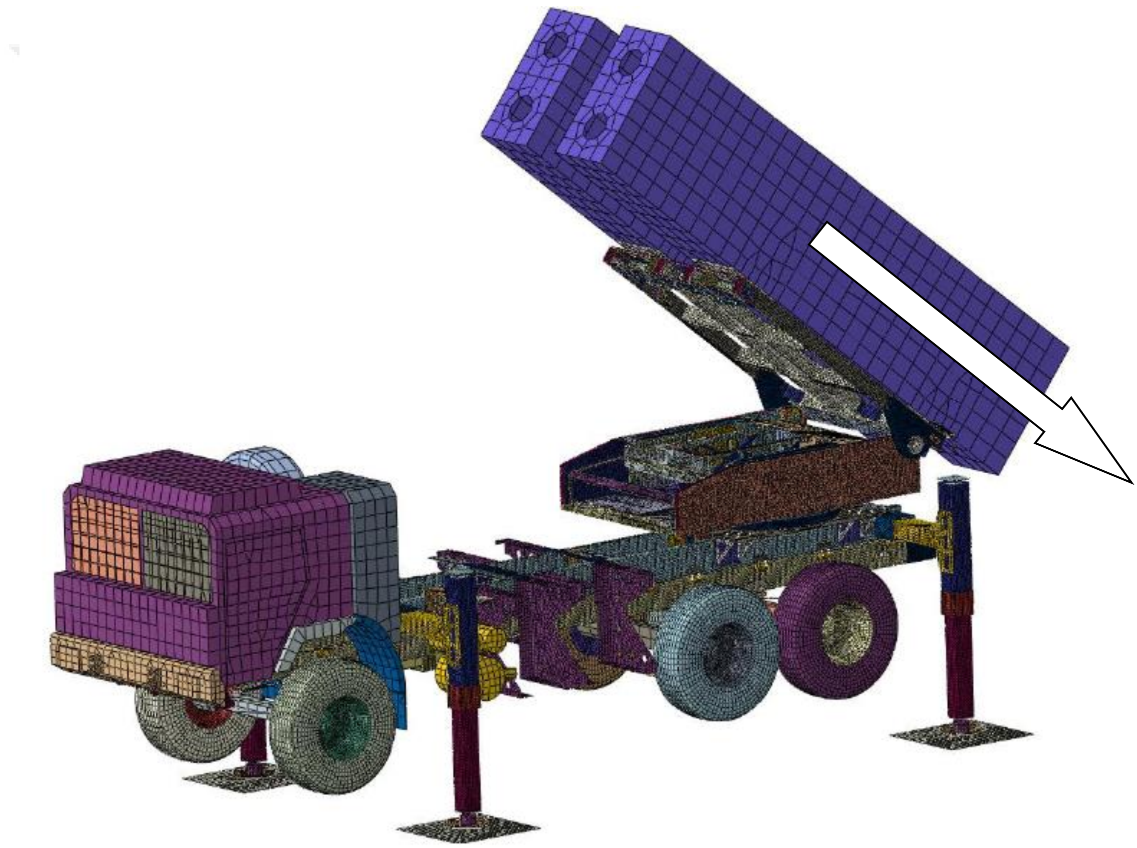

Figure 24. Plume Force Direction

Von Mises Stresses and Strain Equivalent to Mises Stresses (PEEQ) on Subframe FE Model is obtained by using Abacus Programmer. According to results, some portion of subframe are defined as St-37 and St-57 material.

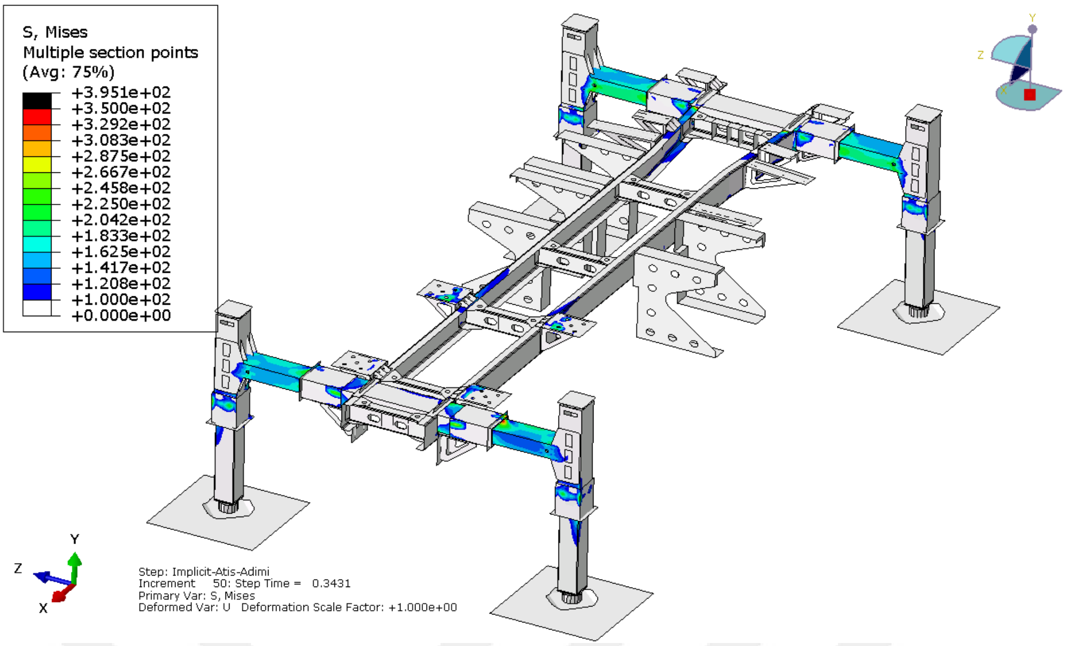

Figure 25. Von Mises Stresses on Subframe FE Model During Firing

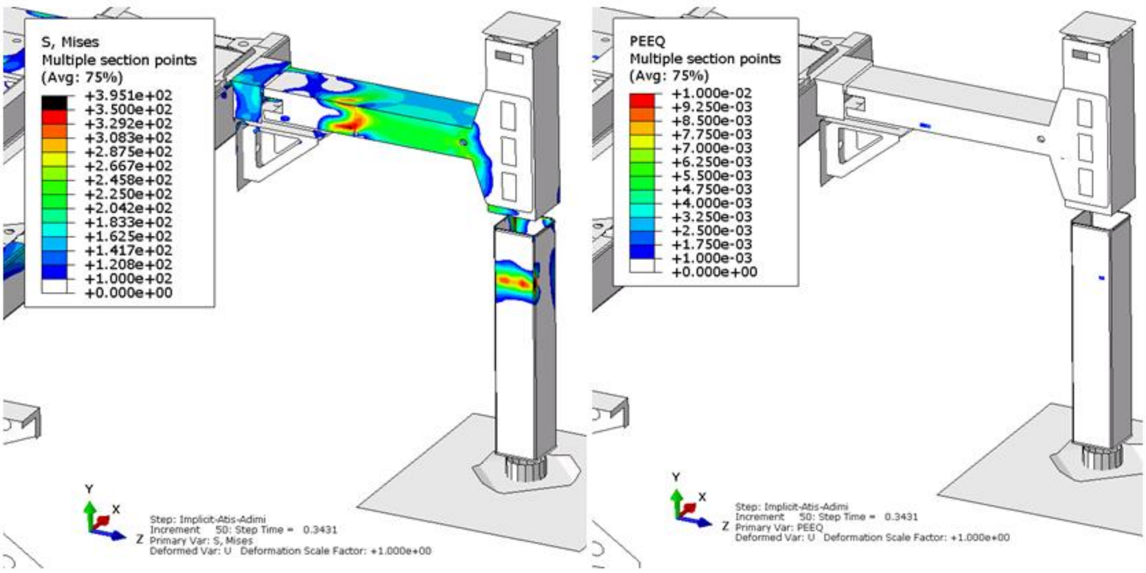

Figure 26. Von Mises Stresses and PEEQ on Outtriger and Stabilizer FE Model During Firing

