Determination of Dynamic Loads from the Road Surface Acting on the Chassis by Experimental Methods

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Abstract

Chassis is the main structural component of an automobile, which is subjected to the full weight load being suspended. In the process of moving, the vehicle can both move and cut the tree while moving and sweeping the garbage as well as moving water. During the operation, the chassis is subject to dynamic loads depending on the driver and road conditions. The variation of dynamic loads causes fatigue failure to reduce the life of the chassis. Therefore, the determination of dynamic loads as input for chassis durability problem is necessary. This paper presents the research results on the determination of dynamic loads from the road surface acting on the chassis of multi-purpose forest fire fighting vehicles by experimental methods. Experiments are performed when vehicles are moving on forest roads, under the actual working conditions of the vehicle.

Keywords: Chassis, Dynamic loads, multi-purpose forest fire-fighting vehicle.

1. Introduction

In Vietnam, most durability tests are carried out on test bench with static load modes. In this way, they are limited in assessing the durability of vehicles in actual operating conditions. Therefore, they need to use dynamic loads as input parameters for durability determination models that have increasingly been developed in recent years. The chassis is a girder system bearing loads installed and loaded, receiving and transmitting jets during vehicle operation. Besides, it is influenced by vibrations from engines, powertrain, etc. A study of the load mode applied on the chassis is only within a theoretical model but there are no practical tests to assess the reliability of this model [1, 2, and 3]. Stemming from that reason, the author proposed a method to determine the dynamic load from the road surface to the cement frame by an experimental method with existing equipment in Vietnam. The purpose of the experiment is to measure the pavement reaction force acting on the sphere when the vehicle passes the standard scale. The reaction value from the road surface to the axle via suspension will affect the chassis. Experimental results are compared with the theoretical results to verify the simulation model.
to determine the dynamic load, as the reason for the calculation of durability of a multi-purpose forest fire truck.

Calculations that determine the impact on the chassis are carried out on multi-purpose forest fire fighting vehicle manufactured by Vietnam. This is a vehicle integrating many forest fire fighting functions including cutting trees, cleaning garbage grass, opening roads to create a fire isolation corridor; fire sprinkler with wide spray area; create high-pressure wind spray on the fire; using sandy soil on spot to extinguish the fire has been designed based on the vehicle URAL 4320, which has three active main axles used in the military field.

Studies to determine the force reaction from the road surface to the rear axle are limited, especially the method of experimentally determining when the vehicle is moving on the road. Many studies on the durability of rear axle cover under the effect of the effective loads [7, 8, 9, and 10]; these studies indicate the stress and deformation that appear on the active bridge cover. In their research, M H Trinh and colleagues [11] have determined the dynamic load from the road acting on the rear axle of the truck by experiment method, tested on real roads, vehicles passing through sinusoidal models when the vehicle is moving at different speeds.

![Figure 1. Experimental multi-purpose forest fire fighting vehicle](image)

2. Model of load determination on the bridge shell

2.1. Vertical load impacts on the rear axle of multi-purpose forest fire fighting vehicle

![Figure 2. Diagram of forces acting on active rear axles of multi-purpose forest fire fighting vehicle](image)

As can be seen in the diagram, the shell is subject to the reaction of the jet from the road surface $F_{z1}$, $F_{z2}$ (N) and force from leaf spring $F_{zn1}$ và $F_{zn2}$ (N); $a$ shows the distance from the point of
the jet from the road surface to the point of the force from leaf spring (m); b displays the distance from two points of the jet from the left and right pavement (m).

2.2. Determination of dynamic load impacting the bridge shell after active multi-purpose forest fire fighting vehicle

Generally, when the vehicle moves on the road, the forces acting on the axle are dynamic and they are determined by solving the differential equation system describing the general dynamic model of the vehicle. In this study, the author limited the testing of vertical Fz31 and Fz32 reaction tests from the road surface to the axles. To verify and compare with the theoretical model developed, the author uses the input agitation function, which is the sinusoidal scale of the road surface. The height of the sinusoidal model is determined by the following formula:

$$h(x) = \begin{cases} 
\frac{1}{2}H \left(1 - \cos\left(\frac{2\pi x}{L}\right)\right) & \text{when } 0 < x < L \\
0 & \text{when } x \leq 0, \; x \geq L
\end{cases}$$

$H$ - maximum surface roughness height, $H= 0.1$m; $L$ - surface roughness length ($L= 0.6$m); $v$ - velocity of vehicle movement.

