Determination of Impact Loads for a Tracked Military Vehicle During a Crash Scenario

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1 Abstract

In this study, crash simulation for a tracked military vehicle is performed and equivalent static and dynamic design loads are determined for a subsystem using LS-DYNA® and LS-OPT®. Detailed finite element model of the track geometry, suspension system and the hull is created. In order to have an accurate vehicle suspension behavior; some verification simulations are conducted with another commercial multibody software and the suspension kinematic is optimized. Full vehicle crash simulations are performed firstly and stress results are obtained from the sub-system mounts of the vehicle. Afterwards, small scale simulation model of the sub-system is created and LS-OPT® is used to get equivalent static and dynamic acceleration loads using the stress results which are obtained from crash simulation.

*KEYWORDS: Crash simulation, equivalent design loads, tracked military vehicles,

2 Introduction

Tracked military vehicles such as battle tanks and armored personnel carriers designed for high mobility capability for a wide range of terrain surfaces. These vehicles operate under harsh conditions and should withstand high impact loads at various fields as shown in Figure 1.

Fig.1: Some operating conditions of military vehicles [1], [2]

In order to have a successful final design in terms of strength and durability; structural engineers carry out various computer simulations during the design phase of the vehicle. Since the full vehicle crash simulations require extensive computational resources, mostly design iterations are solved with static or dynamic small-scale simulations.

The aim of this study is to determine static and dynamic designs load for a subsystem by using the stress results of a detailed crash simulation. In this study, LS-DYNA® is used for static implicit and dynamic explicit simulations of the vehicle and LS-OPT® is used for load determination. Firstly, full vehicle crash simulations are performed and stress results are obtained from the sub-system mounts of the vehicle. Afterwards, small-scale simulation model of the sub-system is created and LS-OPT® is used to get equivalent static load using the stress results, which are obtained from crash simulation.

Different crash scenarios are designed in order to determine the ultimate design loads that the military vehicles are exposed to under operational conditions. As shown in Figure 2, for some cases; the vehicle is crashed to different types of obstacles or fall on a flat or sloping ground at different speeds. In this study, rigid barrier crash scenario of the vehicle is investigated.

