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RESEARCH ON DURABILITY CHASSIS OF MULTI-PURPOSE FOREST FIRE FIGHTING VEHICLE

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SUMMARY OF ENGINEERING DOCTORAL THESIS

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Reviewer 1:

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The defense will be taken in front of the Institutional Board of Thesis Evaluation at: Vietnam National University of Forestry

At: … time, Date ….Month…..year 2020

The thesis can be found in the libraries:

National Library; Library - Vietnam National University of Forestry; Library - Vinh Long University Of Technology Education

INTRODUCTION

1. The urgency of the thesis

In 2013, Vietnam National University of Forestry chaired the implementation of state-level scientific research projects: *"Research technology and design and manufacture specialized equipment for forest fire fighting*", code No KC07.13/06-10. Results of the project designed and manufactured multi-purpose forest fire fighting vehicles, forest fire-fighting vehicles within the sample test area. However, when the fire-fighting vehicle operating in the forest has no roads, under the impact of the forest ground, obstructions on the way, the impact of the fire-fighting systems on the vehicle makes the chassis was deformed, affecting the durability of the chassis leading to the stability of the work of the vehicles and equipment on the vehicle. The scientific basis for the completion of a multi-purpose forest fire fighting vehicle (MFFV) is necessary to research to ensure the durability of the chassis including the study of load modes acting on the chassis, stress, and deformation, thereby providing technical solutions perfect vehicle design. That is the reason research student chose and implemented the topic: ***"Research on Durability Chassis of Multi-Purpose Forest Fire Fighting Vehicle"***.

2. Research objective of the thesis

Studying and evaluating the durability of the chassis is the scientific basis for the completion of the structure of the chassis of MFFV.

3. Research subject

The research subject of the thesis is chassis of MFFV was product and assembly in VietNam basic on Ural 4320 vehicle.

4. Research scope

Assessing the durability of static and fatigue of chassis under the effect of the vertical load when the vehicle is moving on the road moving through single-format bumpers and moving on the road with random.

5. New contributions of the thesis

- Has built a model to calculate static load, dynamic load acting on the chassis during fire fighting.
- Has built the system of differential equations, surveyed to determine the dynamic load acting on the chassis of MFFV.
- Has evaluated the static and fatigue strength of MFFV when the vehicles are subjected to the maximum load, moving through the format bump and the cars move on random roads.
- Tested to determine the dynamic load on the chassis and displacement the frame at the survey position when the vehicle is moving on the real road. The comparison between experiment and simulation has an acceptable error value.

6. Scientific and practical significance

6.1. Scientific significance

The thesis has evaluated the durability of the chassis of MFFV. The research results of the thesis serve as a scientific basis for the completion of the structure of MFFV chassis.

6.2. Practical significance

The thesis has built a method to determine the dynamic load acting on the chassis by model, built a method to assess the durability of the chassis, as a scientific basis to build models to evaluate the durability of domestic design and manufacturing products, contributing to perfecting the design process of automotive components and assemblies.

The thesis can be used as a reference for truck manufacturers in Vietnam during research and development of new designs as well as evaluating the durability of the details of trucks of the same type.

CHAPTER 1
OVERVIEW OF RESEARCH ISSUES

1.1. Introduction multi-purpose forest fire fighting vehicle

Multi-purpose forest fire fighting vehicle manufactured by Vietnam is a device that integrates many functions of forest fire fighting, including:

Cutting trees, clearing garbage grass, opening roads to create a fire isolation corridor; sprinkler fire spraying area; create high-pressure wind to spray into the fire; Use sandy soil in place to extinguish the fire.

1.2. Overview of MFFV chassis

The chassis of MFFV is the bearing element of the vehicle, on which the engine, the assembly of the drivetrain, the operating part, the control mechanism, cabin, load are installed. When built into a MFFV from a base vehicle, the chassis is subjected to additional load from a set of fire fighting equipment such as high-pressure water pumps, tree cutters to create a separate corridor for fires and vacuums and high-speed blowing wind, sand-blasting hoe quenched the fire, …

Chassis of MFFV has a total length of 7370mm, a width of 832mm, including 2 main bars and 9 horizontal bars. Main bar structure (vertical beams) No. 1 on each side consists of two bars with a thickness of 8mm interlocking, the outer main bar is 7370mm long, the inner main bar has a length of 5760mm from behind the chassis.

1.3. The method of researching the durability of the chassis

1.3.1. Research durability under maximum load

This is a traditional evaluation method, the durability of the chassis is evaluated based on the maximum value of the vertical force in the Z-direction calculated by the dynamic load coefficient when the vehicle is full load.

1.3.2. Study on durability under dynamic load conditions

The above static-stability method is only suitable for vehicles moving at low speeds and not in large volumes. When the vehicle is moving at high speed, the inertia of high-volume parts will generate dynamic loads, affecting the breaking strength and durability of the chassis..

1.3.3. Study on fatigue resistance of concrete frames

1.3.3.1. Load from rough pavement

Excitation from the road surface causes dynamic loads that continuously change over time acting on the chassis. Currently, the method of describing pavement by random function has been standardized according to ISO 8608: 1995.

1.3.3.2. Study on fatigue resistance of concrete frames

n order to assess the fatigue strength of the component under cyclic loading, it is often used empirically measured fatigue curve (also called S - N curve). The different experimental results show that the number of load-bearing cycles corresponding to fatigue limits for steel and cast iron is between $10^6 \div 10^8$. Therefore, we can accept the hypothesis that The part will not be broken by fatigue after withstanding 10^6 cycles.

1.4. Situation of close research in the world and Vietnam

1.4.1. Situation of researching in the world about designing and manufacturing a chassis

The research chassis of the automobile are usually concentrated in manufacturers, factories, manufacturing enterprises. Therefore, the publication of the results of these research works is often limited by technological know-how, copyright, and competition. The research works in the world on the chassis are mainly in the form of announcing the results of theoretical research for the chassis of trucks, passenger cars, etc. The author realized that there was no research work to deal with the problem. to the durability of the chassis of MFFV made by Vietnam.