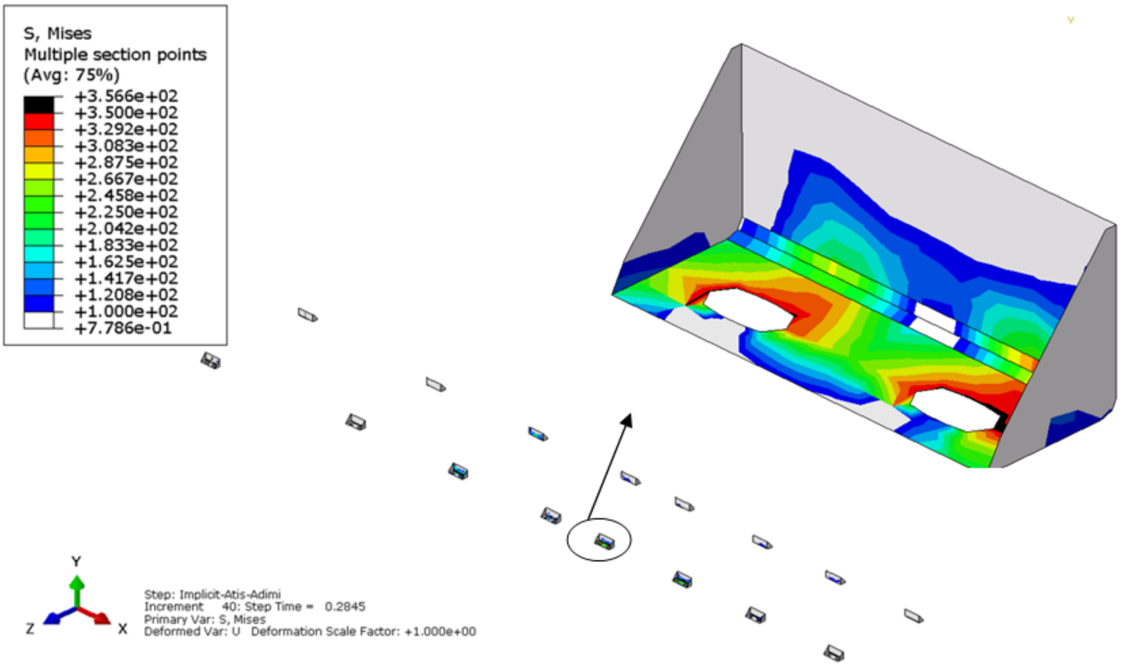

Figure 27. Von Mises Stresses and PEEQ on Brackets FE Model During Firing

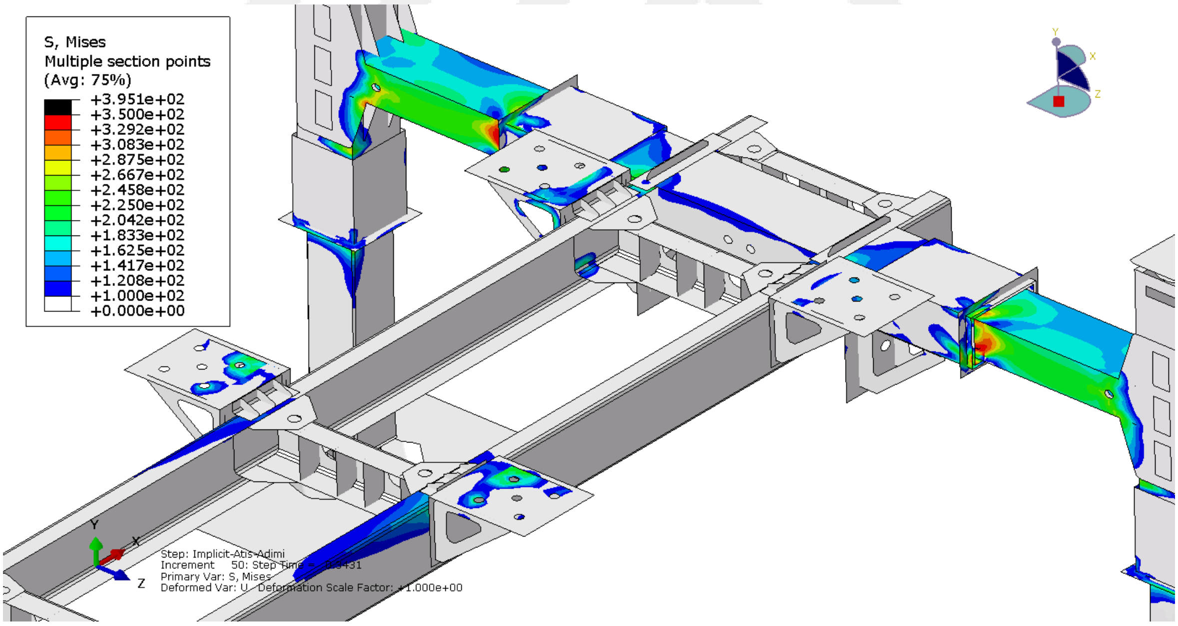

Figure 28. Von Mises Stresses on Cradle Brackets FE Model During Firing

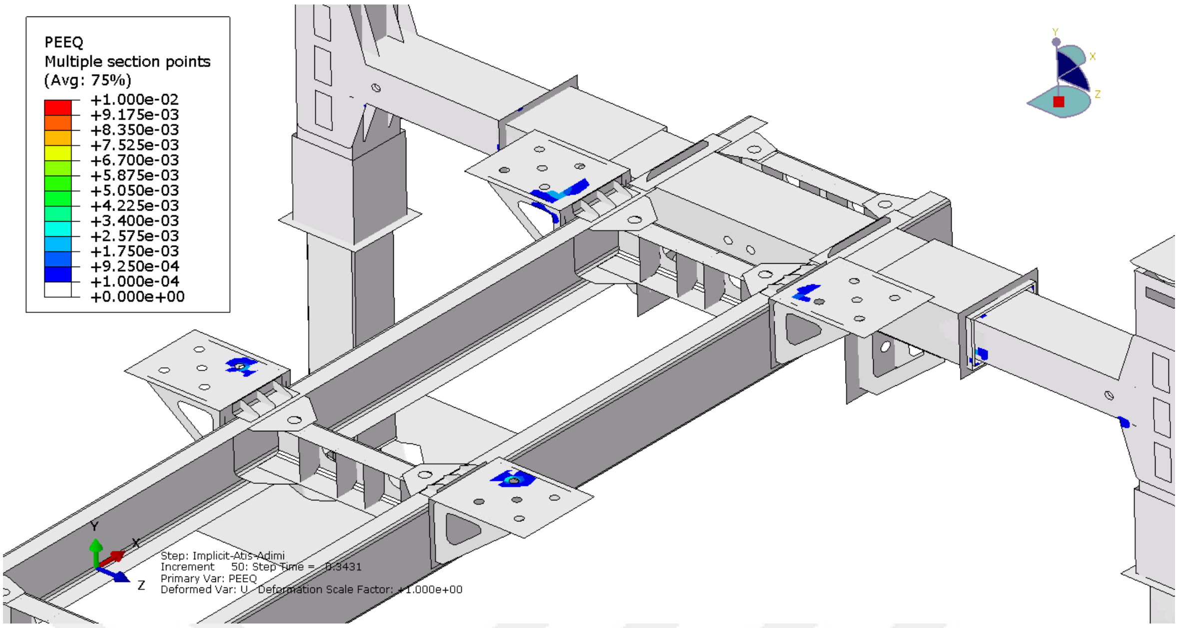

Figure 29. PEEQ on Cradle Brackets FE Model During Firing

Dynamic behavior of subframe is key point of rocket accuracy. Hence, the displacement of subframe in X and Y axis is examined.

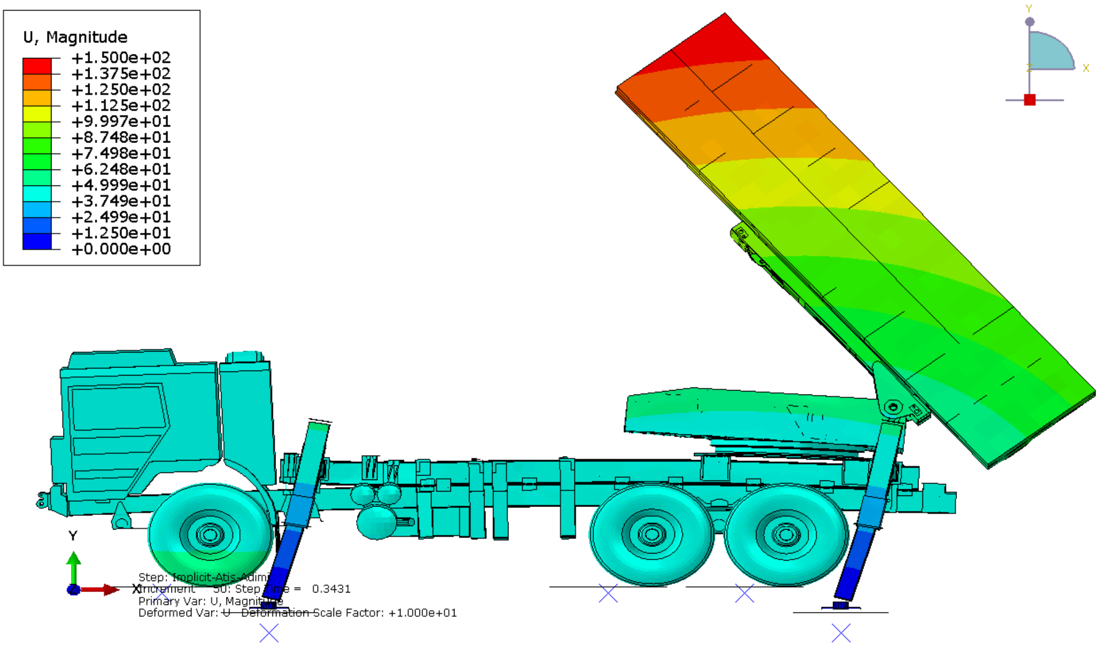

Figure 30. Displacement of Subframe FE Model During Firing

The Y-axis displacement of the subframe is given in Figure 31.