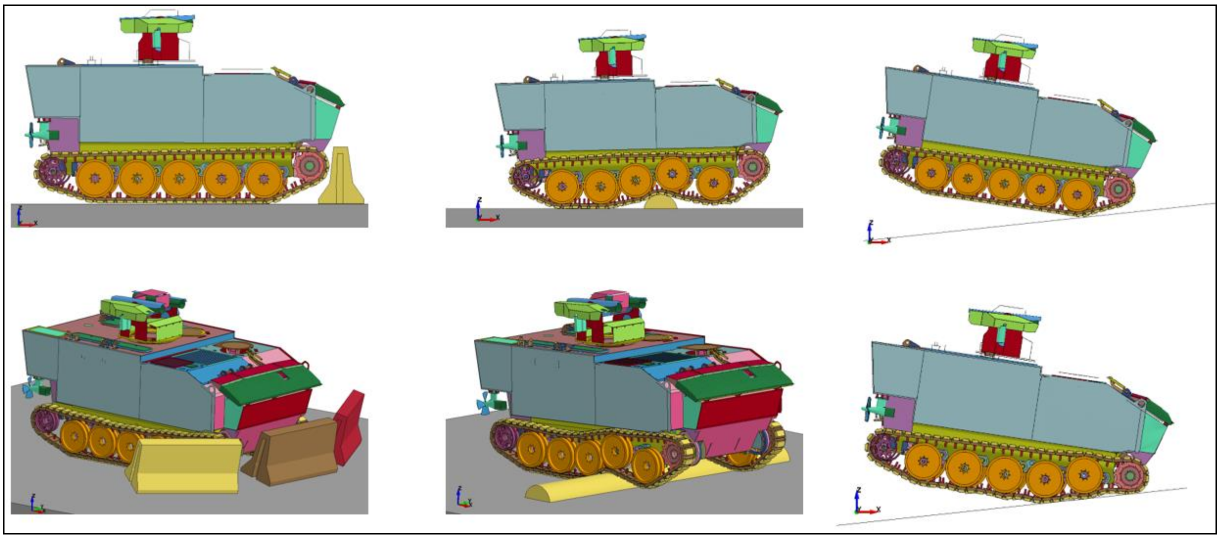

Fig.2: Crash scenarios

3 FE Model of the Vehicle

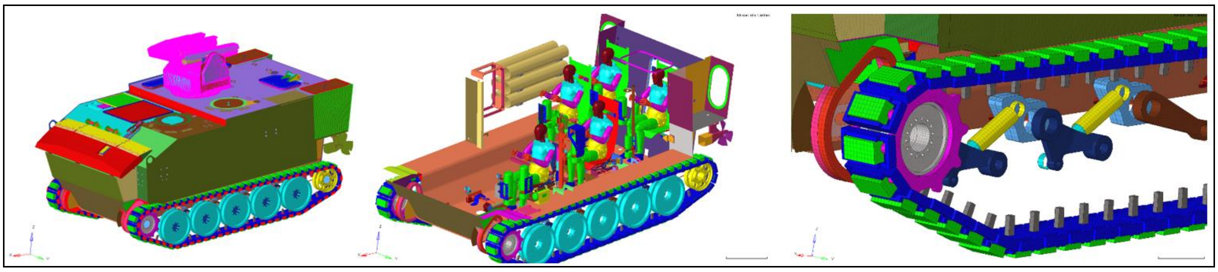

Fig.3: Finite element model of the vehicle

For the first phase of the study, the finite element model of the tracked vehicle was created. Vehicle suspension system, tracks, hull structure, seats, turret, engine-transmission mounting provisions and the main interior equipment are modelled. Rigid dummy models are used to represent the crew visually. Most of the hull structures are modelled with shell elements. The road wheels in the suspension system, the track geometry and the engine mounting plates are modelled with solid elements. “Elform 16” is used for shell elements and “Elform -1” is used for solid elements.

***CONTACT_TIED_SURFACE_TO_SURFACE_OFFSET** is used for the connections of the hull structure and ***CONTACT_AUTOMATIC_SINGLE_SURFACE** contact is used for general interactions.

Vehicle hull structures are made of high strength materials with relatively high thickness as compared to the commercial vehicles. ***MAT_SIMPLIFIED_JOHNSON_COOK** material model is used for metalic parts.

Figure 4 illustrates a tracked vehicle suspension system. Five road wheels on each track support vehicle. Each road wheel is linked to the hull chassis through a torsion bar and trailing arm suspension and each track is extended around the road wheels by the sprocket and idler located on both sides of the hull.
Finite element model of the suspension system is created preserving the details of the original geometry. Elform 6 dicrete beam/cable element formulation is used for joints, torsional bar and dampers. ***MAT_LINEAR_ELASTIC_DISCRETE_BEAM** is used for beam elements.

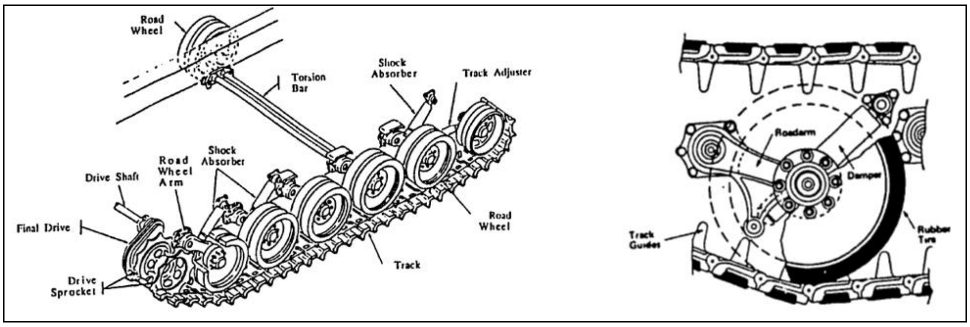

Fig.4: Tracked vehicle suspension system [3]

In order to observe accurate suspension behavior, small scale suspension simulations are conducted. Three dynamic simulations with various frequencies (1Hz, 10 Hz and 50 Hz) are performed with ADAMS® and LS-DYNA® and the results are compared.