1.4.2. Situation of research in Vietnam on designing, manufacturing chassis

Primitive studies are primarily presented in the textures of design and design taught in engineering universities but at a limited level.

1.5. Research subjects

The research subject of the thesis is chassis of MFFV was product and assembly in VietNam basic on Ural 4320 vehicle.

1.6. Content of the thesis

With the analysis presented above, the research student chooses to perform the topic ***“Research on Durability Chassis of Multi-Purpose Forest Fire Fighting Vehicle”*** to complete the structure of MFFV.

1.6.1. Objectives of the study

Studying and evaluating the durability of the chassis is the scientific basis for the completion of the structure of the chassis of MFFV.

1.6.2. Research Methods

The thesis uses theoretical research methods combined with experimentation with the content:

- Building a dynamic model of MFFV to determine the dynamic load on the frame when the vehicle is moving under typical conditions;

- Building a 3-D model of MFFV chassis and durability assessment survey by specialized software. Proposing the structure of an MFFV chassis to ensure durable conditions during fire-fighting activities;

- Experiments verify automobile dynamics and finite element models through determining dynamic load on the chassis and displacement at a point on the frame when the vehicle moves through the format.

1.6.3. Research scope

Assessing the durability of static and fatigue of chassis under the effect of a vertical load when the vehicle is moving on the road moving through single-format bumpers and moving on the road with random.

1.6.4. Nội dung nghiên cứu

From the proposed research objectives, the thesis includes research contents:

- Overview;

- Building a model to study the durability of the chassis MFFV;

- Survey and evaluation of chassis durability;

- Experiment to determine the dynamic load acting on the frame and displacement on the chassis;

- Conclude.

Conclusion of chapter 1

Today, with the strong development of software technology, the main calculation tools used by scientists are structural analysis software. The application of structural analysis software gives us reliable and less time-consuming and cost-effective results, many of which have focused on static and fatigue-resistant frame under effects. of the dynamic load from the bumpy road surface. From the above analysis factors, the research on the durability of the chassis of MFFV is necessary to complete the design and construction of MFFV.

CHAPTER 2
BUILDING MODEL OF RESEARCH DURABILITY FOR CHASSIS OF MULTI-PURPOSE FOREST FIRE FIGHTING VEHICLE

2.1. Methods to assess the durability of the chassis

2.1.1. Equivalent stress (Von Mises)

Equivalent stress (Von Mises) determined on deformation energy theory. Currently specialized software allows export stress results in the form of Von Mises. Therefore, to evaluate the durability of the MFFV chassis, the thesis will use equivalent stress.

2.1.2. Assessing the durability of chassis fatigue

2.1.2.1. Variable load and fatigue limits

According to [48,63], the fatigue strength may also be calculated from the material stress limit S_u:

$S_e^{'} = 0,5S_u$, with $S_u \leq 1400$ MPa;

$S_e^{'} = 700$, with $S_u > 1400$ MPa.

For cast iron materials, $S_e^{'}$ valuable: $S_e^{'} = 0,4S_u$ [45,63].

2.1.2.2. Methods of assessing fatigue

The service life of a part depends mainly on two parameters of the impact load, that is σ_a and σ_m. So, to assess the fatigue strength of the part, people often use the relationship between the two parameters to evaluate fatigue through the lifelines at fatigue limits. The relationship between σ_a and σ_m forms the criteria for assessing fatigue strength. The thesis uses Ansys software to calculate, the fatigue stress σ_e s determined according to Goodman standard: $\frac{\sigma_a}{\sigma_e} + \frac{\sigma_m}{S_u} = \frac{1}{n}$

2.2. Building a model of multi-purpose forest fire fighting vehicle

2.2.1. Building 3-D models multi-purpose forest fire fighting vehicle

Determining the mass and transient moments of the detailed parts of forest fire trucks by experimental methods is difficult and expensive. Therefore, building a 3-D model to determine the mass, moment of inertia of the details, ... is the input parameter for the vehicle's oscillation problem..

2.2.2. Develop a model to calculate the durability of the chassis MFFV

2.2.2.1. 3-D model chassis

Due to the relatively complicated structure, the 3-D model needs to be built correctly. In this study, the author uses Solidworks software to build 3-D models.

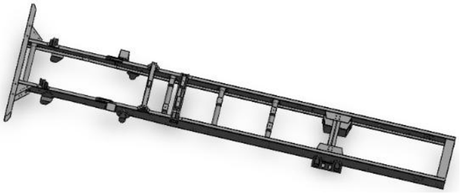


Figure 2.6: 3-D model chassis MFFV

2.2.2.2. Enter the model into Ansys

After designing the 3-D model in Solidworks, we proceed to import the chassis model into the Ansys Workbench environment.

2.2.2.3. Assign materials

In Ansys provide very large proven material inventory with reality.

2.2.2.4. Mesh model

In this study, the meshing method was chosen as the automatic type in combination with manual mesh adjustment. The model consists of 174223 elements and 376982 buttons.

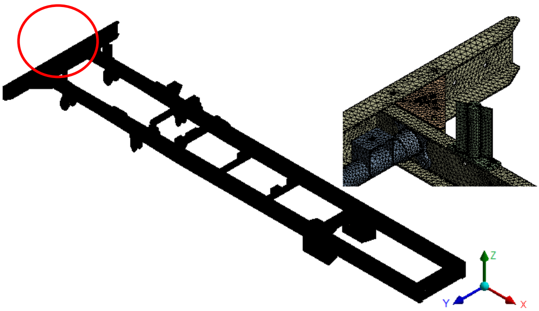


Figure 2.10: Finite element model on the chassis MFFV

2.2.2.5. Boundary conditions

Tweezers have a role to limit the displacement of the frame in 3 translational directions in the xyz plane and the rotation directions. So we choose the mount at the tweezers catch position. The forces acting on the chassis, we converted to separate positions according to each force acting. For simplicity, we return to the main forces as follows:

- Engine block: Worth weight 12258N (figure 2.12).