### Figure 3. The surface roughness described in length

3. Experiment to determine dynamic load from road surface impacting rear axle of a multi-purpose forest fire fighting vehicle

3.1. Experimental purpose

The objective of the experiment is to measure the dynamic load from the road surface acting on the bridge in the process of passing the standard scale. Experimental results are compared with calculation results by dynamic models to verify theoretical models.

3.2. Measurement parameters

The parameter to be measured in the experiment is the force exerted from tires onto the rear axle in a vertical direction $F_z$ (N)

3.3. Methods and measuring devices

3.3.1. Principle of measuring dynamic loads acting on rear axles

The method of measurement determines the forces applied from tires to the rear axle vertically with the application of the Tenzo switch with bending load on any beam. Figure 4 is a diagram showing the measurement structure system that determines the bending load on a beam. The measuring system includes sensors, which receive, amplify, convert, process, display and store measuring results. The electrical signal (current or voltage) from the sensors is amplified many times, then through the A/D converter into a digital signal transmitted to the software installed in the computer (PC).
3.3.2. Experimental equipment

To measure the vertical legal force, the research team used a four-resistor device. Four tenzo resistors are pasted in parallel and arranged symmetrically on the upper and lower sides of the bridge at 12 o'clock and 6 o'clock positions (the upper surface of 02 leaves, the lower surface of 02).

![Diagram of the normal force](image)

**Figure 4.** Diagram of the normal force

1) Bridge beam; 2) Tenzo; 3) Amplifiers and A/D Converter; 4) Computer.

**Experimental devices include:**

a. **Resistor bridge**

A diagram of the axle resistor and a measurement resistor bridge is shown in Figure 4 above. Tenzo resistors are applied directly to the outer surface of the axle. Before that, one must clean the shaft surface to achieve the required roughness, clean with gasoline and acetol.

To measure the vertical force acting on the rear axle proactively, four Tenzo resistive tenzo leaves (120V) are affixed to the upper and lower surfaces of the axle, facing on two leaves, and facing below two parallel leaves and opposite. Four Tenzo are arranged passes through the active axle axis (Figure 5). The resistors are connected into a bridge circuit as shown in Figure 6, called a resistor bridge (i.e. measurement bridge), the bridge circuit has 4 nodes, in which 2 nodes are connected to the feeding source (U) and 2 remaining nodes perform signal transmission function ($U_{ad}$).

![Tenzo affixed on the experimental shell](image)

**Figure 5.** Tenzo affixed on the experimental shell

![Tenzo bridge circuit](image)

**Figure 6.** Tenzo bridge circuit

b. **Experimental equipment**

The force signal measured on the axle is received and amplified by the Spider8 device. This is a signal amplification device and an A/D converter is connected to a computer manufactured by the German HBM company.
c. Calibration of force measurement value

Calibrate the value of the measure of normal force to determine the relationship between the measured voltage in the bridge resistor and force from the road surface applied to the wheel in units of measurement, is N. Tenzo resistors are calibrated with the Spider8 measuring device and the Z4 load cell. To create a vertical force from the loads acting on the bridge, the team used hydraulic jacks in conjunction with the standard Z4 load cell to act on the bridge vertically.

To calibrate the measuring device, the research team progressively increased the load applied to the load cell Z4 by hydraulic jerks (lifting the axle), now under the effect of loads placed on the vehicle as an axle. deformed, change the resistor value and voltage value sent to the computer. The measurement results are shown in Table 1 and the calibration graph in figure 8.