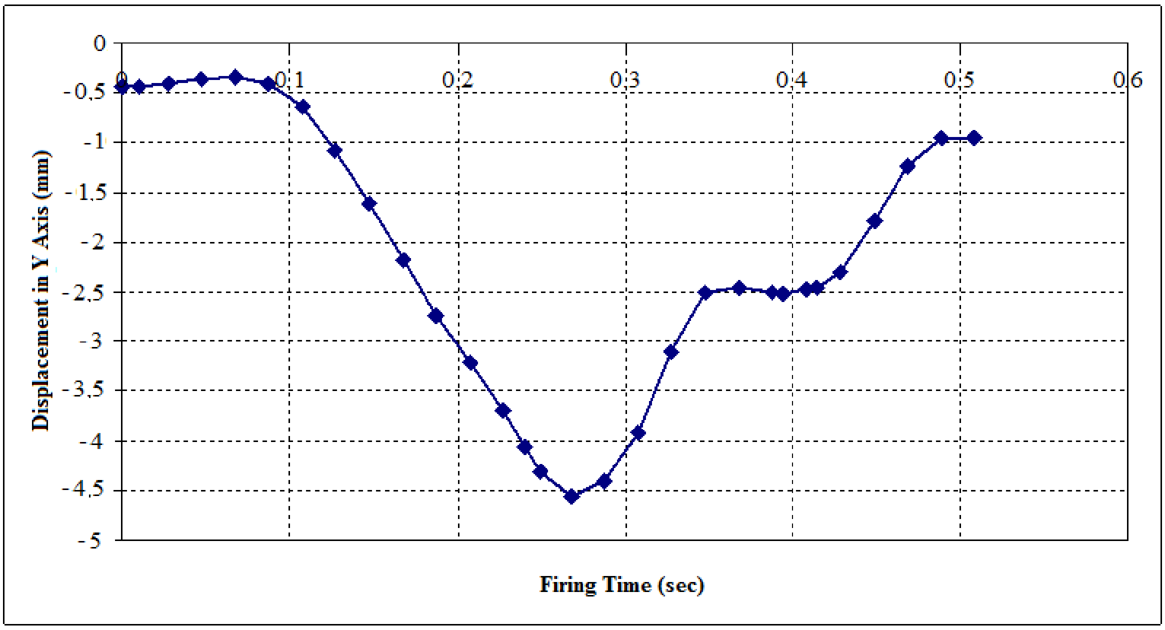

Figure 31. Y-axis displacement of subframe during firing

The displacement in the X axis of the the subframe is given in Figure 32.

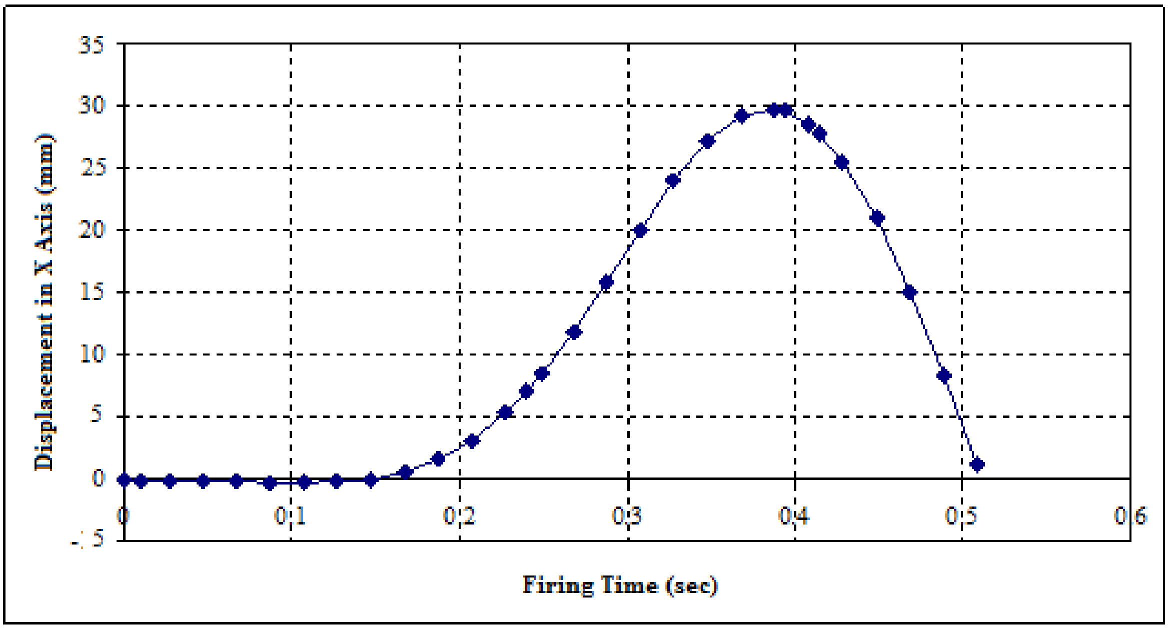

Figure 32. X-axis displacement of subframe during firing

3.5Structural Analysis of the FE Model On Off-Road Condition

On off-road condion, 3 different scenarios create different effects on Rocket Launcher Subframe:

- Bumping Up on Off-Road
- Bumping Down on Off-Road
- Torsion on Off-Road

3.5.1 Structural Analysis of the FE Model On Bumping Up Off-Road Condition

The bumping up force (between 3g-5g) is applied to FE Model in Y axis shown in Figure 33 and the results are noted. (Figure 34, Figure 35, Figure 36, Figure 37)