- Cabin cluster: Weights 8340N evenly distributed on the chassis according to the points described in figure 2.13.

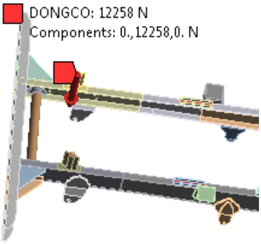


Figure 2.12: Weight distribution of engine cluster acting on the frame

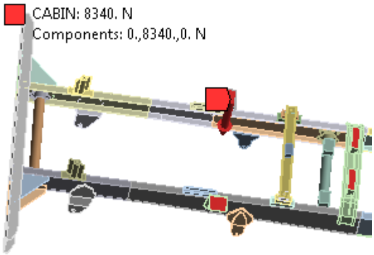


Figure 2.13: Weight distribution of cabin assembly acts on the frame

- Container volume: Including the entire weight of the container, with a payload value of 118500N.

- In addition to the weight of the three basic blocks above, the MFFV also weights the front cut cluster of 9810N, grass clippers, and rear hoe valued 7848 N.

2.2.2.6. Export results

After performing the calculation, the software will obtain equivalent stress, deformation, displacement in the form of the color spectrum. In addition to the analytical results in the static problem, we can give the problem of persistent results over time.

2.3. Building a model to determine the dynamic load acting on the chassis

2.3.1. Method of modeling

To build the dynamic model of the MFFV using this method, include the following steps:

- Make initial assumptions;
- The definition of a reference system;
- Set up the system of differential equations;
- Solving software differential equations (numerical method).

After solving the system of differential equations, we determine the acceleration of the axles in the vertical direction. Taking the acceleration times the weight of the bridge in the static state we determine the dynamic load from the road surface acting on the chassis through the bridge.

2.3.2. Building space model

2.3.2.1. Some assumptions when building models

- The tank is full of water and views the water in the tank as a solid mass because the tank is divided into several small compartments. The link between the cabin and chassis, the tank, and the chassis is like a suspension link consisting of an elastic and a damper shown on the space model..

The weight of the cabin is considered to be hard, the cabin has three movements: moving in the Z direction, turning around the horizontal axis (Y-axis), and turning around the vertical axis (X-axis).

The part of the weight of the box is considered to be hard, the 3-motion container is moved in the Z direction, rotated around the horizontal axis (Y-axis), and rotated around the vertical axis (X-axis).

The chassis has 3 movements: moving in the Z direction, turning around the horizontal axis (Y-axis), and turning around the vertical axis (X-axis).

The mass that is not suspended is considered as absolute stiffness, the suspended mass has two movements: moving in the Z direction corresponding to the front, middle and back axles.

The weight of the front cutting device, the rear lawn cutter, is considered to be absolutely hard, with two movements: moving in the Z direction and turning around the vertical axis (X-axis).

Ignore the source of vibration on the vehicle, considering the forest ground and the impulses due to the grass cutting machine is the only source of vibration. The contact between the wheels and the road surface is the point contact and ignores the slip between the wheels and the road. Vehicles moving on the road at a low and constant speed. Therefore it is considered that the inertial resistance and the air resistance are equal to zero. Ignore the effect of wheel drive friction.

2.3.2.3. Space model of MFFV

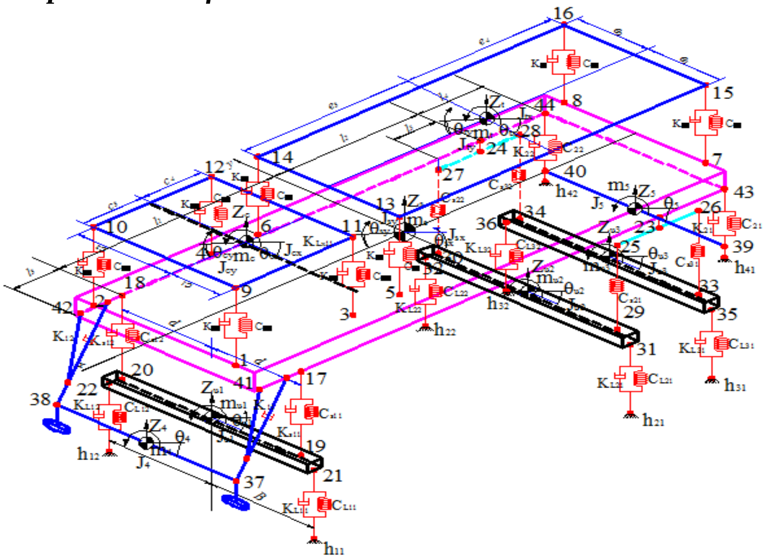


Figure 2.15: Oscillating model of MFFV in space

Structural model of MFFV with 19 extrapolated coordinates (19 DOF) include: 3 DOF of cabin (Z_c, θ_{cx}, θ_{cy}), 3 bDOF of the tank (Z_t, θ_{tx}, θ_{ty}), 3 DOF of chassis (Z_s, θ_{sx}, θ_{sy}), 2 DOF of the front axle (Z_{u1}, θ_{u1}), 2 DOF of middle axle (Z_{u2}, θ_{u2}), 2 DOF of rear axle (Z_{u3}, θ_{u3}), 2 DOF of cut the tree forward (Z_4, θ_4) and 2 DOF of rear lawn cutter (Z_5, θ_5).