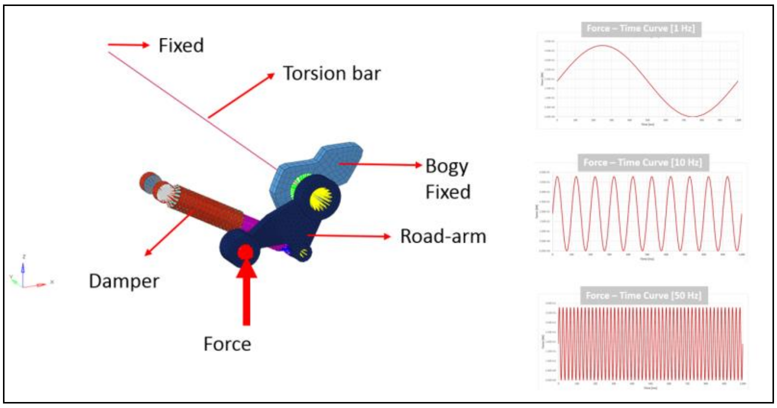

Fig.5: Suspension model

4 Crash Scenario

The crash scenario examined in this study is shown in the Figure 6. The whole vehicle model is crashed into a rigid barrier with an initial velocity. The acceleration, displacement and stress results are investigated during this collision.

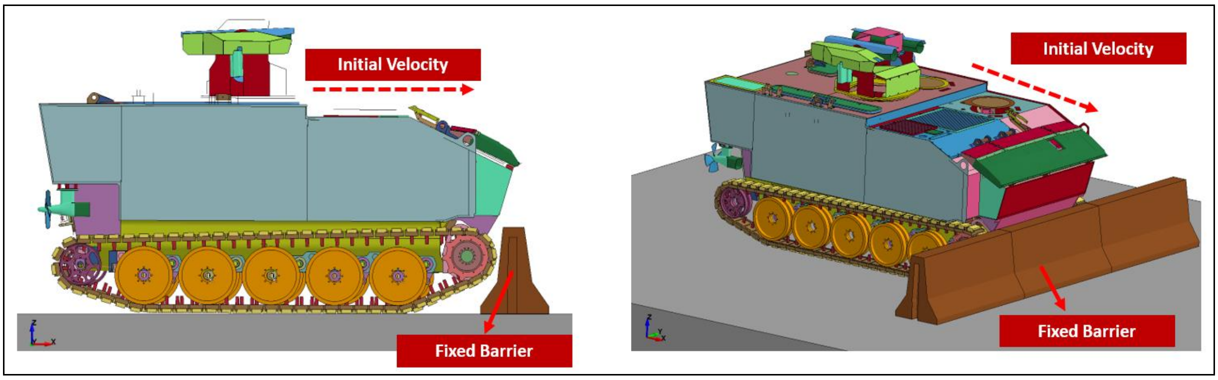

Fig.6: Crash scenario

5 Crash Simulation Results

Simulation is run at 72 CPU Linux cluster. LS-DYNA® MMP 9.1.2 solver and Intel® MPI is used. Figure 7 illustrates simulation stages up to 85 ms. Total run time is 200 ms.

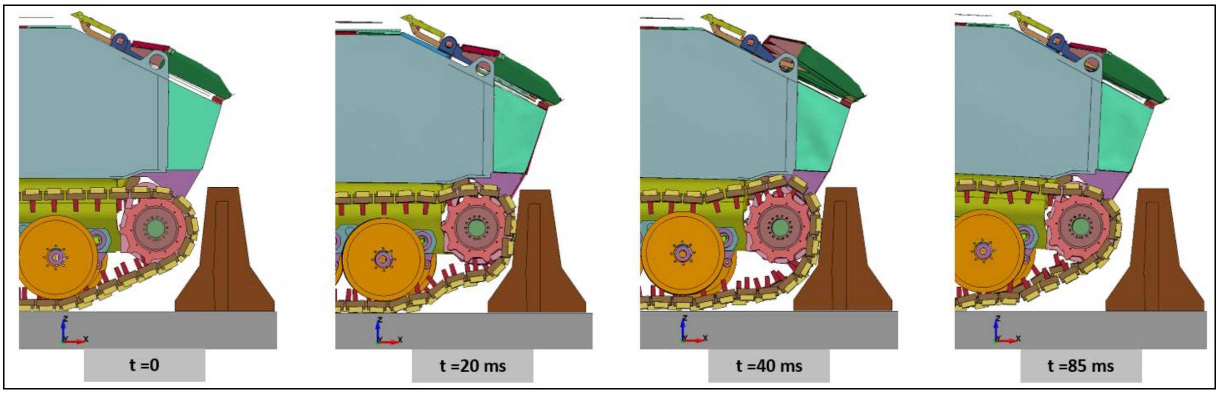

Fig.7: Simulation stages

Figure 8 shows the acceleration time history of the engine mounts. The impulse time is approximately 24 ms. The maximum acceleration value on the structure will be compared with the equivalent static and dynamic acceleration loads after optimization studies.