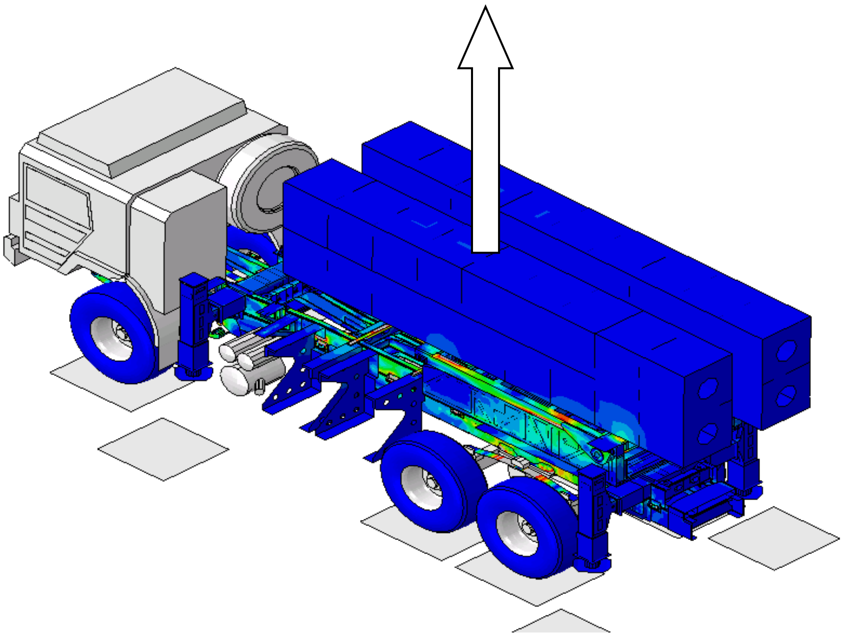

Figure 33. Bumping Up Force Direction

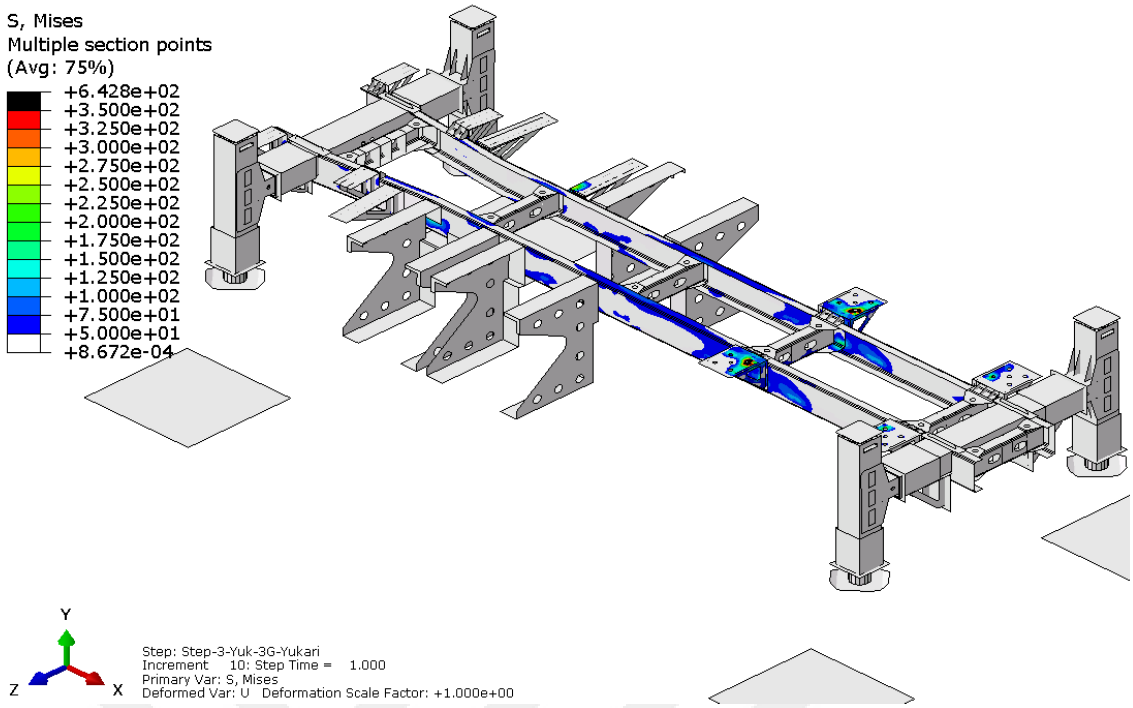

Figure 34. Von Mises Stresses on Subframe FE Model During Bumping Up

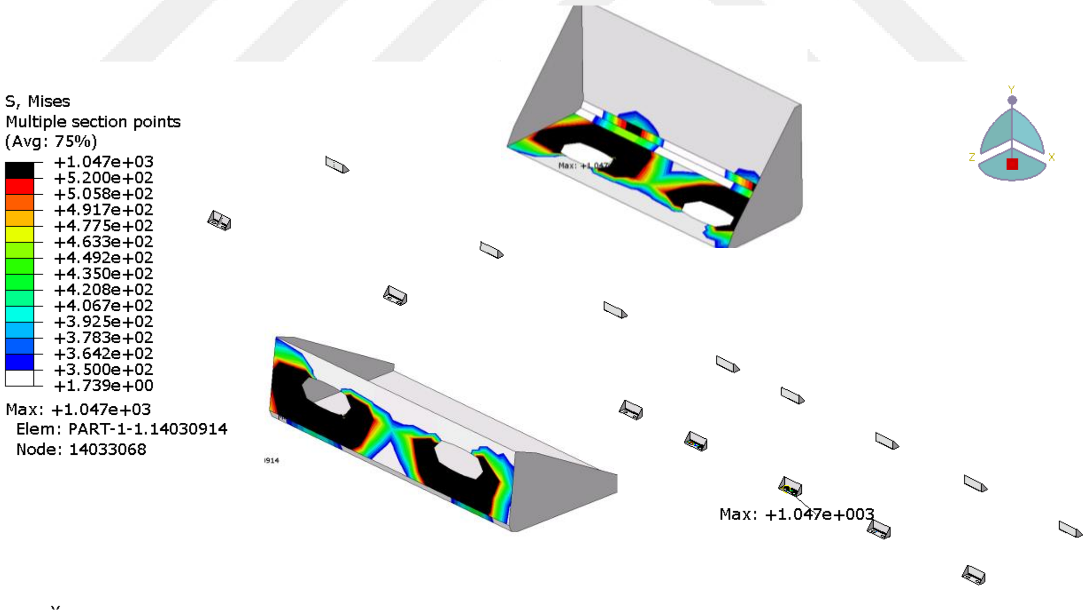

Figure 35. Von Mises Stresses on Subframe Brackets FE Model During Bumping Up

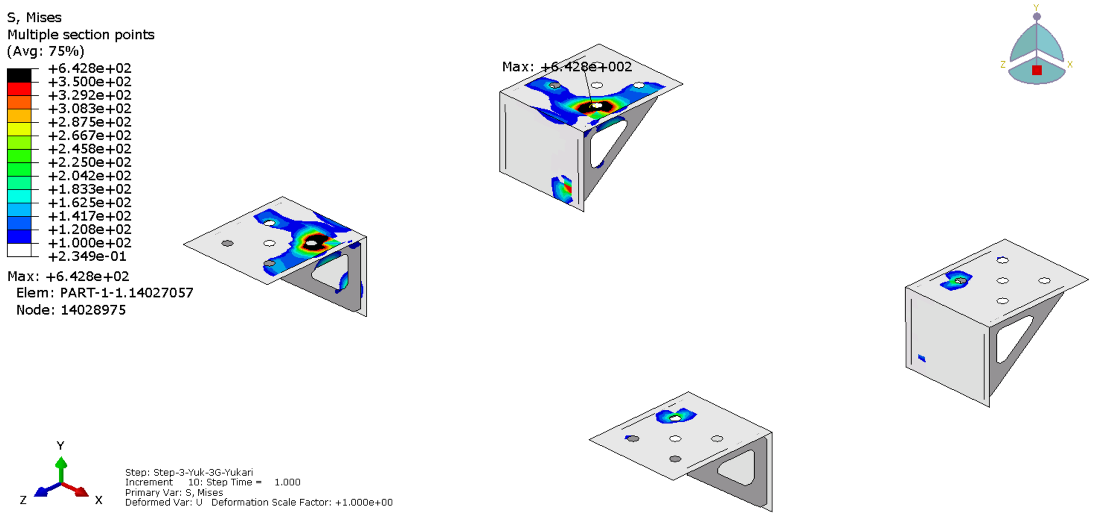

Figure 36. Von Mises Stresses on Cradle Brackets FE Model During Bumping Up

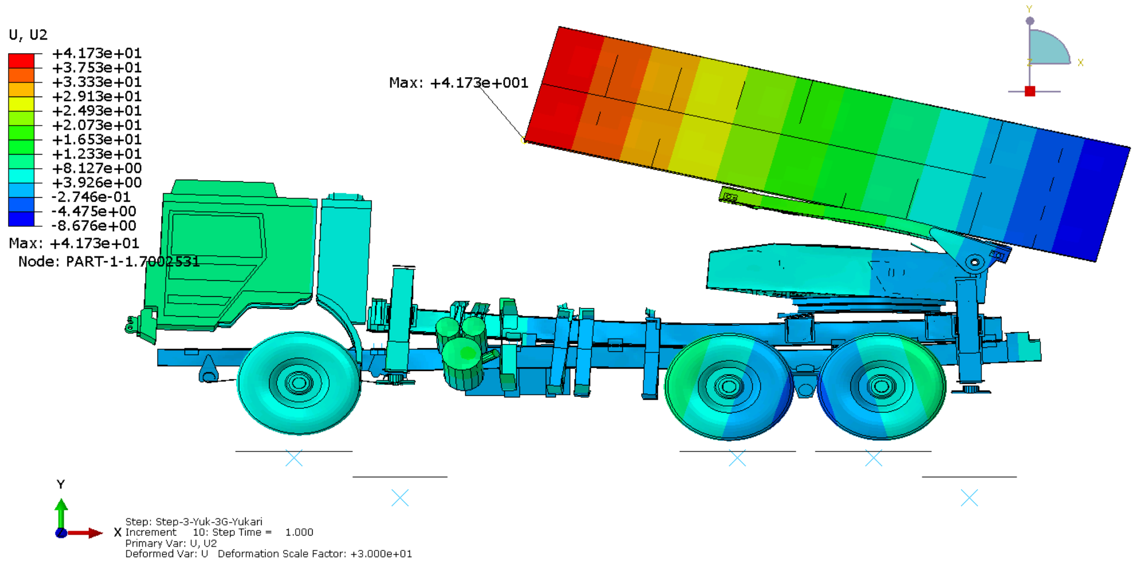

Figure 37. Displacement of Subframe FE Model During Bumping Up

3.5.2 Structural Analysis of the FE Model On Bumping Down Off-Road Condition

The bumping up force (between -4g and -6g) is applied to FE Model in Y axis shown in Figure 38 and the results are noted. (Figure 39, Figure 40, Figure 41)