2.3.2.4. Establish a system of differential equations describing the MFFV

The system of differential equations of oscillations can be formulated based on the second law of Newton. These equations have been established through balancing force and torque acting on the object. In this study, the author only gave 3 equations describing the displacement of the front, middle, and rear bridges.

$$m_{u1}\ddot{Z}_{u1}+K_{s1}\left[2\dot{Z}_{u1}-2\dot{Z}_s-2\dot{\theta}_{sy}l_1\right]+K_{L1}\left(2\dot{Z}_{u1}-\dot{h}_{11}-\dot{h}_{12}\right)$$
$$+C_{s1}\left[2Z_{u1}-2Z_s-2\theta_{sy}l_1\right]+C_{L1}\left(2Z_{u1}-h_{11}-h_{12}\right)=0$$
$$m_{u2}\ddot{Z}_{u2}+K_{L2}\left(2\dot{Z}_{u2}-\dot{h}_{21}-\dot{h}_{22}\right)+C_{s2}\left[2Z_{u2}-2Z_s+2\theta_{sy}\left(l_2-l_5\right)\right]+C_{L2}\left(Z_{u2}-h_{21}-h_{22}\right)=0$$
$$m_{u3}\ddot{Z}_{u3}+K_{L3}\left(2\dot{Z}_{u3}-\dot{h}_{31}-\dot{h}_{32}\right)+C_{s3}\left[2Z_{u3}-2Z_s+2\theta_{sy}\left(l_2+l_5\right)\right]+C_{L3}\left(2Z_{u3}-h_{31}-h_{32}\right)=0$$

2.4. Calculation to determine dynamic load

Dynamic loads from the pavement acting on the chassis through tires and bridge cover are determined from the dynamical model of the car. Investigate dynamic loads in including cases:

- Vehicles moving straight on the road going through the bumpy format;
- Vehicles moving straight on the bumpy road by ISO 8608: 1995.

2.4.1. Vehicles moving straight on the road encounter bump

Call F_{z11}, F_{z12}, F_{z21}, F_{z22}, F_{z31}, F_{z32} s the reaction from the road surface acting on the left, right, left, right, right, and left front wheels respectively. The survey case with bumpy format included: Single contour 2 front wheels; bump, put 1 on the front wheel, rear wheel; Ripped unset set 2 wheels. The survey results are the components placed on the poker frame. These results serve as an input to the survey of the durability of the chassis (chapter 3) and comparison with the verification test model (chapter 4).

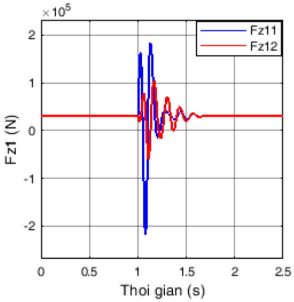


Figure 2.31a: Dynamic load F_{z1} when the front and left wheels are bumping (v = 20 km/h, h = 0,4m)

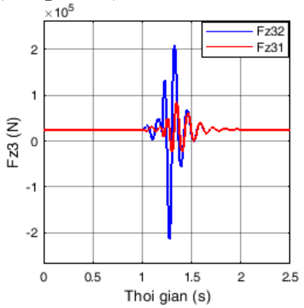
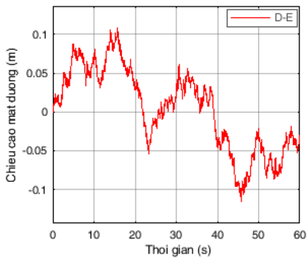


Figure 2.31b: Dynamic load F_{z3} when the front and left wheels are bumping (v = 20 km/h, h = 0,4m)

2.4.2. Vehicles moving straight on bumpy roads according to ISO 8608: 1995



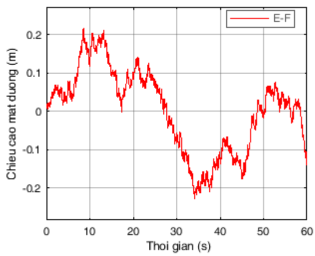


Figure 2.34a: Bumpy road surface D-E (v = 20 km/h)

Figure 2.34b: Bumpy road surface E-F (v = 20 km/h)

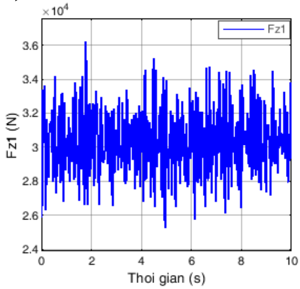


Figure 2.35a: Front axle load F_{Z1} (v = 20 km/h, D-E)

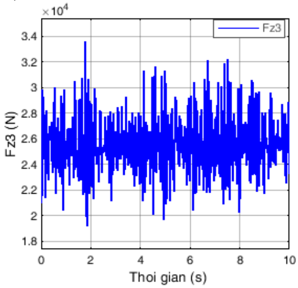


Figure 2.35b: Rear axle load F_{Z3} (v = 20 km/h, D-E)

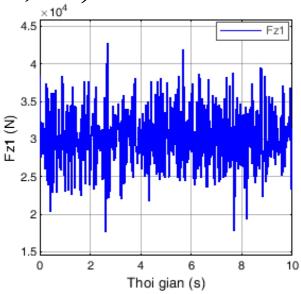


Figure 2.36a: Front axle load F_{Z1} (v = 20 km/h, E-F)

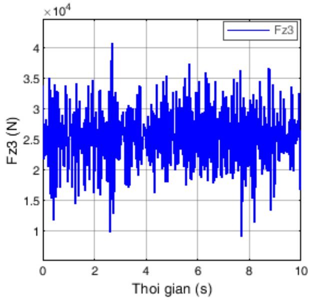


Figure 2.36b: Rear axle load F_{Z3} (v = 20 km/h, E-F)

When the vehicle runs at a speed of v = 20 km / h on the road E-F, the maximum value of maximum frontal vertical force F_{z1max} is 42762,9 N, maximum vertical force value at 1,412 compared with the case of static loading (stationary vehicle). For the rear axle, the maximum value of maximum vertical middle force F_{z3max} is 40852,1 N. The Maximum vertical force is 1.60 times higher than in case of static load (stationary vehicle).

Conclusion of chapter 2

Chapter 2 has built a 3-D model of the chassis by Solidworks and has built a model to study the durability of the frame by finite element method based on specialized software Ansys.

