MINISTRY OF EDUCATION AND TRAINING - MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT
VIETNAM NATIONAL UNIVERSITY OF FORESTRY

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RESEARCH ON VERTICAL DYNAMIC OF SINGLE AXLE TRAILER TRACTOR WHEN HAULING ON FORESTRY ROADS

Major: Mechanical Engineering
Code: 62 52 01 03
SUMMARY

HANOI, 2017

COMPLETED AT VIETNAM NATIONAL UNIVERSITY OF FORESRTY

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INTRODUCTION

1. Research urgency

At present, research, design, manufacture and testing of specialized equipment based on motivational resources for various purposes are being studied by scientists. State-level scientific research project number KC 07/26 has researched, designed and manufactured an axle mounted with Shibaura 3000A four-wheel tractor. However, this reserach is just to study the design of the machine model, not to deeply study machine dynamics. In order to improve the efficiency and safety in the work process, it is necessary to conduct full research on the dynamics of the machine complex, especially the vertical dynamics of the machine complex during the process of hauling on forest road conditions.

Starting from the above practical issues, the author conducts the reserach : "Study of vertical dynamic of the one axle trailer tractor when hauling on forestry roads."

2. Research purpose

Constructing a dynamic model for of the single axle trailer tractor with regard to flexible coupling and active wheel distortion in tangential direction. Investigation of the influence of structural parameters coupling to normal jet impact on bridges as a basis for defining safe work mode on vertical slopes and completing machine design.

3. Research content

Modeling the vertical dynamics of a single axe trailer four-wheel tractor when referring to tangential deformation of active wheels and flexible couplings between tractors and trailers.

Investigate the effect of flexible coupling to normal jet on the front axle of the tractor as it accelerates to determine the working range of the machine coupling according to driving conditions; Time and distance when braking to evaluate braking performance.

Experimental research identifies several input parameters for solving theoretical problems and verifying some theoretical results.

4. Research object

The object of the thesis is a combination of single axe trailer four-wheel tractor with flexible couplings when hauling on forest road conditions.

5. Research Methodology

The thesis used a theoretical method based on the application of the Lagranger type II equation for differential equations, using the matlab - simulink software to examine the system of equations. At the same time, the thesis also uses empirical method to measure non-electric quantities to determine input parameters of theoretical problems and verify the results of theoretical research.

6. The scientific and practical significance of the thesis

Building the theoretical basis for the vertical dynamics study of a single axle trailer four wheel tractor.

Calculating to create a resonable design, contributing to determining the reasonable working mode of the machine complex in production practices.

7. Structure of the thesis

Introduction

Chapter 1. Overview of Research Issues.

Chapter 2. Longitudinal dynamic model of single axle trailer- tractor.

Chapter 3. Longitudinal Dynamics of the Machine .

Chapter 4. Empirical research.

Conclusions and recommendations.

Chapter 1. OVERVIEW OF RESEARCH

Overview of the current status for wood transporting includes : Means and commodities involved in logging; Roads are built in forestry and bumpy. Understand the current use of tractors in agricultural and forestry production. Find out the overview of the dynamics study of the machine in Vietnam and in the world.

For various research purposes, research in general has achieved certain results, has high practical value and is a reference material for subsequent studies.

The longitudinal dynamics study of a four wheel tractor with single axle trailers, including the twisting of tire and flexible coupling when working on forest road conditions, is a necessary research direction. This is the research direction that underlies the next steps, defining the safe working mode of the machine complex on the steep condition and the proposed design of the machine combined structure.

On that basis, the author identifies the research contents as follows:

- Study the vertical dynamics model of a four wheel tractor with a axle trailer when working on forest road conditions.
- Research on driving dynamics in tangential direction.
- Study the dynamics of flexible couplings between tractor and trailer.
- Longitudinal dynamics survey of tractor.
- Experimental research to identify some parameters for solving theoretical problems and to verify the results of theoretical research.

Chapter 2. MODEL LEARNING MODELS OF THE FIXED FOOTWEAR COMPONENT AND MOOC TORQUE

The tractor studied is a four-wheel tractor and single axle trailerr linked together by flexible coupling. Within the research boundary of the thesis, in order to model the vertical dynamics of the machine complex, the thesis assumes the following hypotheses:

- The tractor is a two-element system: tractors and trailers are concentrated at the O1 and O2 are gravity centers of tractors and trailers, respectivelly (Figures 2.1 and 2.2);
- The load on the trailer is fixed to the trailer and is assumed to be a unitary block and there is no relative motion with the trailer.
- Non-slip motion machine with reaction of the linear working limits;
- The structure of the tractor, the trailer and both the load on the trailer are symmetrical across the longitudinal vertical plane, the center coordinates lying on the plane. The dynamics model of the tractor is attributed to a traces model in which the forces and momentum set in the wheels are the quantities converted from the respective axes;
- The engine only transmits torque to the active shaft of the tractor, the engine is considered as a huge flywheel;

The link between the tractor and the trailer is a four-degree coupling (three-axis rotation and x-axis displacement due to the flexible coupling);

- Ignore the resistance of air and friction in bearings.

2.1. Model

Based on the structure and working principle of the tractor, the thesis builds on the dynamic model shown in Figure 2.1 and Figure 2.2.

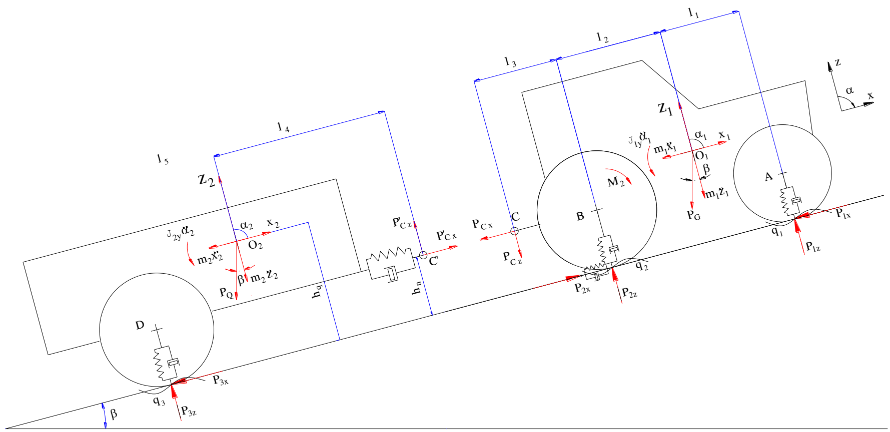

Figure 2.1. Dynamic model of single axle trail - four wheel tractor when accelerating