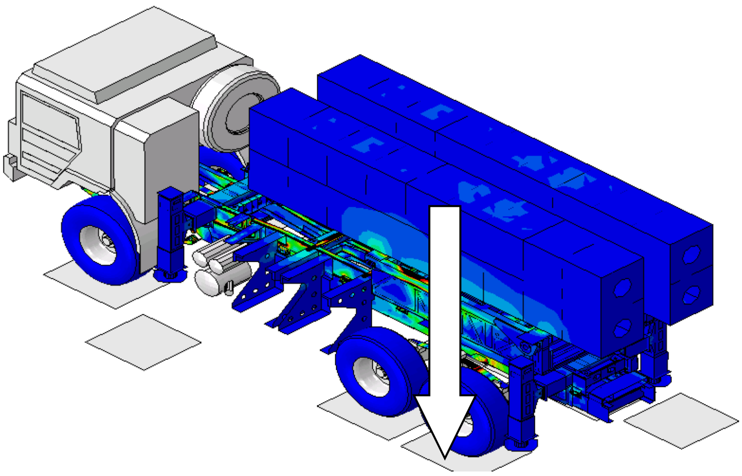

Figure 38. Bumping Down Force Direction

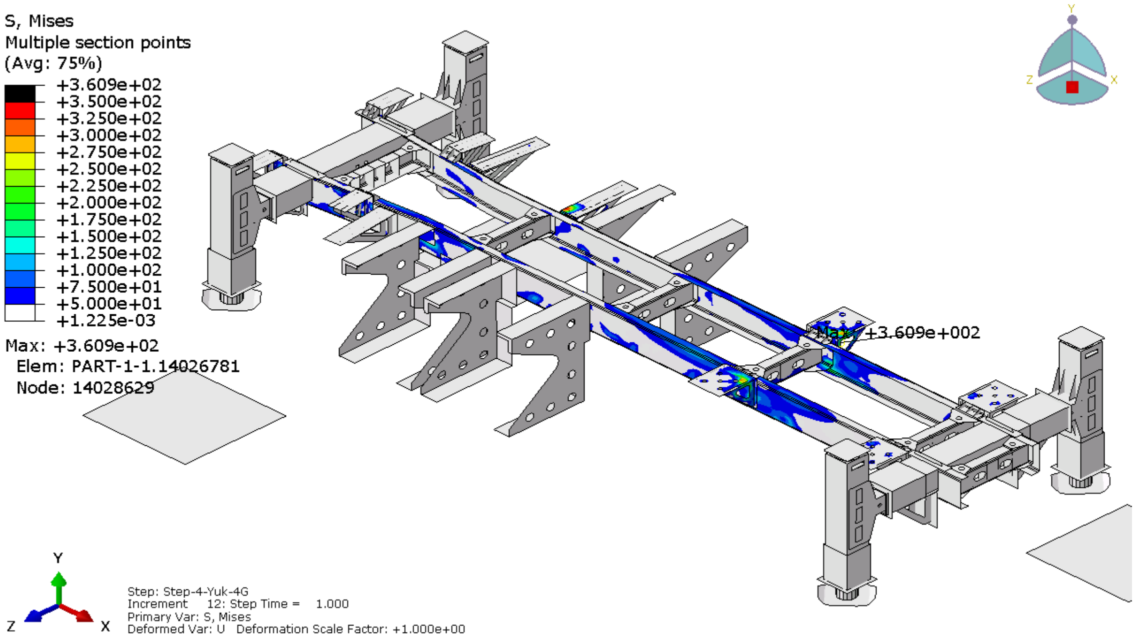

Figure 39. Von Mises Stresses on Subframe FE Model During Bumping Down

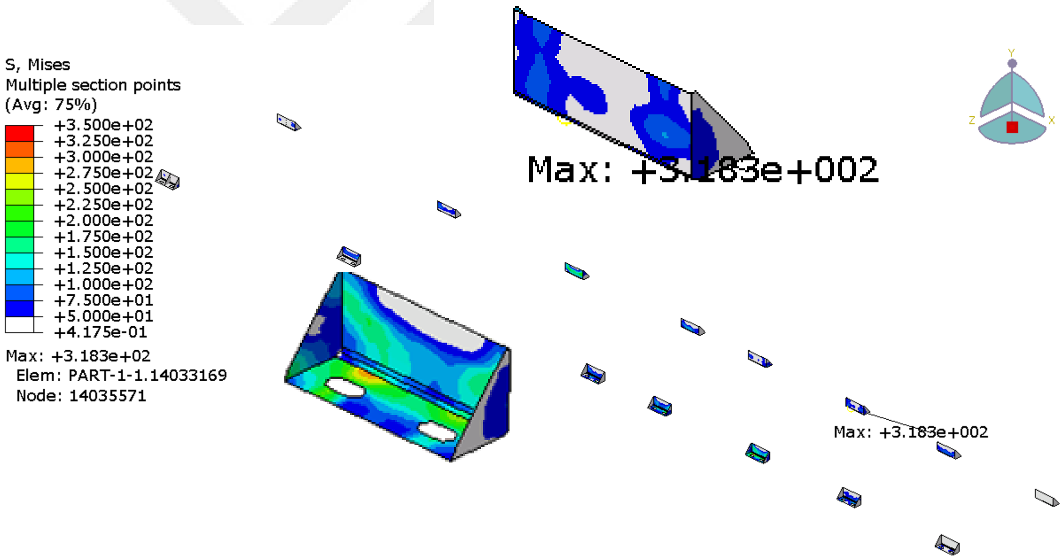

Figure 40. Von Mises Stresses on Subframe Brackets FE Model During Bumping Down

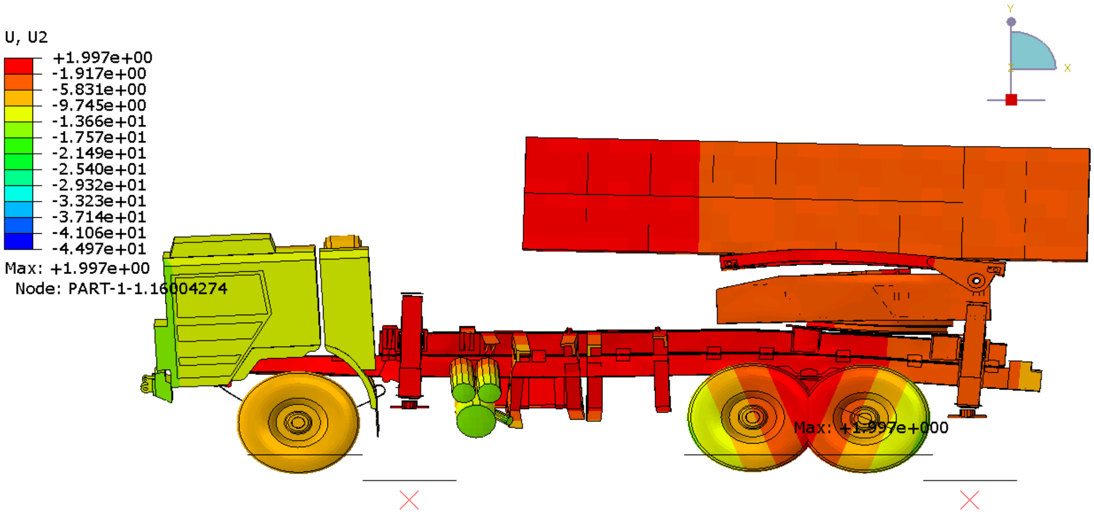

Figure 41. Displacement of Subframe FE Model During Bumping Down

3.5.3 Structural Analysis of the FE Model Torsion Off-Road Condition

The torsional angle (between -4° and -6°) is applied to FE Model in Y axis shown in Figure 42 and the results are noted. (Figure 39, Figure 40, Figure 41)