Developed a model to determine the dynamic load on the chassis based on the dynamic analysis model of the vehicle when moving on the road. A system of differential equations has been established, from which vertical loads from the road surface can be applied to the chassis when the vehicle is moving on the road when the wheels are deformed and moving on two roads is bad (DE) and very bad (EF) according to ISO 8608: 1995 corresponding to different speeds.

CHAPTER 3
SURVEY DURABILITY CHASSIS OF MULTI-PURPOSE FOREST FIRE FIGHTING VEHICLE

3.1. The regime of durability according to the load

In this survey study, the loads acting on the chassis cover the case:

- Case 1: The chassis is subjected to a static maximum load;

- Case 2: Vehicles moving on the road are subjected to the maximum vertical jet from the road surface acting on the chassis when one of the front wheels, front wheels, rear wheels, and two wheels cross each other to meet the road surface.;

- Case 3: Vehicles moving on random bumpy road according to ISO 8608: 1995 (D-E and E-F roads) are subjected to vertical reaction effects on the chassis..

3.2. Analyze individual vibration of frame

Separate vibration analysis of the frame is a linear analysis method to determine the specific vibration frequency of the frame [11,41]. The purpose of determining the frame's unique vibration frequency is to avoid resonance that occurs when the vehicle is operating.

In the separate oscillation analysis of the frame, if the mass matrix *[M]* and hardness matrix *[C]* constant then the value of force acting on the frame is 0. The linear equation in the natural oscillation problem to determine the vibration frequency is as follows [11, 58]:

$$[M]\{\ddot{u}\}+[C]\{u\}=0$$

The results of the analysis of vibration and vibration frequency of the frame by Ansys software for the chassis are shown in table 3.1.

Table 3.1: The specific format and frequency of the MFFV

Mode	Frequency (Hz)	Deformation (mm)	Mode	Frequency (Hz)	Deformation (mm)
1	17.812	3.4996	11	100.58	4.6058
2	31.436	2.4011	12	103.55	8.8978
3	54.127	4.1007	13	111.42	13.564
4	63.506	2.347	14	114.53	2.8216
5	64.404	4.5987	15	115.75	14.297
6	76.248	5.0434	16	124.61	6.1435
7	77.961	4.4542	17	129.88	6.6524
8	82.337	0.3608	18	133.73	6.9162
9	98.081	3.1975	19	138.64	15.304
10	100.21	3.2097	20	140.1	14.795

3.3. Assess the destructive strength of the chassis MFFV

3.3.1. Cases with maximum load

3.3.1.1. The chassis is subject to the maximum static load

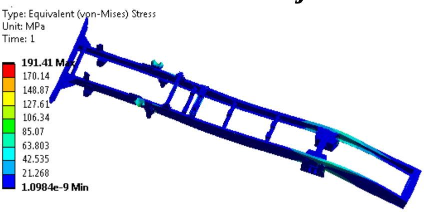


Figure 3.8: Von Mises on the chassis and the position of maximum value

Bảng 3.2: Deformation, maximum stress on chassis close to maximum static load

	Deformation (mm)	Stress (MPa)
Maximum	3.2138	191.41

The analytical results show that the maximum stress is 191.41 MPa, lower than the limit value of flow, and destruction of materials is 785 MPa and 980 MPa, so the cement frame ensures durable conditions in the field.

3.3.1.2. Where front-wheel encounter bump

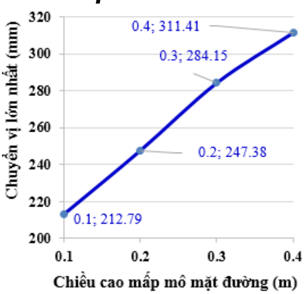


Figure 3.18: Maximum deformation on the chassis when the front wheel must encounter bumpy, bumpy height changes

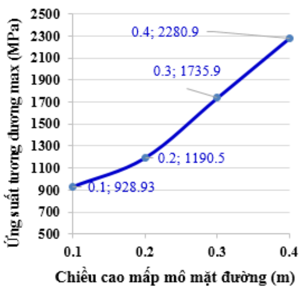


Figure 3.19: Von Mises max on the chassis when the front wheel must encounter bumpy, bumpy height changes

The results of the analysis when the front wheel was encountered bumpy road surface (road surface height varies) shows that the maximum stresses are greater than the flow limit value of the material is 785 Mpa, so the cement frame does not guarantee breaking conditions in this case. Therefore, it is necessary to insert a xi rod like the rear main bar, and increase the thickness of the inner and outer main bar by 10mm to ensure durability. The results of the improved survey frame durability with main bar size 10 + 10 show the highest equivalent stress value when the front wheel encountered a bump with a value of 470.69 MPa, smaller than the gender value the yield term of the material is 785 MPa.

3.3.1.3. Where the front two wheels encountered bump

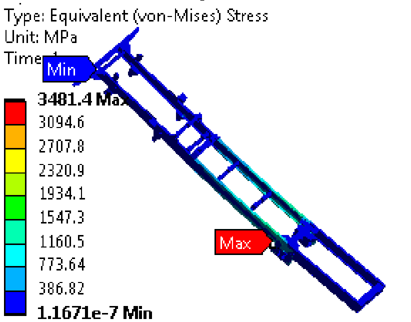


Figure 3.26: Equivalent stress on the chassis when the two front wheels met bumpy, bump height 0.4m

Table 3.4: Maximum deformation and stress on the chassis when the two front wheels encounter a bump

		Deformation (mm)	Stress (MPa)
bumpy height	0.1m	118	879.67
	0.2m	232.79	1850.2
	0.3m	321.92	2628.7
	0.4m	422.77	3481.4

The analysis results show that the maximum stresses are greater than the yield limit of the material is 785 MPa. When the height of the pavement is 0.1m, the equivalent stress is 879.67 MPa, which is nearly equal to the destruction limit and 980 MPa, so the cement frame does not guarantee durable conditions in this case. Therefore, to reduce stress in this case, it is necessary to increase the thickness of the main bar. When increasing the main bar thickness to 10mm, the survey results show that the highest equivalent stress value appears on the smaller frame smaller than the yield and destruction limits of the material.