![Figure 7. Calibration of force measurement value](image)

**Table 1. Results of calibration of the normal reaction**

| Force [kN] | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|------------|---|---|----|----|----|----|----|----|----|----|----|
| Volt output [mV] | 0 | 4,7 | 9,5 | 13,8 | 18,3 | 22,6 | 27,1 | 31,2 | 35,5 | 39,8 | 44,2 |

![Figure 8. The calibration graph between the voltage signals measured at the resistor and the vertical force on the bridge](image)

3.4. Experimental options

The experiment was conducted on a fine, flat, dry, bumpy asphalt road selected as random bumps on a road with a height of 0.1m, a length of 0.6 m. (Figure 9). In fully loaded vehicles, rear right wheels go up bumping at the speed of 10 km/h, 15km/h, and 20km/h.
3.5 Experimental results

The experimental results are compared with simulation results under the same conditions (when vehicles on the rear wheels have to be disguised with the format speed of 10, 15, 20 km/h.) to assess the accuracy of the model. Theoretical simulation results were simulated by Matlab Simulink on the dynamic model of the vehicle [6] when the vehicle passed the sinusoidal model (section 2.2), moving at a changing speed of 10, 15, 20 km/h. The final test results are the average results of 3 experiments, the author has evaluated and compared the experiments on the same road surface and the same speed of movement, the value is equivalent. In the comparison of this result, due to the simulated and experimental content is relatively similar, the researcher uses the method of graph overlap to evaluate the similarity of rules and frequencies between research and reason theory and experiment. Besides, to evaluate errors, compares the maximum force values at the vertices of the graph (to compare the maximum amplitude of dynamic loads). The comparison results in each case are shown in the graphs and tables below:

![Graph](image)

**Figure 10.** Force reaction when the right wheel bump into the rough (Fz32) at speed 10 km/h

![Graph](image)

**Figure 11.** Force reaction when the right wheel bump into the rough (Fz32) at speed 15 km/h
Figure 12. Force reaction when the right wheel bump into the rough \( (F_{z2}) \) at speed 20 km/h

The experimental results show the right wheel description of these physical phenomena, on the same type of road when the vehicle is moving at a higher speed, the force reaction will be bigger. When the rear wheel collides with a bump, the determined jet value corresponding to the speed of vehicle 10, 15, 20 km/h is 91; 78; 124, 8; 149, 8 kN. When the wheel comes in contact with the bump, the bridge deformation bends, and changes the voltage value of the Wheatstone bridge. From the voltage value we can determine the value of the force reaction. At this point, the value of the force reaction increases (the first peak forces). When the wheel passes over the bump, because the bridge is more bent, the force reaction is higher than the value when the wheel has just come into contact with the bump (the second peak forces). When passing over the bump, under the influence of the weight of vehicle and the suspension system, the vehicle returns to its original state.

| V = 10 km/h | V = 15 km/h | V = 20 km/h |
|-------------|-------------|-------------|
| \( F_{z2}^{\text{max}} \) (kN) | 89,73 | 134,3 | 152,7 |
| Error (%) | 2,23 | 7,02 | 1,86 |
| \( F_{z2}^{\text{min}} \) (kN) | 9,98 | -30,8 | -50,8 |
| Error (%) | 16,8 | 6,49 | 11,83 |

Table 2. Comparisons between the force reaction simulations (Sim) and experiments (Exp) results

A comparison between simulation and experiment results show that the law of transforming vertical forces according to theoretical and measured calculations is the same. The maximum difference between simulation results and experimental results is 12,01%. With accepted assumptions when building simulation models, such deviation is acceptable. The difference between calculation results by the model and experimental results is not too huge which shows that the dynamic model of forest fire engines correctly describes the physical processes occurring in the system, with acceptable accuracy and reliability.

4. Conclusion

This paper presented the methods and results of testing the forces applied to the rear axle of a multipurpose fire truck to verify the theoretical model used in calculating dynamic loads. The authors have selected experimental methods and equipment suitable to conditions in Vietnam. In order to compare calculation results with experiments, this experiment is performed under the same conditions as theoretical simulations. The experiments were performed when the rear wheels had to pass through the bumps at speeds of 10, 15 and 20 km/h. These experimental results show that the rules are similar to the ones obtained from survey calculations by theoretical models. The maximum deviation between room tissue results and the test results is determined by maximum points at acceptable levels.
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