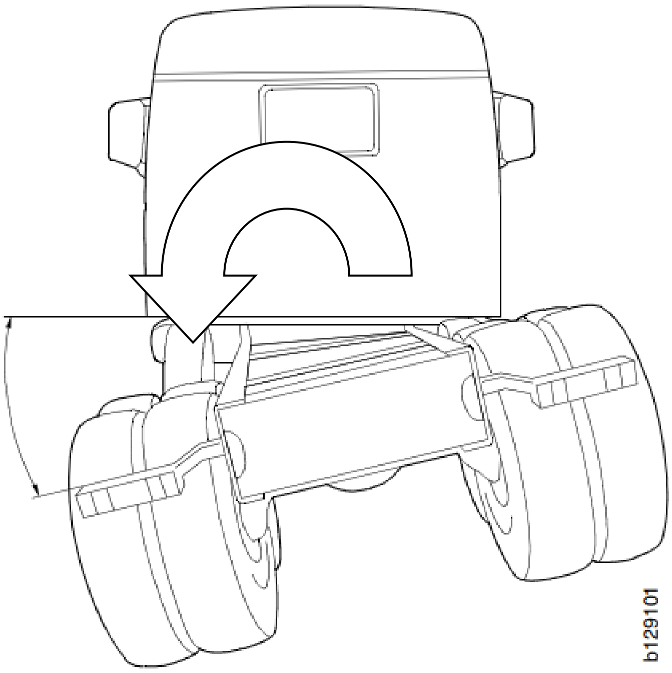

Figure 42. Angular Torsion Direction

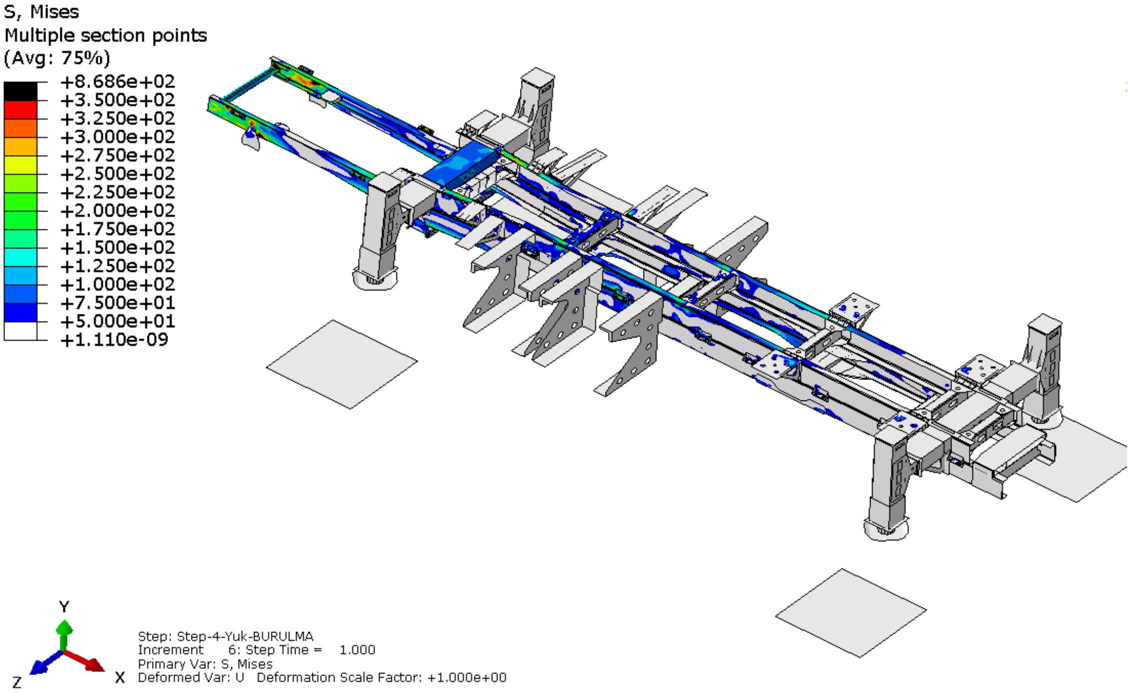

Figure 43. Von Mises Stresses on Subframe FE Model During Torsion

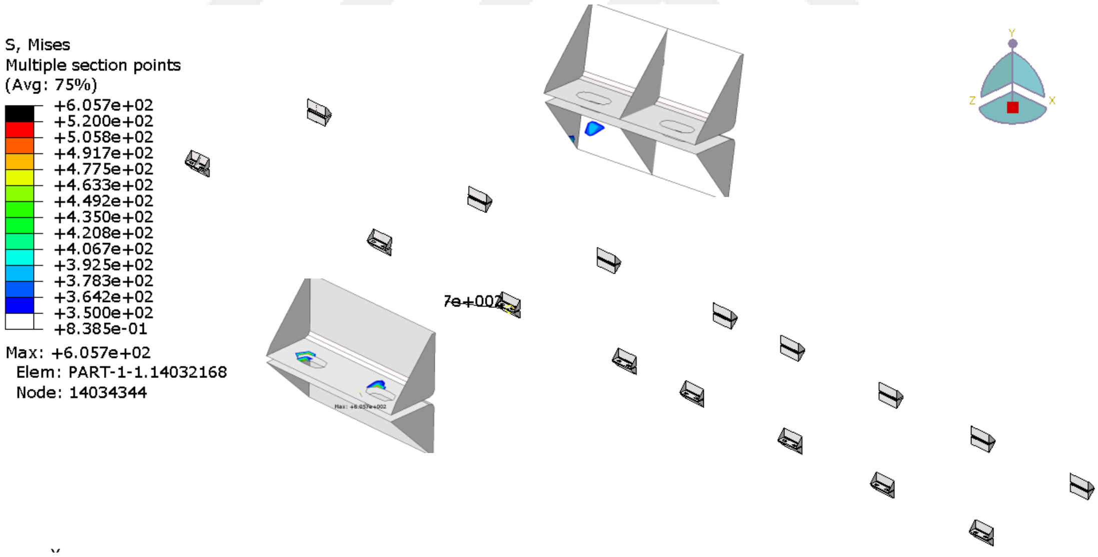

Figure 44. Von Mises Stresses on Subframe Brackets FE Model During Torsion

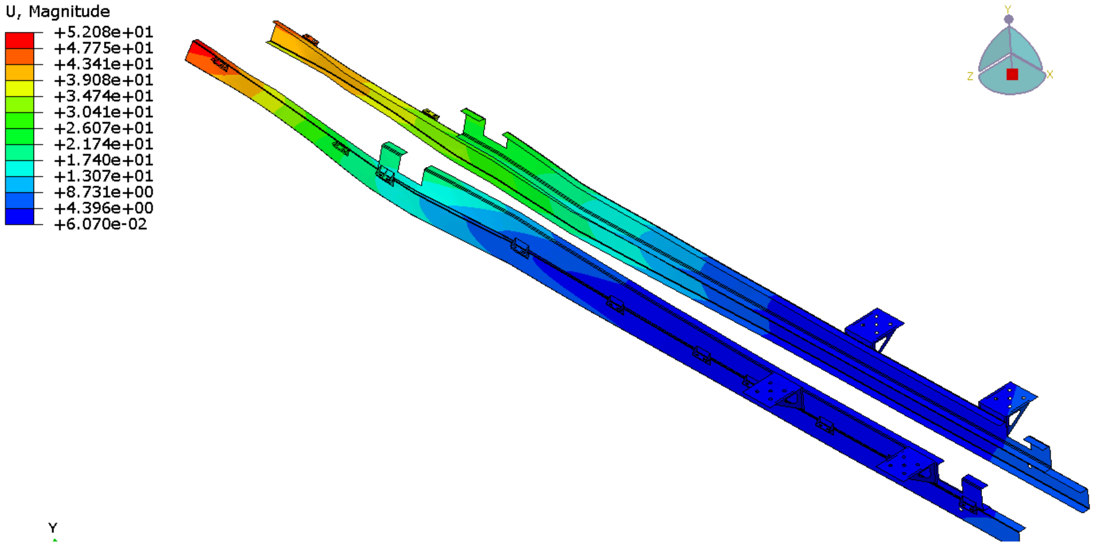

Figure 45. Displacement of Truck Chassis and Subframe FE Model During Torsion

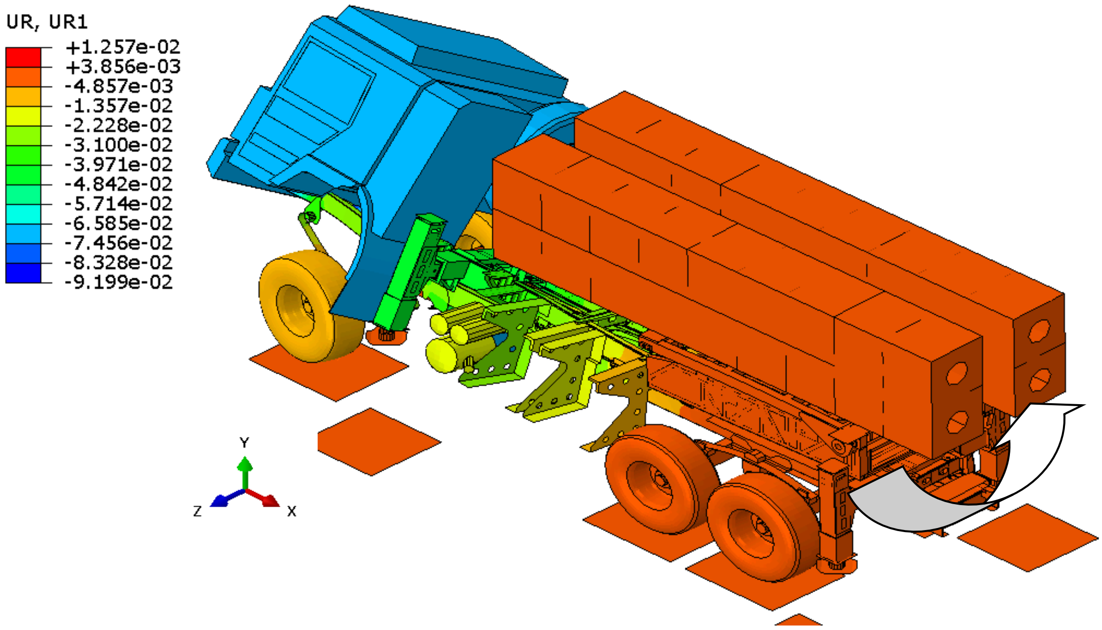

Figure 46. Angular Deformation of Rocket Launcher FE Model During Torsion

SECTION 4

RESULTS AND VERIFICATION OF FEM ANALYSIS

FE Model of Rocket Launcher subframe is created and analyzed for firing condition to get perfect rocket/missile accuracy. Also, this FE Model is analyzed for off-road condition because the system will move with different speed and acceleration on different terrain. FE Model will help the designers to design the subframe and select the material of subframe portions.