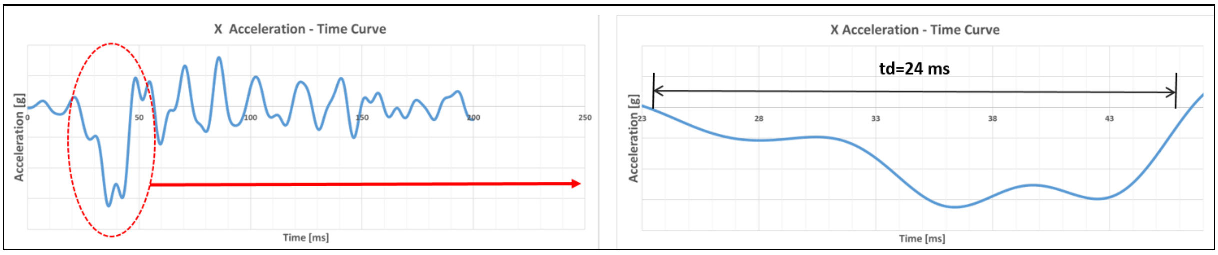

Fig.8: Acceleration – time history

Stress results are obtained from four points on engine mount structures. Figure 9 illustrates the stress-time history for each point. In the optimization studies, maximum stress values will be defined as optimization targets.

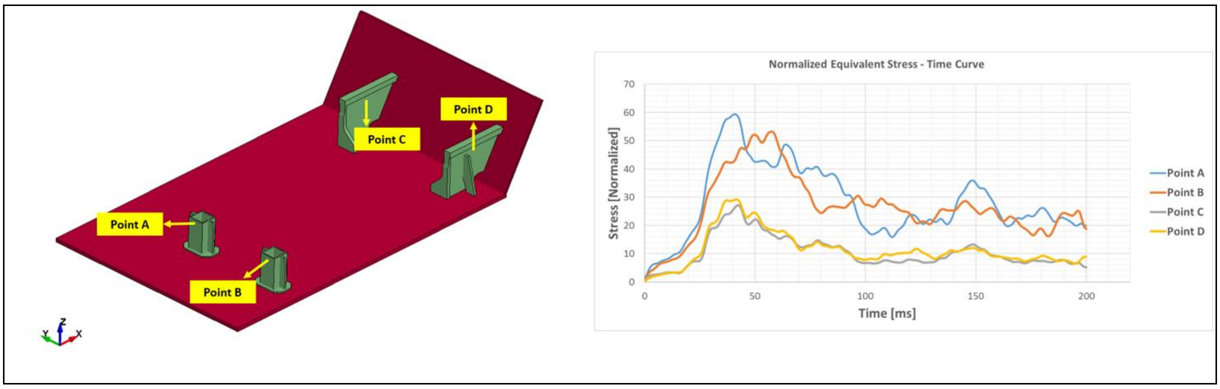

Fig.9: Stress – time histories

6 Determination of Static and Dynamic Impact Loads

In the second phase of the study, the aim is to determine static and dynamic impact loads for the engine mount structures by using the stress results from crash simulation.