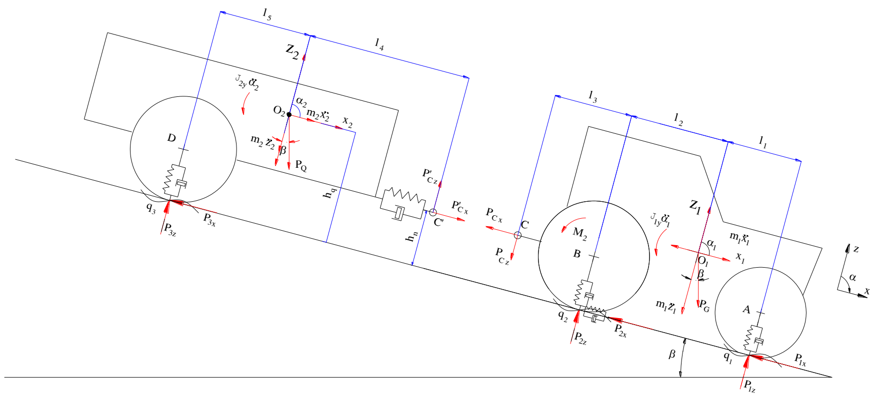

Figure 2.2. Dynamic model of single axle trail - four wheel tractor when deaccelerating

Identification of elements in the model: Parameters of geometric dimensions (l1, l2, l3, l4, l5, hk, hm, hn, r2), mass parameters m1, m2 are determined by experimental measurement or inherit data from published works [14], [8];

Hardness parameters, kinetic coefficient (kiz, ciz) are inherited according to the published results [8];

The hardness and drag coefficients of the flexible coupling in OX direction (c4x, k4x) are theoretically calculated (chapter 3 of the thesis), hardness and drag coefficient of tractor tires (c2x, k2x) is determined experimentally (chapter 4 of the thesis); The drag coefficient fi and stickiness coefficient ψ are determined experimentally (chapter 4 of the thesis);

The Piz and Pix force on the wheels are determined by the force and torque equations for the tractor and trailer system (presented in Section 2.1.3 of the thesis):

U4x soft spring coupling is a variable that changes over time and is determined by studying the dynamics of the coupling between tractor and trailer (presented in section 2.3):

The tangential deformation of the active tire u2x is a variable that changes over time and is determined by studying the tangential wheel dynamics in tangential direction (see Section 2.2):

The elements x1, z1, α1, and z2 are the solutions of the machine dynamic differential equation.

2.2. Differential equation system

To make differential equations, the thesis applies the Lagranger type II equation. By calculating the kinetic energy function, the potential energy, the dissipative function and the exaggerated external forces of the system, the thesis establishes the system of differential equations of the system in two cases as follows:

- Tractor is studied in case of acceleration:

$$\begin{cases}(m_1+m_2)\ddot{x}_1+k_{2x}\dot{x}_1+c_{2x}x_1-k_{2x}r_2\dot{\varphi}_2-c_{2x}r_2\varphi_2-m_2\ddot{u}_{4x}=P_k-P_{1z}f_1-P_{3z}f_3\\ (m_1+m_2)\ddot{z}_1+(k_{1z}+k_{2z}+k_{3z})\dot{z}_1+(c_{1z}+c_{2z}+c_{3z})z_1-m_2u_{4x}\ddot{\alpha}_1+(k_{1z}l_1+k_{2z}l_2\\ \quad +k_{3z}u_{4x}-2m_2\dot{u}_{4x})\dot{\alpha}_1+(c_{1z}l_1-c_{2z}l_2-c_{3z}u_{4x}-m_2\ddot{u}_{4x}-k_{3z}\dot{u}_{4x})\alpha_1+k_{3z}l_5\dot{\alpha}_2\\ \quad +l_5c_{3z}\alpha_2-k_{1z}\dot{q}_1-c_{1z}q_1-k_{2z}\dot{q}_2-c_{2z}q_2-k_{3z}\dot{q}_3-c_{3z}q_3+(m_1+m_2)g=P_{1z}+P_{2z}+P_{3z}\\ (m_2u_{4x}{}^2+J_{1y})\ddot{\alpha}_1+(k_{1z}l_1^2+k_{2z}l_2^2+k_{3z}u_{4x}{}^2+m_2u_{4x}\dot{u}_{4x})\dot{\alpha}_1\\ \quad +(m_2u_{4x}\ddot{u}_{4x}+k_{3z}u_{4x}\dot{u}_{4x}+c_{1z}l_1^2+c_{2z}l_2^2+c_{3z}u_{4x}{}^2+m_2\dot{u}_{4x}^2)\alpha_1-m_2u_{4x}\ddot{z}_1\\ \quad +(k_{1z}l_1-k_{2z}l_2-k_{3z}u_{4x}+m_2\dot{u}_{4x})\dot{z}_1+(c_{1z}l_1-c_{2z}l_2-c_{3z}u_{4x})z_1+k_{3z}l_5u_{4x}\dot{\alpha}_2-l_5c_{3z}u_{4x}\alpha_2\\ \quad -k_{1z}l_1\dot{q}_1-k_{2z}l_2\dot{q}_2-k_{3z}u_{4x}\dot{q}_3-c_{1z}l_1q_1+c_{2z}l_2q_2-c_{3z}u_{4x}q_3-m_2gu_{4x}=P_{1z}f_1l_1-P_{2z}f_2l_2\\ J_{2y}\ddot{\alpha}_2+k_{3z}l_5^2\dot{\alpha}_2-k_{3z}l_5\dot{u}_{4x}\alpha_2+c_{3z}l_5^2\alpha_2\\ \quad +k_{3z}l_5\dot{z}_1+c_{3z}l_5z_1-k_{3z}l_5u_{4x}\dot{\alpha}_1-l_5c_{3z}u_{4x}\alpha_1-k_{3z}l_5\dot{q}_3-c_{3z}l_5q_3=P_{3z}f_3l_5\end{cases}\qquad(2.32)$$