3.3.1.4. Where rear-wheel encounter bump

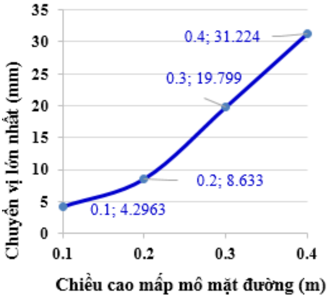


Figure 3.38: Maximum deformation on the chassis when the rear wheel must encounter bumpy, bumpy height changes

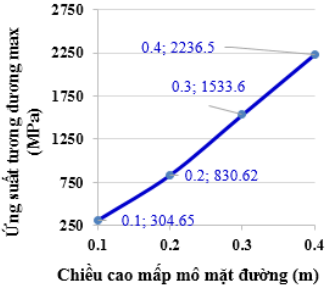


Figure 3.39: The max equivalent stress on the chassis when the rear wheel is facing a bump, the height of the pavement is changed

3.3.1.5. In the case of two cross-wheels (front left and right)

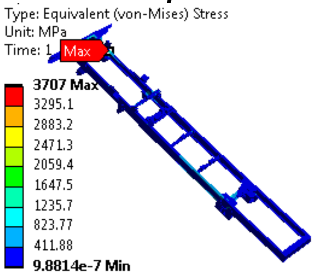


Figure 3.46: Equivalent stress on the chassis when the two diagonal wheels encountered bump, bump height 0.4m

Table 3.6: Maximum deformation and stress on the chassis when the two diagonal wheels encounter a bump

		Deformation (mm)	Stress (MPa)
bumpy height	0.1m	134.96	612.04
	0.2m	175.61	1927
	0.3m	255.51	2817
	0.4m	335.41	3707

Table 3.7: Compare values of equivalent stress concentration points and maximum displacement on the original frame

Survey case	Equivalent stress max (MPa)			
Height bumpy road surface (m)	0.1	0.2	0.3	0.4
Right front wheel bump	928.93	1190.5	1735.9	2280.9
Distorted front wheels	879.67	1850.2	2628.7	3481.4
Right rear wheel bumpers	304.65	830.62	1533.6	2236.5
Distorted two cross wheels	612.04	1927	2817	3707

3.3.2. Assess the durability of the chassis under the dynamic loads

The conditions for the load and the effective mount are the same as in the static problem in the case where the chassis is subjected to the maximum load..

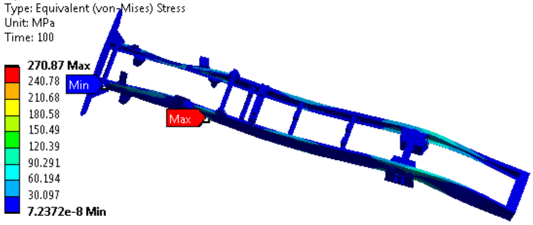


Figure 3.60: Dynamic equivalent stress distributed over the upper cylinder frame (E-F line)

The analysis results of the dynamic load problem on the chassis of versatile forest fire trucks show that the stress is relatively evenly distributed over the entire detailed surface. When moving on the road E-F, the stress generated on the chassis is more valuable when the vehicle is moving on the road D-E. The maximum value recorded is 357.26 MPa less than the allowable stress, in this case to ensure the breaking conditions of the chassis.

3.4. Evaluate fatigue strength of chassis of the MFFV

In this survey content, assess the fatigue strength of the chassis in case the chassis is subjected to dynamic loads with the mode of regular operation of vehicles moving on very bad roads..

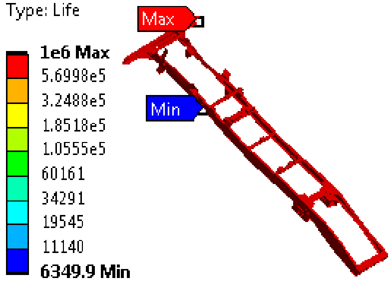


Figure 3.63: The number of fatigue cycles on the chassis while moving on the road E-F

Dynamic load applied to the chassis when the vehicle is moving on D-E and E-F roads according to ISO 8608: 1995 with a travel speed of 20 km / h determined from the dynamic model.

On the E-F road, the smallest number of fatigue cycles is worth 6349.9 cycles. It is found that the number of fatigue cycles on the chassis on both types of roads is less than 10^6, so the chassis does not guarantee fatigue conditions at work.

For the chassis after the improvement by increasing the main cross-section size 10 + 10mm, while increasing the cross-section of the horizontal bar No. 20 (Figure 1.10) 12mm thick to ensure durable conditions in the event of destruction. After the improvement, it shows that when the vehicle is moving on the E-F road, the smallest number of fatigue cycles is 10^6, therefore, the chassis ensures fatigue condition. After improving the weight of the cylinder frame weighing 1361kg, an increase of 346.6 kg compared to the original weight (1014.4kg).

Conclusion of chapter 3

Investigated stress and displacement of the chassis in case of maximum static load. The survey results show that the largest stresses appearing on the cement frame reaches 190.73MPa lower than the yield and destruction limits of materials are 785MPa and 980 MPa, so the cement frame ensures durable event destroyed in this case.

Investigation of stresses and displacements of the chassis in case the wheels were stimulated by the pavement.

Evaluated the breaking strength and fatigue strength of the chassis which is subjected to the load from the pavement surface D-E and E-F following ISO 8608: 1995 with a speed of 20 km/h.

Investigation of the breaking strength and fatigue strength of the improved poker frame showed that when increasing the main bar inside and outside by 10mm thick, and the horizontal bar No. 20 (figure 1.10) with the thickness of 12mm, the frame is close. xi satisfies working conditions. Other details of the crosshair frame with size and position do not change.