FE Model shall be verified by real tests; off-road and firing tests. Off-road tests are performed on different terrain but to simulate the same road profile and to provide the same loads with FE Model analyses is very difficult. However, Off-road real test results shall be lower than FE Model results. If not, FE Model could not be verified and shall be revised.

For firing tests, the designers have a chance to perform limited number of firing test because preparation takes lots of time and military permissions are needed. Hence, before firing test, the boundary conditions and inputs of real tests shall be same with boundary conditions and inputs of FE Model. For instance; firing direction, the position of stabilizer and outriggers, the static loads on Rocket Launcher and the thrust force of rocket/missile etc. are the other critical inputs of FE Model. The thrust force of a rocket/missile can be measured by static firing tests. The measurements are entered as an input FE Model Analysis of Rocket Launcher. The results are also checked by taking load measurement from the stabilizer in real test (Figure 47).

Figure 47. Load Measurement from the Stabilizers

Displacement measurement data is taken from subframe-truck chassis due to Linear Position Transducer (LPT) as shown in Figure 48.

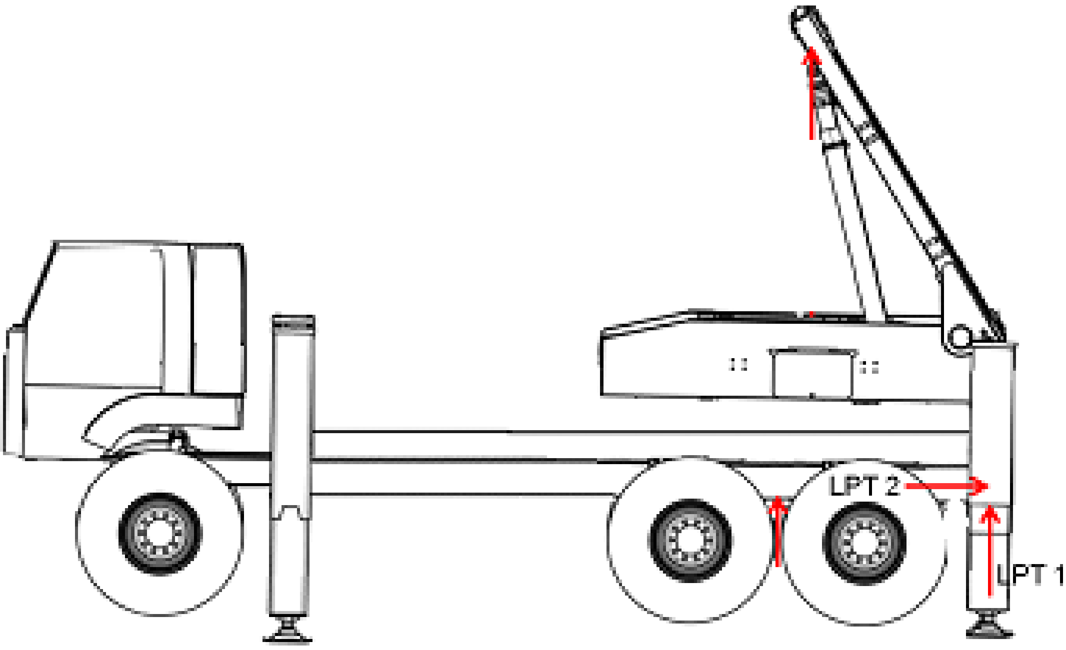

Figure 48. Displacement Measurements in X and Y Axis

LPT 1 and LPT 2 positions are shown in Figure 49.

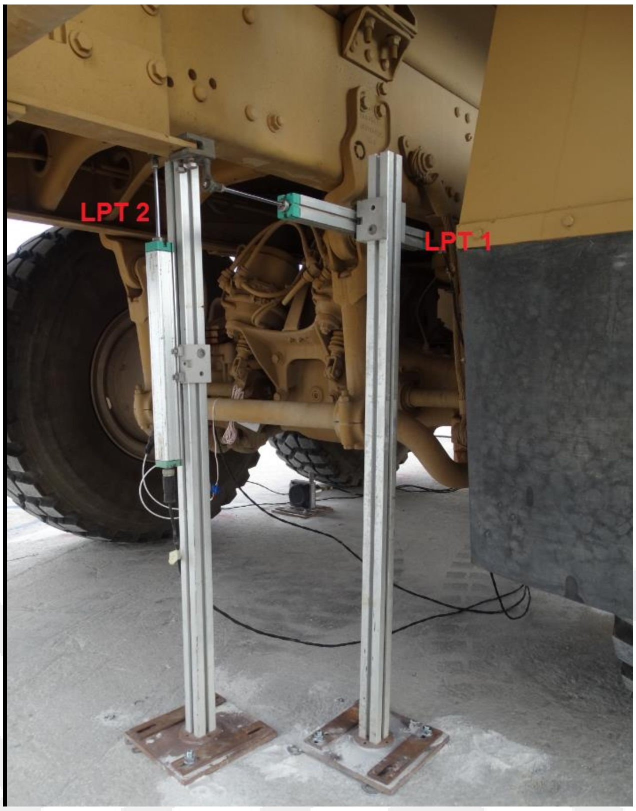

Figure 49. LPT 1 and LPT 2

3 times firing test were performed and the data were obtained via LPT 1 and LPT 2. The data are given in Figure 50 and Figure 51.