Tractor is studied in case of braking

$$\begin{cases}(m_1+m_2)\ddot{x}_1+k_{2x}\dot{x}_1+c_{2x}x_1-k_{2x}r_2\dot{\varphi}_2-c_{2x}r_2\varphi_2-m_2\ddot{u}_{4x}=P_P+P_{1z}f_1+P_{3z}f_3\\ (m_1+m_2)\ddot{z}_1+(k_{1z}+k_{2z}+k_{3z})\dot{z}_1+(c_{1z}+c_{2z}+c_{3z})z_1-m_2u_{4x}\ddot{\alpha}_1+(k_{1z}l_1+k_{2z}l_2\\ \quad +k_{3z}u_{4x}-2m_2\dot{u}_{4x})\dot{\alpha}_1+(c_{1z}l_1-c_{2z}l_2-c_{3z}u_{4x}-m_2\ddot{u}_{4x}-k_{3z}\dot{u}_{4x})\alpha_1+k_{3z}l_5\dot{\alpha}_2\\ \quad +l_5c_{3z}\alpha_2-k_{1z}\dot{q}_1-c_{1z}q_1-k_{2z}\dot{q}_2-c_{2z}q_2-k_{3z}\dot{q}_3-c_{3z}q_3+(m_1+m_2)g=P_{1z}+P_{2z}+P_{3z}\\ (m_2u_{4x}{}^2+J_{1y})\ddot{\alpha}_1+(k_{1z}l_1^2+k_{2z}l_2^2+k_{3z}u_{4x}{}^2+m_2u_{4x}\dot{u}_{4x})\dot{\alpha}_1\\ \quad +(m_2u_{4x}\ddot{u}_{4x}+k_{3z}u_{4x}\dot{u}_{4x}+c_{1z}l_1^2+c_{2z}l_2^2+c_{3z}u_{4x}{}^2+m_2\dot{u}_{4x}^2)\alpha_1-m_2u_{4x}\ddot{z}_1\\ \quad +(k_{1z}l_1-k_{2z}l_2-k_{3z}u_{4x}+m_2\dot{u}_{4x})\dot{z}_1+(c_{1z}l_1-c_{2z}l_2-c_{3z}u_{4x})z_1+k_{3z}l_5u_{4x}\dot{\alpha}_2-l_5c_{3z}u_{4x}\alpha_2\\ \quad -k_{1z}l_1\dot{q}_1-k_{2z}l_2\dot{q}_2-k_{3z}u_{4x}\dot{q}_3-c_{1z}l_1q_1+c_{2z}l_2q_2-c_{3z}u_{4x}q_3-m_2gu_{4x}=P_{1z}f_1l_1-P_{2z}f_2l_2\\ J_{2y}\ddot{\alpha}_2+k_{3z}l_5^2\dot{\alpha}_2-k_{3z}l_5\dot{u}_{4x}\alpha_2+c_{3z}l_5^2\alpha_2\\ \quad +k_{3z}l_5\dot{z}_1+c_{3z}l_5z_1-k_{3z}l_5u_{4x}\dot{\alpha}_1-l_5c_{3z}u_{4x}\alpha_1-k_{3z}l_5\dot{q}_3-c_{3z}l_5q_3=P_{3z}f_3l_5\end{cases}\qquad(2.33)$$

Comment:

In the system of equations (2.32) and (2.33), we find that: The displacement, acceleration of the center of the tractor and trailer depends on the deformation of the spring u4x and the deformation of the active wheel in the U2x route.

To investigate the system of equations (2.32) and (2.33) we must define the normal jet components on the wheels (defined in 2.1.3).

Chapter 3. COMPUTER LEARNING RESEARCH

3.1. Determine the parameters to solve the theoretical problem

The input parameters for solving the theoretical problem solved by the thesis by theoretical, experimental and inheritance of the research results of the published works [14], [8].

The thesis proposes a preliminary calculation of the hardness and drag coefficient of the soft coupling as a basis for examining the effect of the flexible coupling on the vertical dynamics. Calculated preliminary results: C4x = 243,541 N / m; (Ns / m).

Proceed to determine the center of gravity of the trailer after loading as the basis for dynamic survey along with the change of load. The results give the vertical and height coordinates are as follows:

$$l_5 = \frac{P_{Q_m}(L_m - l_{4m}) + P_{Q_g} l_{5g}}{P_{Q_m} + P_{Q_g}} \qquad (3.8) \qquad h_q = \frac{P_{Q_m} h_m + P_{Q_{S1}} h_{S1} + P_{Q_{S2}} h_{S2}}{P_{Q_m} + P_{Q_{S1}} + P_{Q_{S2}}} \qquad (3.12)$$

To solve differential equations, the thesis uses Matlab - Simulink software. The results of the differential equation solving program are shown in Figure 3.5

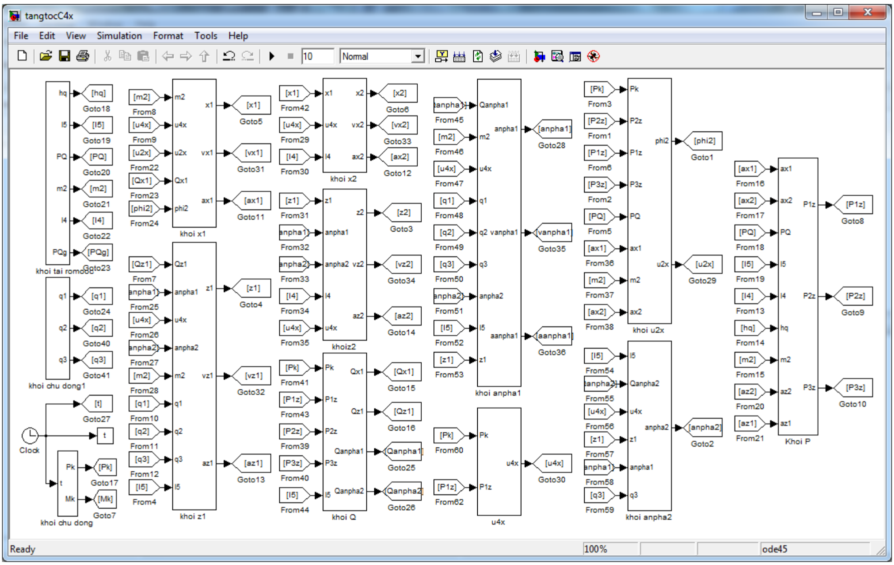

Figure 3.5. Program to solve differential equations using Matlab software – Simulink

3.2. Investigation on vertical dynamic the single axle trailer - four wheel tractor when accelerating

3.2.1. Investigation on the effect of spring stiffness in flexible coupling on normal jet of tractor front axle in case of acceleration

Proceed to solve the equation of kinetic dynamics of tractor using Matlab - Simulink software with the survey conditions: Geometric and structural parameters are taken as appendix 01 of the thesis; C4x = [150.000 200.000 220.000 250.000 300.000] N / m; with road condition type 3 in the experiment of identifying rolling resistance coefficient = 0.0161 and coefficient of grip = 0.7602; Bipartisans of sinusoidal road surface, q0 = 60 mm, s0 = 1 m; with horizontal road conditions: β = 0%; Wood Length: Lg = 4 m; Wood loading height: hg = 0.85 m; Calculated Load Volume: mg = 3,000 kg.

The results of a change in the normal range over time corresponding to the five values of the spring joint stiffness are shown in Figure 3.6

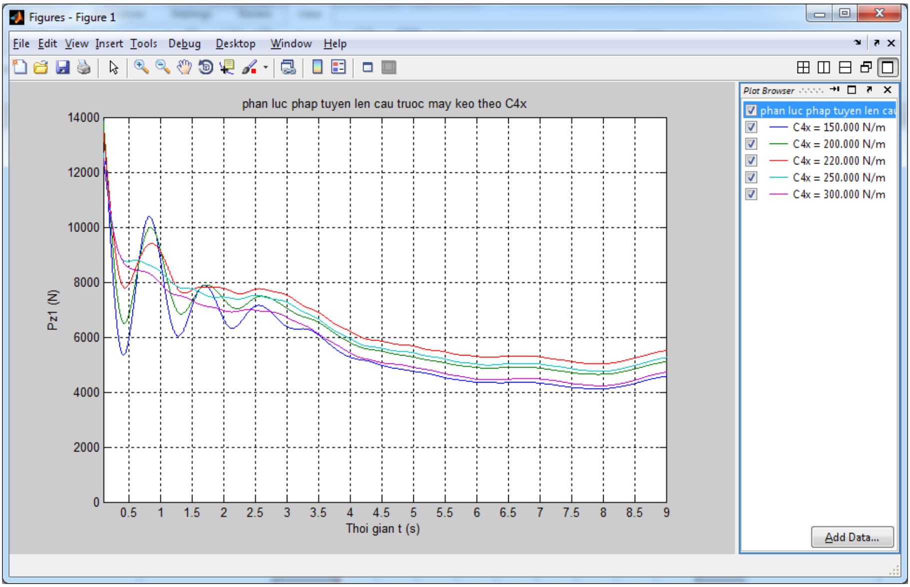

Figure 3.6. Normal deflection on the front of the tractor front with the spring stiffness values in the different joints.