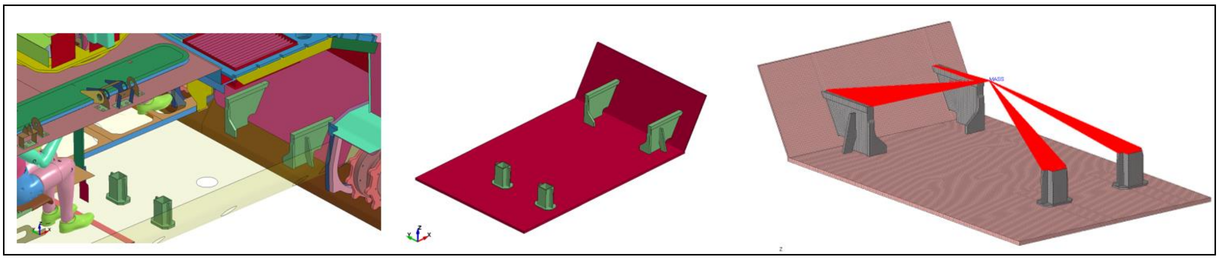

Fig.10: Sub system model

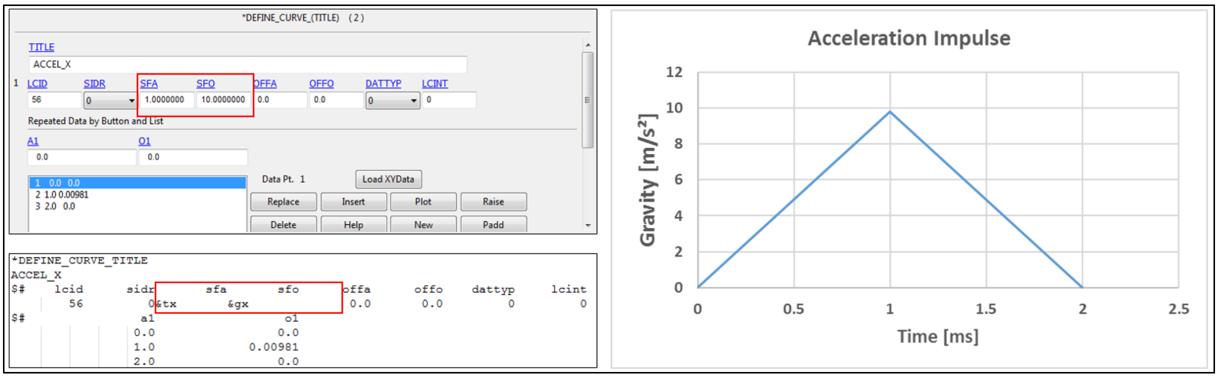

Fig.11: Parameter definition and Acceleration – time curve

A triangle shock pulse is defined (Figure 11) with the **`*DEFINE_CURVE`** keyword. Absis and ordinate scale factors (SFA and SFO) are defined parametrically and optimum acceleration and load duration times are tried to be obtained in the optimization study.

The equivalent static and dynamic loads are calculated with the LS-OPT® software respectively. The stress values at the regions shown in Figure 9 are defined for the optimization objective function. The goal in optimization is to calculate the x acceleration level that will result in these stress values in the structure.

Figure 12 shows the static load determination process in LS-OPT®. For the optimization study, gx (x acceleration) is defined as a continuous type paremeter with minimum and maximum values. Radial basis function networks is used for metamodel and space filling DOE is chosen. Totally 30 static calculations are performed.

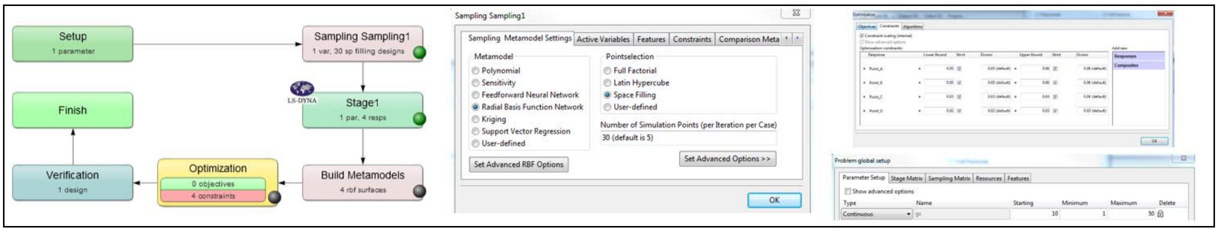

Fig.12: Static load determination process with LS-OPT®

Figure 13 illustrates the dynamic load determination process in LS-OPT®. The aim of this optimization is to obtain triangle shock curve which will provide same stress results at engine mounting structures. For this study, dynamic simulation model was created. Optimization parameters are defined, gx for x acceleration tx for shock impulse time. Polynomial metamodel and D-Optimal DOE is used and 20 simulations are performed.