CHAPTER 4
EXPERIMENTAL STUDY

4.1 Purpose and subject of the experiment

4.1.1. Purpose of the experiment

The purpose of the experiment is to determine the vertical reaction from the road surface acting on the wheel when the vehicle moves through the format bump, determining the bending deformation at the position of the chassis. Experimental results are compared with theoretical calculation results to verify the simulation model of the thesis.

4.1.2. Experimental subjects

The object of the experiment is MFFV manufactured and assembled in Vietnam. It is fitted with full fire fighting equipment and full load.

4.2. Measured parameters

Parameters to be measured in experiments include:

- The perpendicular jet from the road surface acts on the wheel vertically F_z (kN);
- Deformation at a point on the chassis in the z-direction (mm).

4.3. Select method and measuring equipment

The test to determine the normal force from the pavement acting on the wheel and displacement at a point on the frame can be used to measure non-electrical quantities with the application of a tenzo conversion with a bending load on. The measuring system includes sensors and components that receive, amplify, convert, process, display, and store measurement results.

4.4. Methods and laboratory equipment

4.4.1. Experimental determination of normal force

To measure vertical normal force, research students using a resistor bridge. Four tenzo resistors are placed in parallel and arranged symmetrically on the top and the bottom of the bridge at 12 o'clock and 6 o'clock (top 2 leaves, lower side 02 leaves).

Figure 4.4: Tenzo stuck on the bridge

4.4.2. Experiment to determine the deformation at a point on the chassis

Experiment to determine the deformation at a point on the chassis, research students also use resistors, including 4 tenzo resistors affixed symmetrically above and below the xi frame (upper surface 2 resistor leaves, lower side 02 resistor leaves). The position of resistor foil is on the right frame, the resistor leaf is stuck on the frame between the cabin and the container, 60mm from the front of the container.

Figure 4.6: Tenzo paste position on the chassis

4.4.3. Devices, sensors, and software used in the experiment

4.4.3.1. Experimental equipment

To collect, amplify, and convert measurement information into digital signals, Ph.D. students use Spider8 device manufactured by HBM, Federal Republic of Germany.

4.4.3.2. The sensor

To determine the relationship between the voltage the resistance change on the resistor foil and the load acting on the bridge. Research student uses the Z4 load cell during the standard understanding of measured values.

To measure the deformation of the chassis when calibration we use the WSF d deformation sensor of Germany.

4.5. Calibrate measured values

4.5.1. Calibrate the measured value of the normal force

Calibrate the normal jet measurement value to determine the relationship between the voltage measured at the resistor bridge and the force acting on the bridge shell, thereby determining the correct value of the normal force from the pavement acting on the wheel in units of N.

Figure 4.11: Calibration of normal jet measurement value

Table 4.3: Results of standard vertical force measurement

Force [kN]	0	5	10	15	20	25	30	35	40	45	50
Voltage [mV]	0	4.7	9.5	13.8	18.3	22.6	27.1	31.2	35.5	39.8	44.2

4.5.2. Calibration of frame deformation measurement

Similar to the calibration of normal force measurement, calibration of frame deformation measurement is used to determine the relationship between the voltage measured at the resistor bridge glued to the frame and the deformation of the frame at the Tenzo paste position..

Table 4.4: The result of taking the displacement frame of chassis

Voltage out [mV]	0	2.75	5.06	7.53	10.12	12.72	15.2	17.03	19.54
Deformation (mm)	0	1.13	5.36	10.64	15.79	21.11	25.68	30.232	36.23

4.6. Conduct experiments on the road

The experiment was conducted on asphalt roads when one side of the wheel passed over the pavement and was carried out on a forestry road in Lot mountain of the Forestry University..

Experimental plans include:

- ***Experiment 1:*** Vehicles moving on flat roads, moving right front wheels, performed at 3 speeds of 10, 15 and 20 km/h;

- ***Experiment 2:*** Vehicles moving on flat roads, moving the right rear wheels, performed at 3 speeds of 10, 15, and 20 km/h.

4.7. Experimental results

4.7.1. Normal jet measurement results

Experimental results are compared with the simulation results in the same conditions (when the vehicles running on the rear wheels have to be distorted format, speed 10, 15, 20 km/h) to assess the accuracy of the tissue.

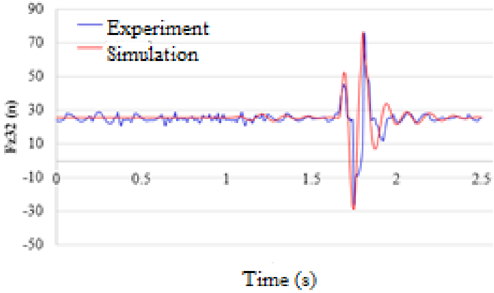


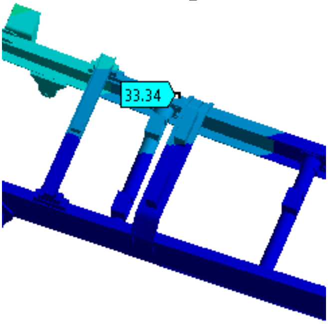
Figure 4.21: Comparing results between simulation and experiments when the wheels have to bump, the speed is 20 km/h

Table 4.5: Compare vertical force results between simulation (Sim) and experiment (Exp)

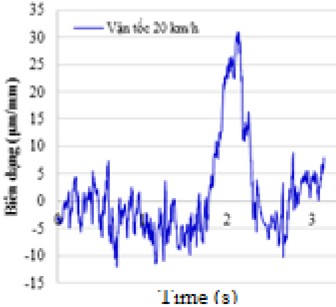
	V = 10 km/h			V = 15 km/h			V = 20 km/h		
	Sim	Exp	Eror (%)	Sim	Exp	Eror (%)	Sim	Exp	Error (%)
F_{z32max} (kN)	44.86	45.89	2.23	67.15	62.44	7.02	76.36	74.94	1.87
F_{z32min} (kN)	4.99	6.01	16.8	-15.4	-14.41	6.49	-28.8	-25.41	11.84

Comparison between simulation and experiment, the results show that the law of vertical force variation according to theoretical calculations and measured experimentally is the same. Comparing the maximum deviation between theory and experiment is done by taking large values, subtracting small values, and dividing by large values. The largest deviation between simulation results and experimental results is 16.8%..