Based on Figure 3.6, we see: When the accelerator coincides, due to the redistribution of load on the tractor's axles, the normal force on the tractor front axle decreases. The normal deflection on the front of the front of the tractor reduces depending on the spring stiffness in the soft coupling, however the change is not proportional. When the stiffness is too small and too large, the normal force on the bridge in front of the tractor decreases. From the above results, the thesis selects the spring hardness value in the soft coupling as C4 x = 220,000 N / m to observe the next parameters and to calculate the soft coupling design. Serve experimental research.

3.2.2. Investigate the effect of the drag coefficient of the soft coupling to the normal jet on the tractor front axle.

Investigate the effect of the drag coefficient on the normal jet with conditions similar to Section 3.2.1, but survey with C4x = 220,000 N / m; Ksx = [0 10.000 20.000 30.000 40.000] Ns / m.

The results of the survey of the normal range of change over the time corresponding to the 5 values of the coefficient of resistance of the coupling are shown in Figure 3.9.

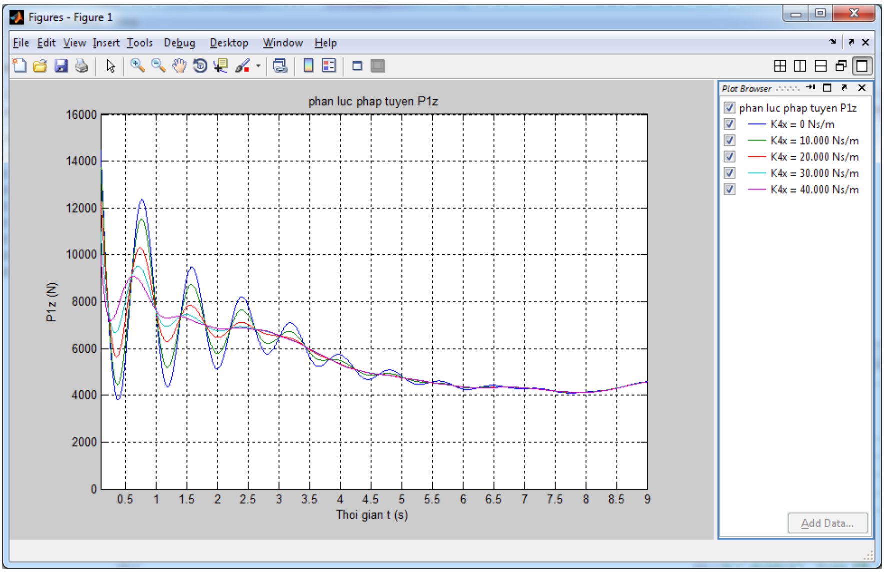

Figure 3.9. The normal force on the front of the tractor over time corresponds to the 5 values of the damping factor

From the results, the value of the damping coefficient influences the relative vibration quench rate between the tractor and the trailer without affecting the normal force value on the front of the tractor. The effect of the damping coefficient is to extinguish the vibration, so the we chose K4x = 30,000 Ns / m as the value for subsequent investigations.

3.2.3. Survey of normal force on the front axle, taking into account the effect of hard coupling, soft and deformation of the tire tires,

Conduct the calculation with the same parameters as in Section 3.2.1 and the case of using flexible coupling with the following values: C4x = 220,000 N / m; K4x = 30.000 Ns / m.

The results of the survey are determined as follows:

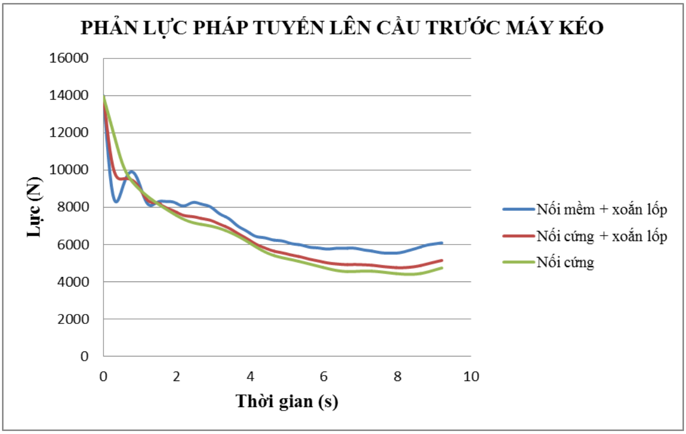

Figure 3.10. Normal deflection on tractor front axles in three cases: Hard coupling - hard coupling including tire twisting - flexible coupling including tire twisting

From Figure 3.10, it was found that, in three cases, the value of the normal reaction decreased as the momentum increased. However, in the case of hard hinges regardless of the linear tangential deformation of the active tire, the normal braking force will be reduced the most, with the softening of the joint being reduced to the tangential strain of the active tire being minimized. Where the soft coupling of normal jet values has varied in the initial stage before stabilizing.

3.2.4. Determination of safe working limits according to driving conditions (minimum value of anti-tractor minimum radial force) when using hard / flexible coupling

Conduct the calculation with the same conditions as in Section 3.2.1 and the slope of the pavement change β = [0 5 10 15 20]%. The results of the normal range of time-varying jetliners corresponding to the 5 different slope values along the road surface are shown in Figure 3.11 and Figure 3.12.

- Use of hard coupling:

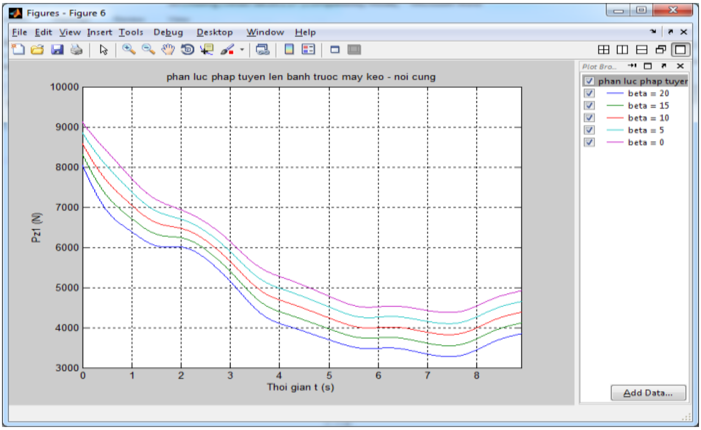

Figure 3.11. The normal counterbalance to the front of the tractor with the slope along the road in the case of hard coupling