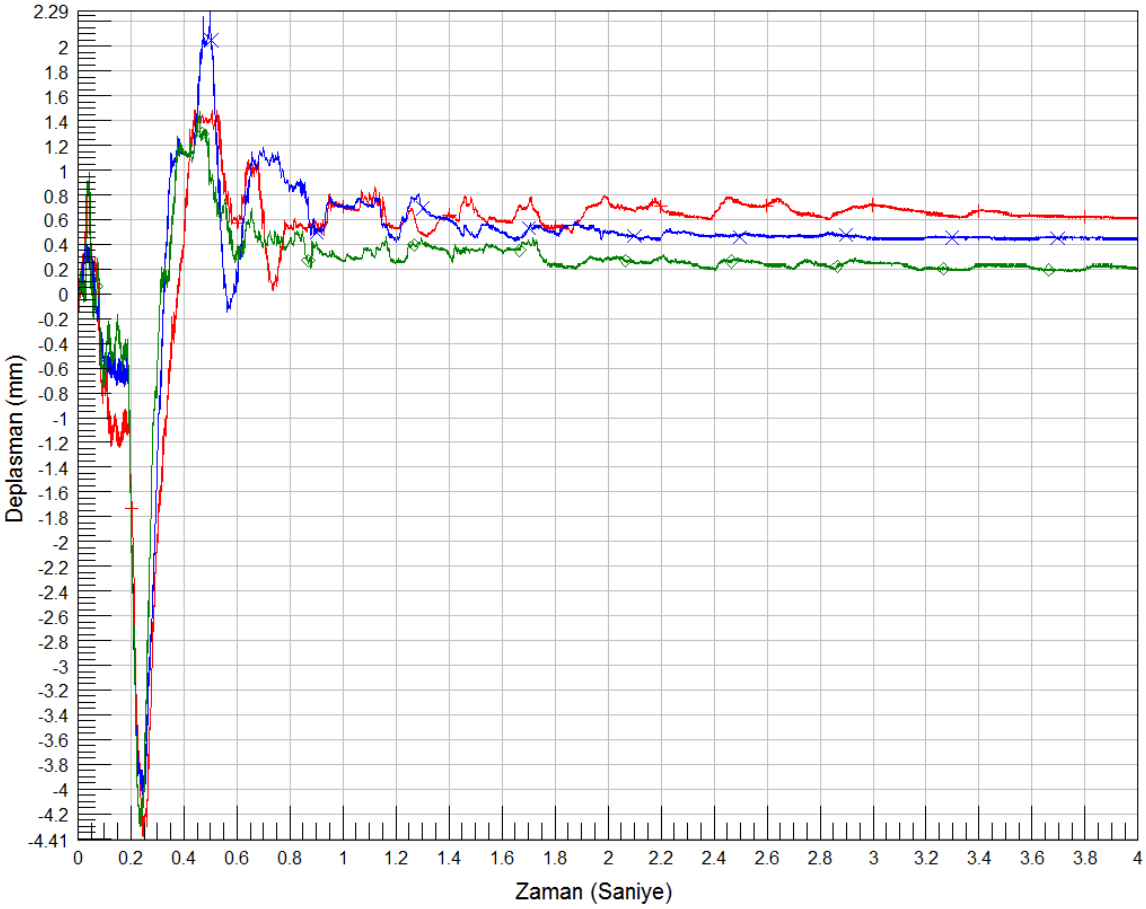

Figure 50. LPT 1, Displacement of Subframe in Y Axis During Firing

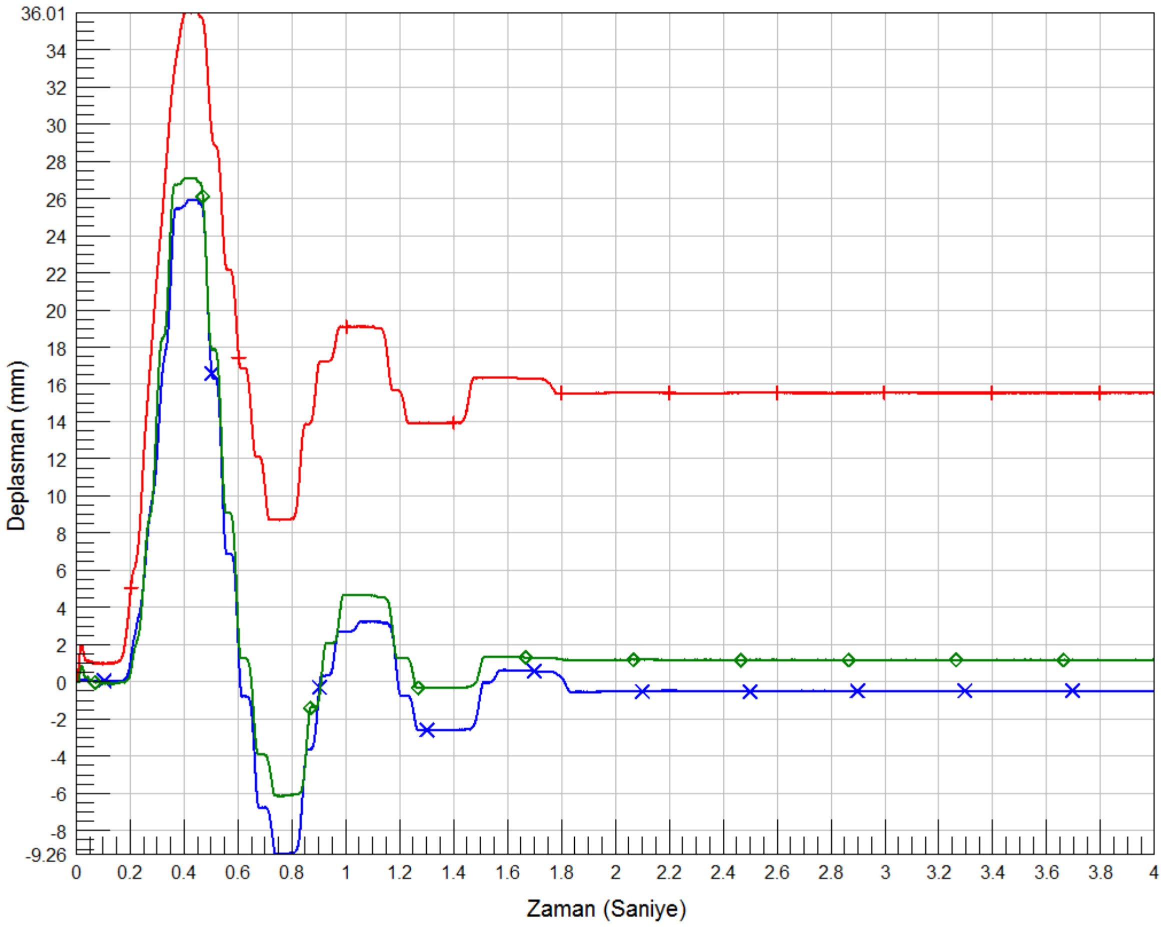

Figure 51. LPT 2, Displacement of Subframe in X Axis During Firing

FEM analysis is correlated with the rocket launcher system by matching the displacements of subframe.

The comparison of subframe displacements in Y axis in real tests and subframe displacement in Y axis of FE Model is demonstrated in Figure 52.

The distinction between FE Model and real test is 10% during firing.

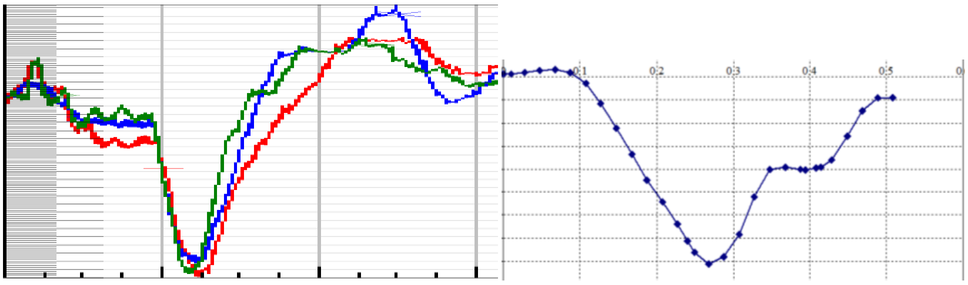

Figure 52. Comparison of Subframe Displacement in Y axis During Firing

The comparison of subframe displacements in X axis in real tests and subframe displacement in X axis of FE Model is shown in Figure 53.

When the displacement measurements were examined, it was obvious that the movement of the truck chassis-subframe was around 27 mm in the 2nd and 3rd fire. Only for the 1st fire, this movement reached 36 mm. When the displacement values in the equilibrium state are analyzed, it is evaluated that this difference is caused by the sliding of the vehicle.

The distinction between FE Model and real test is 10% during firing.

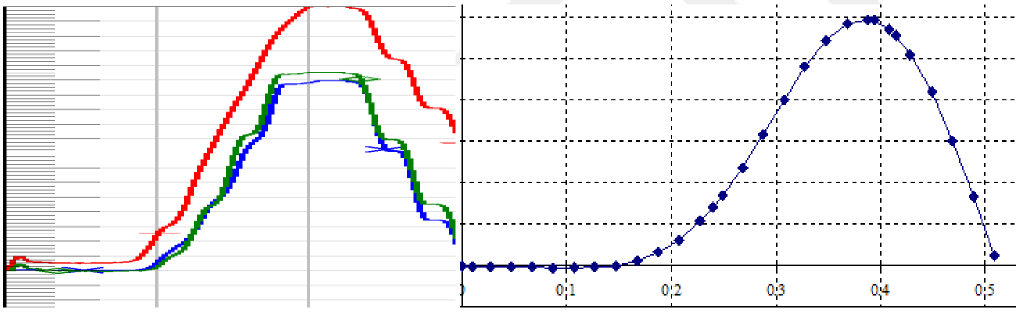

Figure 53. Comparison of Subframe Displacement in X axis During Firing

Due to the outputs of the tests, it can be revealed that detailed FE model is verified.

SECTION 5

SUMMARY

In this thesis, some tips about the design of Rocket Launcher Subframe are given. With respect to the design, FEM analysis of Rocket Launcher is created and analyzes of FE Model were carried out to examine the structural suitability of the Rocket Launcher Subframe on off-road conditions and during firing. For off-road condition, different “g” loads are used an input for FE Model while for firing condition dynamic rocket thrust load is used an input for FE Model.

After analyzes of FE Model, some structural revisions related to the subframe design and selection of subframe material is completed. The design of subframe is ended and the prototype production is started. Thanks to this revisions and material selection, weight optimization of subframe including C shaped frames, cross members, brackets, outriggers and stabilizers.

In this thesis, stress-critical locations on C shaped frames, cross members, brackets of subframe, the contact areas of the bearings which are on stabilizers and outriggers are pointed. According to the results of the analysis, there are some regions on subframe that is over the yield stress (355 MPa) of the ST52 structural steel. Hence; the subframe has an acceptable finite-life.

In this thesis, displacement of truck chassis-subframe during firing in X and Y axis is obtained due to FE Model Analysis. Because the subframe displacement is the key point of better rocket accuracy and dispersion.

The displacement results of the FE Model analysis and real firing test results are compared. It is observed that the displacement difference in X and Y axis between FE Model and real test is 10% during firing. Hence, it can be concluded that detailed FE model is verified.

In summary; a reliable FE Model, which can be used for different types of rockets and used for different firing angles, is obtained and verified. The model also can be used without the need for additional firing tests by changing the boundary conditions and input.

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