4.7.2. Results of displacement measurement of the chassis



a. Simulation



b. Experiment

Figure 4.26: Move the chassis close to the front wheel when bumping, speed 20 km /h

Bảng 4.6: Compare the deformation results on the chassis between simulation and experiment

	V = 10 km/h			V = 15 km/h			V = 20 km/h		
	Sim	Exp	Eror (%)	Sim	Exp	Eror (%)	Sim	Exp	Error (%)
Deformation (mm)	8.72	7.58	15.1	22.01	18.25	20.5	20.9	26.5	26.1

Conclusion of chapter 4

- In chapter 4, selected methods, equipment, subjects, and testing process were suitable to the existing conditions in Vietnam, The experiment has determined the dynamic load acting on the chassis and the displacement of the chassis at the measuring position. Tenzo sensors have been used according to the principle of Wheatstone bridge so that the dynamic load is applied to the chassis and the displacement of the chassis at the measuring position. Experimental results are plentiful and reliable. The comparison of the maximum values of vertical and displacement forces between simulation and experiment results shows that the maximum deviations are 16.8% and 26.1%.

CONCLUDE

1. The thesis has built the method of assessing the durability of the chassis of MFFV by using Ansys software. A dynamic model of MFFV has been built, set up the system of differential equations, building algorithm diagram in Matlab Simulink to determine dynamic loads from the pavement acting on the chassis with different pavement conditions and velocities.

2. The thesis has evaluated the destructive strength to be carried out in cases where the chassis is subjected to maximum load, chassis is loaded with loads when the wheels face a bump in different heights. With the above-mentioned cases showing that the wheel faces a bump in the road, the maximum stresses appearing on the chassis are mostly greater than the stress and destruction limits of the material are 785 MPa and 980 MPa, therefore, the chassis is not guaranteed to be durable.

3. The thesis has evaluated the destruction of the chassis which is subjected to the load from the pavement surface D-E and E-F following ISO 8608: 1995 with a speed of 20 km/h. Destructive durability survey shows that when the road is very bad (E-F), the stress generated on the chassis is more valuable when the vehicle is moving on the bad road (D-E). The maximum value recorded on the D-E line is 314.1 MPa and the E-F line is 357.26 MPa, smaller than the allowable stress limit so the cement frame ensures durable conditions.

4. The thesis has evaluated the fatigue strength of the original frame and improved frame by Ansys software with dynamic load determined from the dynamic model, D-E, and E-F pavement according to ISO 8608: 1995 with a speed of 20 km/h. Survey results show that the original frame does not guarantee fatigue conditions when working, for improved chassis, it ensures fatigue.

5. The thesis has identified and proposed the structure of MFFV chassis to ensure durable conditions when vehicles move on the fire-fighting operation road.

6. The thesis has chosen the methods, experimental equipment and built the experimental process following the research conditions in Vietnam to measure the dynamic load applied to the chassis and measure the deformation of a point in chassis, using tenzo sensor according to the principle of Wheatstone bridge so that the dynamic load is applied to the frame and displacement of the frame at the measuring position. Experimental results are plentiful and reliable. To compare the calculation results with the measurement results, the experiments were carried out under the same conditions as the simulated theoretical calculation conditions. Experimental results gave laws similar to those obtained from survey calculations by theoretical models. The comparison of the maximum values of vertical and displacement forces between simulation and experiment results shows that the maximum deviations are 16.8% and 26.1%, respectively. This discrepant result is acceptable.

Some limitations of the thesis and subsequent research directions:

- The thesis only uses the sinusoidal pavement contour profile to evaluate and determine the load applied to the chassis when the wheel is inactive without surveying the other bumping profiles.

- The fatigue testing of the chassis only investigates the case of dynamic loads acting on the frame when the vehicle is moving on the road according to ISO 8608: 1995 but has not been investigated in the case of a vehicle under dynamic load when moving on. Therefore, further research is needed on this issue.

LIST OF PUBLICIZED ARTICLES, SCIENTIFIC WORKS RELATED TO THE THESIS

[1]. Van Van Luong, Tuong Van Tran, Quang Thanh Nguyen (2017) *Analysis Structure And Calculator Dynamic of Multimaterial Forest Fire Fighting Vehicle*. Vietnam Journal of Mechanics 6/2017, ISBN 0866-7056, 6^{th} edition, 06/ 2017, page 117-125

[2]. Assoc. Prof. Dr. Quang Thanh Nguyen, Dr. Tuong Van Tran, Van Van Luong (2018) *Analysis Structure General of Multifunction Forest Fire Fighting Vehicle*. Vietnam Journal of Mechanics 6/2017, ISBN 0866-7056, 10^{th} edition, 10/ 2018, page 114-119

[3]. PGS.TS Nguyễn Thanh Quang, TS. Trần Văn Tưởng, ThS.NCS Lương Văn Vạn, ThS Đào Trọng Cường (2018) *Analysis Design of Chassis Multifunction Forest Fire Fighting Vehicle With Ansys Workbench*. Vietnam Journal of Mechanics 6/2017, ISBN 0866-7056, 10^{th} edition, 10/ 2018, page 206-221.

[4]. Van Van Luong, Quang Thanh Nguyen, Tuong Van Tran (2018) *Study on Development of 3D for Consider the Response of Multifunction Forest Fire Fighting Vehicle*, Proceeding of The 9th TSME International Conference on Mechanical Engineering (ICoME 2018, AME009, Page 182 – 196).