- Use of flexible coupling:

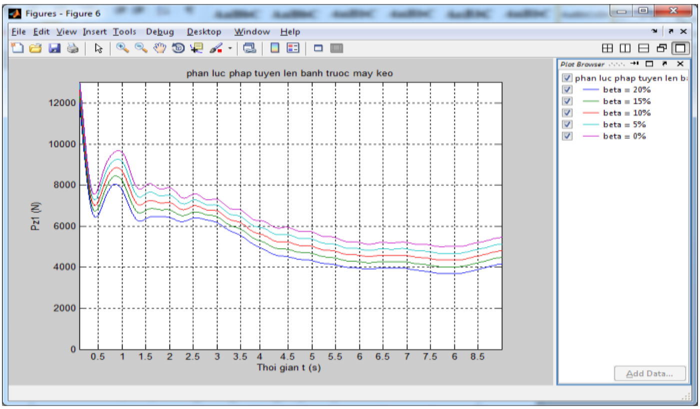

Figure 3.12. Regular deflection on the front of the tractor in front of the slope along the road in case of soft coupling

The results of the calculation of the normal value on the tractor front axle shown in Figure 3.13.

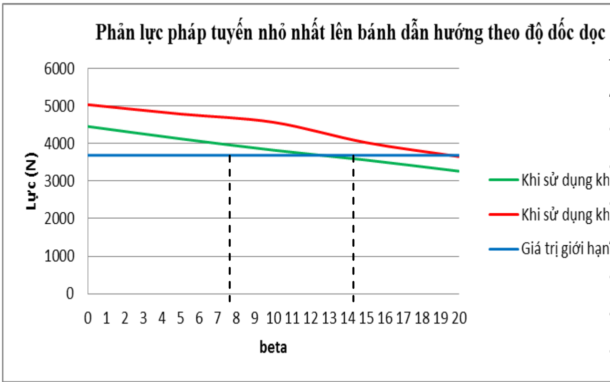

Figure 3.13. the smallest normal on tractor front axle by slope along the road surface in two cases of hard and soft coupling coupling

Compared to driving conditions (P1z-min> 0.25 PG = 3.690 N), the soft coupling improves the ability to work on sloping land along the road from 12.5% to 19.5. %.

3.2.5. Investigation of the impact of log lengths on normal force on tractor front axles using rigid couplings and soft couplings in case of acceleration on ramps.

The thesis constructing a graph expressing the minimum value of normal force on the tractor front in two cases of hard and soft coupling (Figure 3.16).

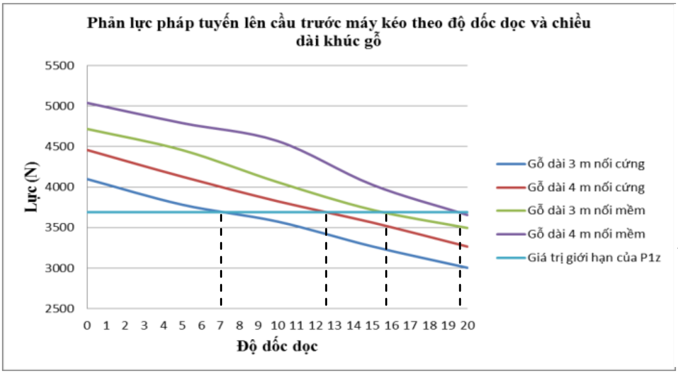

Figure 3.16. The smallest normal force on the front of the front of the tractor in slope along the road for two 3m and 4m long logs in two cases of hard and soft coupling.

Recommendation for users: If use a 3 meter long hard coupling + 3m long wood, working only on a maximum vertical slope of 7%; if Rigid couplings + 4m long type of wood, then working only on slopes of 12.5%; Soft couplings + 3m long type of wood, then working only on the slope of

15.5%; Soft couplings + 4m long, then wood working only on slopes of 19.5%;

3.3. Investigate the effect of flexible couplings on the braking process

The braking effect (braking time, slower acceleration, braking distance) and braking stability are studied to evaluate braking performance. Under limited research conditions, the thesis investigates and compares the braking time and braking distance of the tractor coupling in two hard and soft couplings with the most dangerous working conditions when braking is intermittent.

3.3.1. Theoretical basis evaluates the braking process

Using equation of traction equilibrium of tractors applied when braking on the road in the general case and regardless of wind resistance (slow speed combination should be ignored), we have:

$$P_j = P_f + P_p - P_i - P_{Cx} \qquad (3.16)$$

Of which: - Pj - inertia force when braking, $P_j = \delta' m_1 \ddot{x}_1$

- δ' coefficient of rotation effect on clutch break, in this case we assume $\delta' = 1$.
- $\ddot{x}_1$ acceleration of the tractor when braking, the solution of the differential equation (2.33).
- Pf - wheel rolling resistance, Pf = Pf1 + Pf2
- Ppp - brake force.
- Pi - slope resistance, Pi = PG
- PCx - force at coupling, calculated by formula (2.43).

We can rewrite (3.16) as follows:

$$m_1 \ddot{x}_1 = P_{1z} f_1 + P_{2z} f_2 + P_p - P_G \sin\beta - P_{Cx}$$

Transform (3.17) and determine the minimum braking distance and time according to (3.19) and (3.20).

$$t_{P\min} = \frac{m_1 v_1}{P_{1z} f_1 + P_{2z} f_2 + P_p - P_G \sin\beta - P_{Cx}} \qquad (3.19)$$

$$S_{\min} = \frac{m_1 v_1}{P_{1z} f_1 + P_{2z} f_2 + P_p - P_G \sin\beta - P_{Cx}} \qquad (3.20)$$

3.3.2.The results of the survey are determined as follows:

Conducting calculation, we receive results of brake distance and brake time in two cases of hard and soft coupling shown in Figures 3.21 and 3.22.

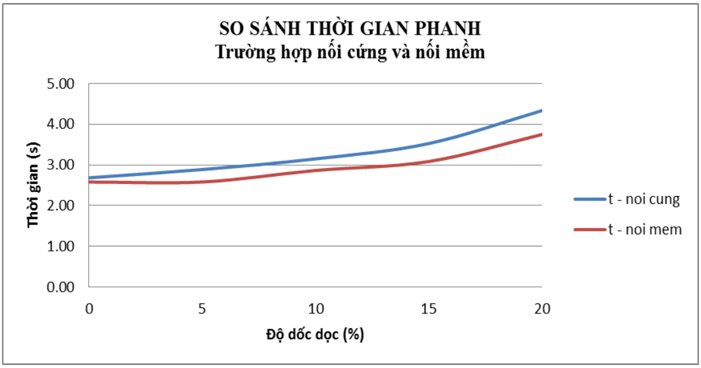

Figure 3.22. Comparing the results of brake time survey according to the vertical slope in two cases of hard and soft

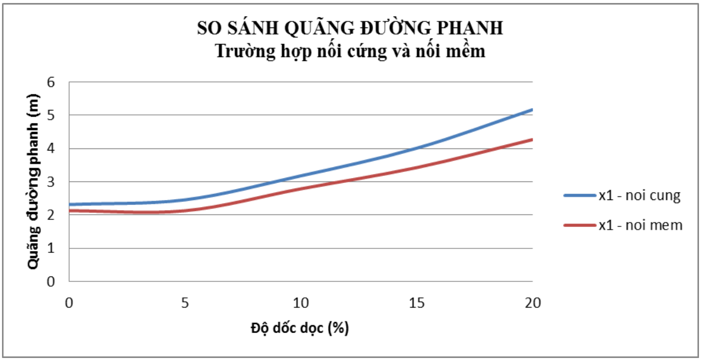

Figure 3.23. Comparing the results of braking distance according to the vertical slope in two cases of hard and soft joints.