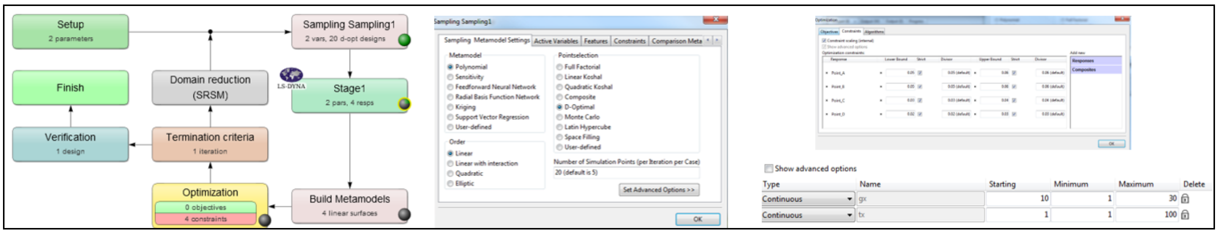

Fig.13: Dynamic load determination process with LS-OPT®

7 Results and Conclusion

Table 1 shows the optimization results. As stated in the previous sections, according to the initial crash simulation results, maximum duration is 24 ms. Calculated equivalent static and dynamic values are in similar range and ratio to crash analysis results is 0.95. Static model run time is 5 minutes at 8 cpu and it can be practically used for design iteration studies.

	Maximum acceleration [Normalized]	Time duration (ms)
Crash Analysis	1	24
Equivalent Dynamic Load	0.95	51
Equivalent Static Load	0.95	-----

Table 1: Acceleration results

Figure 13 shows the shock impulse curves of crash analysis and optimization result. Shock impulse shape is an important parameter for the structure and in addition to this study, it is planning to get acceleration curves with various shock impulse types such as trapezoidal, half-sine etc. Furthermore, load determination simulations are going on for other sub-systems in the vehicle.

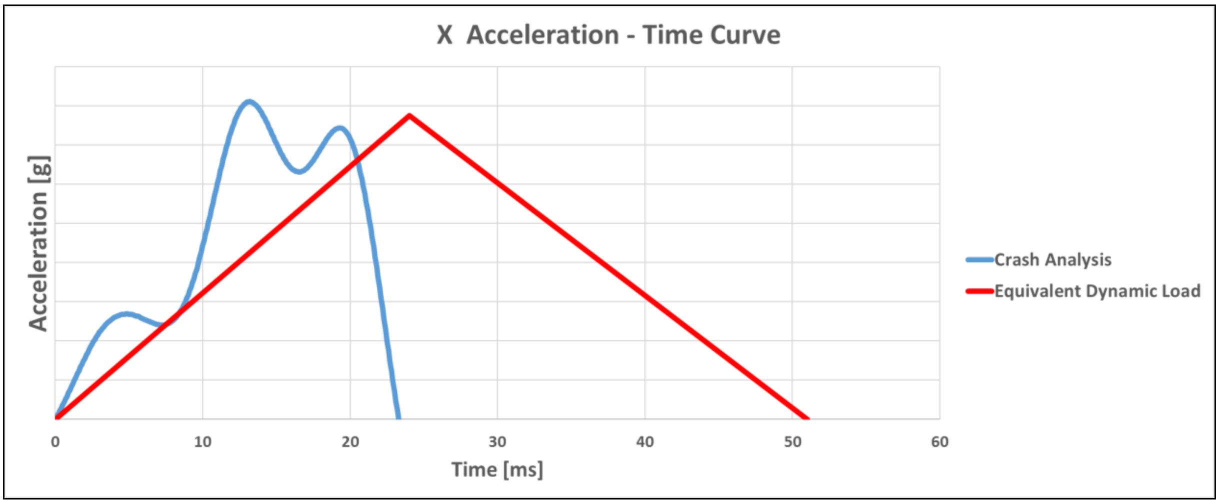

Fig.14: Shock impulse

In this study, detailed crash simulation for a tracked military vehicle is performed and equivalent static and dynamic loads are determined for a subsystem using LS-DYNA® and LS-OPT®. This study is an example and initial work for design load determination for military vehicle. Simulations were conducted with rigid barrier and rigid surface but deformable obstacles and soil surface is planning to use for further simulations.

FNSS analysis and simulation teams conduct many detailed studies to determine the loads that military vehicles are exposed to under operational conditions. The purpose of these studies is to obtain the most accurate design loads at sub system level.

8 Literature

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