Investigate the influence of soft couplings on braking distance and braking time on downhill. The results of the survey showed that when using the coupling, the braking time was reduced by 11,164%, the braking distance was also reduced by 15,239% compared to using the coupling in the case of different slope survey.

Chapter 4
EXPERIMENTAL STUDY

4.1. Objectives, tasks and objects of empirical research

4.1.1. Objectives of empirical research

The objective of the study was to determine the value of some parameters for solving the theoretical problems and to verify some of the results of the survey according to the theoretical model from which the credibility of the mathematical model was established. .

4.1.2. The task of empirical research

The task of empirical research is to: determine the drag coefficient of the tractor; Determination of drag coefficient of tractor; Determination of hardness and drag coefficient of tractor tires in tangential direction; Determine the torque on the axle of the tractor; Determine the normal road surface of the road ahead of the tractor; Determine acceleration in the direction of tractor and trailer movement; Determine the slippage of the tractor drive wheels in two cases using rigid couplings and flexible couplings.

4.1.3. Object of empirical research

The subject of empirical research is the shibaura 3000A four-wheel tractor combination and the axle trailer which is the product of the State-level research project KC 07/26. Between the tractor and the trailer are fitted with soft joints as shown in Figure 4.2

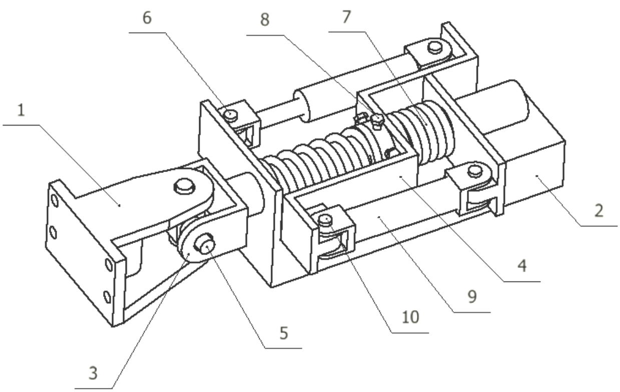

Figure 4.2. Flexible coupling between tractor and trailer
1. Suspension hook on tractor; 2. Trailer frame; 3. The shaft; 4. Z-frame; Cross coupling; 6. Locking between demarcation and demarcation;
7. Springs; 8. locating pin; 9. demoted parts; 10. Centered pins giảm chấn với khung chữ Z.

4.2. Measurement parameters, measuring methods and measuring devices

4.2.1. Roller coefficient and gripping coefficient

The thesis uses a motive force to pull the Shibaura 3000A rear-end tractor, between the tractor and the power source with the force gauge to record the results. In this case we use a Z4 force sensor connected to a computer-controlled DMCPlus signal acquisition and amplification system.

- For the case of deflection coefficient, we use the measured results in the velocity range of the machine complex at steady state. The results of rolling resistance and rolling resistance are stored in Appendix 4. After processing and calculating the rolling resistance, see Table 4.1.Bảng 4.1. Kết quả đo lực kéo và hệ số cản lăn

Types of road	P_{cl} (N)	f
1	2159,64	0,014905
2	2256,20	0,015571
3	2335,04	0,016116

- For the case of clamping factor, we use the measured results in the velocity range of the tractorat steady state. The results of Pb and clamping factors are stored in Appendix 05. After processing and calculation of rolling resistance, see Table 4.2.

Table 4.2. Tensile and tensile coefficients

Types of road	P_b (KN)	ψ
1	11,01445	0,76019
2	10,68236	0,73724
3	9,86572	0,68091

4.2.2. Measure the hardness and drag coefficient of tractor tires in tangential direction

The thesis uses the diagram shown in Fig. 4.9 to determine the stiffness and drag coefficient of the tractor in tangential direction

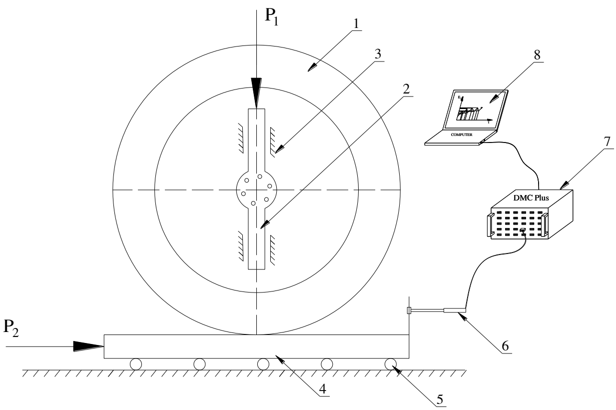

Figure 4.9. Diagram for determining the coefficient of stiffness and drag coefficient of tractor tires

1. Tractor tires; 2. vertical slider; 3. Stand slider stand; 4. horizontal sliding table; 5. rollers; 6. Movement sensor; 7. Equipment to collect, amplify measurement signals; 8. The computer has the

Experiment results

After the results of the experiment, the thesis proceeds to redraw the graph (Fig. 4.27), determining the quantities needed to calculate the hardness and coefficient of drag of the tire.

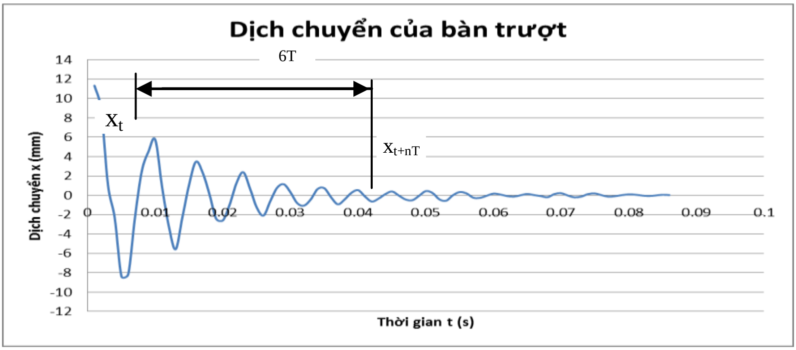

Figure 4.27. Slip oscillation graph of sliding table when testing the hardness and drag coefficient of tractor tire in tangential direction

From Figure 4.27 it can be seen that the sliding of the sliding table is in the form of a gradual decline. The data is saved in both numerical and graphical form so that the thesis can cite the data for calculating the stiffness and drag coefficient of the tractor tire in tangential direction. The calculated result is (Ns / m); (N / m).

4.2.3. Simultaneously determine the torque on the axle active, the normal jet on the front of the tractor front and the acceleratio

a. Research Methods

To measure the acceleration of tractors and trailers in motion, attach the standard Kisler acceleration sensor (Figure 01) and B12 / 1000 (Figure 2) to the appropriate position of the tractor and trailer.

Figure 4.12. Acceleration sensor

On the driving axle of the tractor, the thesis carries out the copy the model tractor, then stick resistance panel on driving axle , (figure 4.15). Use a suitable fetch method to connect to the DMC Plus measurement data acquisition and amplifier.

Calibrate the measurement by means of a comparison between the theoretical value of the torque and the torque measured by the self-test.

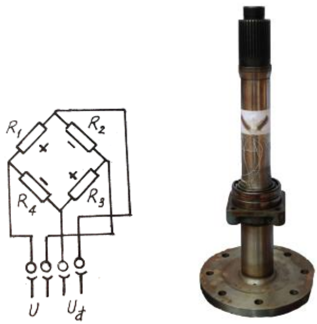

Figure 4.15. diagram of sensor

In order to measure the normal surface of the road on the front axle of the tractor, the thesis proceeds to paste the resistor tenzo onto the front sprocket of the tractor, and connect the resonant leaf to the resistive circuit diagram (Fig.). A sufficiently large resistance is connected to the DMC Plus metering and data acquisition equipment.

To calibrate the measurement, the thesis proceeds to place the entire tractor wheel on the standard force sensor (Figure 4.21). Then, the normal ground-to-center value of the jet is determined by the standard force sensor. Adjust the adaptation value so that the graph of the standard sensor coincides with the graph of the measurement.

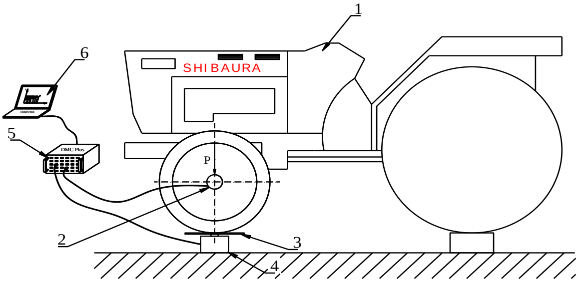

Figure 4.21. Diagram of the calibration of normal force measurement
1 - tractors; 2 - The tractor front bridge with the panel of the resistor; 3 - pads; 4 - standard force gauge; 5 - Equipment for collecting and amplifying measurement information; 6 - Machine tính;

b. Conducting experiments

For the simultaneous identification of four parameters: torque on the axle, acceleration of the tractor and trailer, normal road surface of the tractor on the road ahead of the tractor, the thesis establishes the program of measurement With DMplus Labplus software.

After setting up the measurement program with DMC Labplus software, we install and connect the measuring equipment.

Connect the measuring instruments to the DMC and connect the DMC to the computer.

Select the test line segment that was used to determine the drag coefficient and rolling resistance. Slope is 0%.

Conduct experiments with the same operator in different cases, the same control operation to ensure the same test conditions in the case.

c.Experimental results

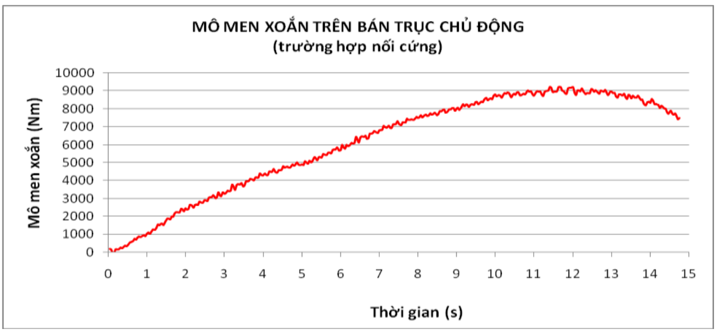

Figure 4.28. Momentary torque on the axle with hard coupling

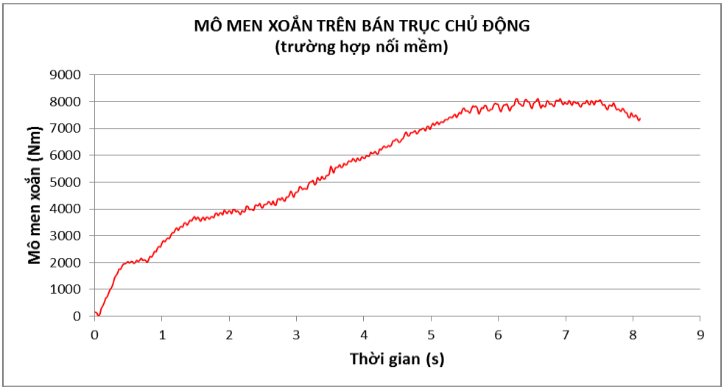

Figure 4.29. Momentary torque on the axle with flexible coupling

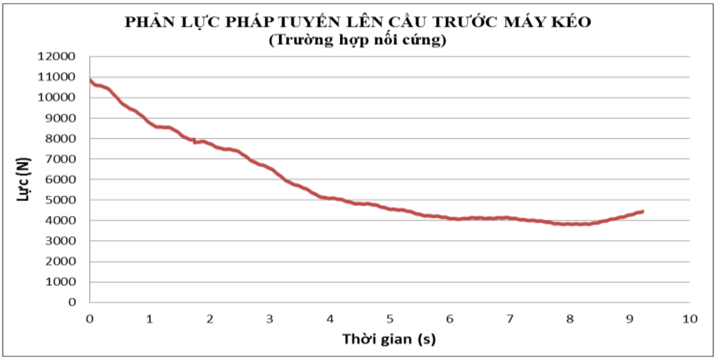

Figure 4.30. Normal force on the front axle with hard coupling

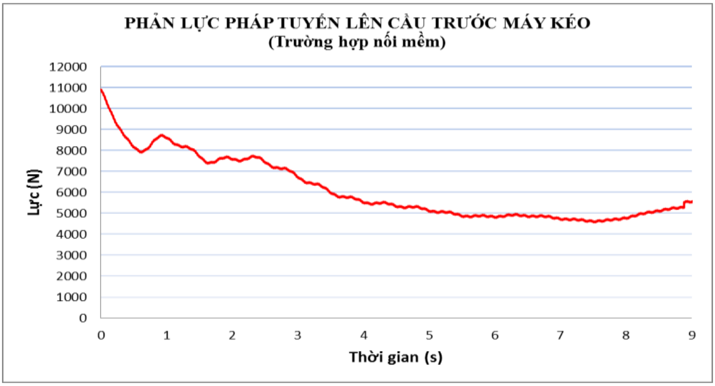

Figure 4.31. Normal force on the front axle with flexible coupling

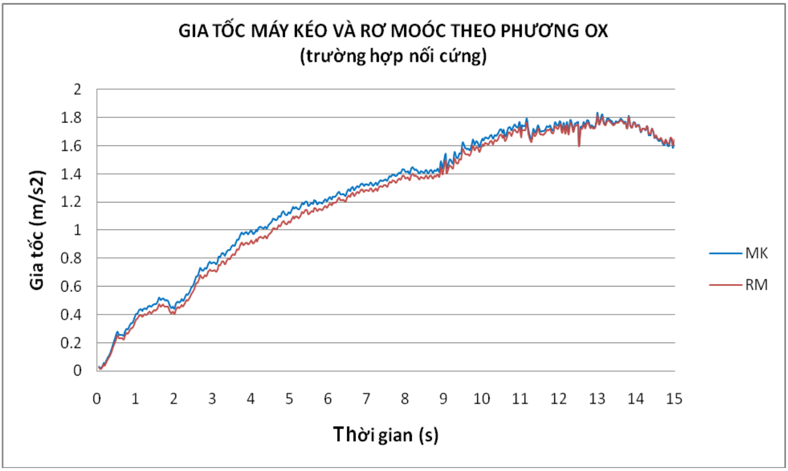

Figure 4.32. Acceleration of tractors and trailers in ox direction in the case of hard coupling

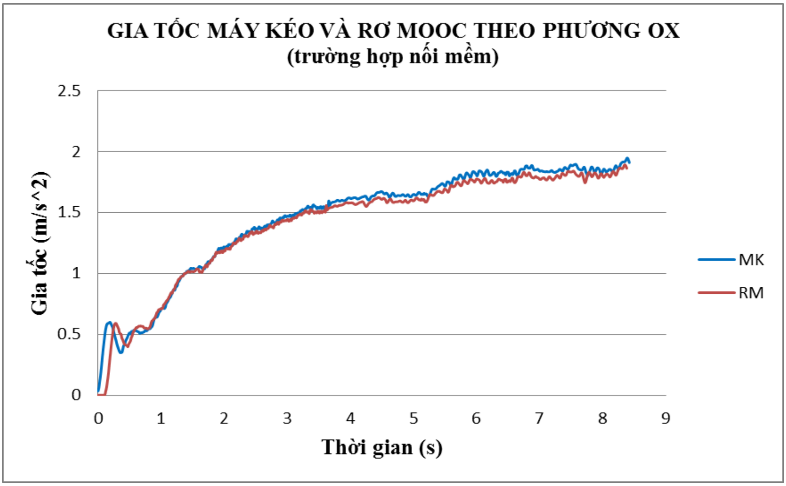

Figure 4.33. Acceleration of tractors and trailers in ox direction in the case of flexible coupling

4.5.5. Determine the sliding coefficient

To investigate the effect of soft couplings between tractor and trailer the thesis proceeds to determine the slip coefficient of the machine coupling in two cases using hard coupling and soft coupling.

Within the limits of the research, the thesis proceeds to determine the slip coefficient of the machine complex in two cases:

Slip coefficient when using hard coupling*:*

$$\delta_c = \left(1 - \frac{n_{0-c}}{n_{b-c}}\right).100\%$$

+ Slip coefficient when using hard coupling:

$$\delta_m = \left(1 - \frac{n_{0-m}}{n_{b-m}}\right).100\%$$

Where,

δ_c - - sliding coefficient when hard-wired as%;

δ_m - slope coefficient of soft coupling in%;

n0-c - number of idle revolutions of the active wheel when rigid;

n0-m - number of idle revolutions of the active wheel when soft;

nb-c - actual number of revolutions of the active wheel when rigid;

nb-m - the actual number of revolutions of the active wheel when it is soft.

Experiment results

Table 4.4. The results of the experiment determine the sliding factor of the case using hard couplings

Number of measurement	n_{0-c} (round)	n_{b-c} (round)	δ_c (%)
1	736.4	817.2	9.887
2	737.6	819.5	9.994
3	734.8	822.8	10.70
Average value			10.192

Table 4.5. The results of the experiment determine the sliding factor of the case using flexible couplings

Number of measurement	n_{0-c} (round)	n_{b-c} (round)	δ_c (%)
1	734.4	785.2	6.470
2	735.8	781.5	5.848
3	732.9	783.8	6.494
Average value			6.270

Comment:

From the results of determining the sliding coefficient in two cases of hard and soft coupling, the sliding coefficient in the case of soft coupling is lower than the case of the other. Specifically: the case of hard coupling coefficient sliding average of 10,192%, the case of flexible coupling coefficient slider is 6.270%.

CONCLUSION AND RECOMMENDATION

Conclusion:

1. A vertical dynamic computational model of a four-wheel tractor with a single axle trailer has been constructed with flexible coupling and includes the tangential distortion of the active wheel. This is the basis for studying the vertical dynamics.

2. Design and manufactur flexible couplings between tractor and trailer with C4x hardness = 220,000 N / m and K4x drag coefficient = 30,000 Ns / m for theoretical and empirical calculation.

3. Investigate the effect of flexible coupling to normal force on the front of the tractor when accelerated up the slope. The results show that, as more flexible couplings will increase the normal reaction to the front of the tractor. Hence, the coupling condition of the tractor joint from the maximum vertical slope is 12.5% and up to 19.5% with flexible coupling.

4. Investigate the effect of flexible coupling to the braking process. The results showed that, when using a flexible coupling, it would reduce 11,164% of brake time and 15,239% of braking distance compared to using hard couplings.

5. Design and manufactur the experimental frame, conducted the experimental research and determined the hardness and drag coefficient of the active gear in the tangential direction, the rolling resistance coefficient and the gripping coefficient of the tractor, Torque on the axle of the tractor. Determine the sliding of the active wheel in the case of flexible coupling compared to the hard coupling from 10,192% to 6,270%.

6. Design, fabricat and calibrate the torque measured on the axle, ; Experimental research identified parameters to verify the theoretical results: tractor and trailer speed accuracies in the Ox, normal to the tractor front axle. Comparing the results with the theoretical study shows that the law of change

of velocity, the normal reaction between theoretical and empirical research is the same; The error between theoretical and empirical research of the normal reaction force when rigid: 6.48%; The error of the normal reaction when using flexible coupling is: 8.19%.

Recomendation:

1. Based on the results of the study, the flexible coupling need to be added (C4x = 220,000 N / m, K4x = 30,000 Ns / m) to improve the structure of the tractor.

2. Within the framework of this thesis, the author concentrates on studying the effect of structural parameters coupling to the normal reaction. In order to improve the efficiency and safety of the tractor, the thesis recommends the further study on trailer tractors with coupling in diferent condition of road surfaces, including the sliding of the driving wheels

LIST OF THE PUBLICATIONS

1. Tran Van Tung, "Vertical dynamics of a four-wheel tractor with single axle trailers", Journal of Agriculture and Rural Development, 23, 2016, pp. 132-139.

2. Tran Van Tung, "Experimental study identifies some dynamic parameters of shibaura 3000A tractor trailer with single axle trailer", Journal of Vietnam Engineering, No. 9, 2016, pp. 46-52. .