Experimental Analysis Considered the Dynamics of Mobiles Agricultural Aggregates

Mihaela-Florentina DAVID, Gheorghe VOICU, Ladislau DAVID, Carmen-Otilia RUSĂNESCU

1) Faculty of Biotechnical Systems Engineering, “Politehnica” University of Bucharest
313 Splaiul Independentei, Bucharest, Romania; davidmihaela1978@yahoo.com, ghvoicu_2005@yahoo.com

Abstract. When working with agricultural mobile aggregate, the traction force of equipment and the speed of the real movement vary due to actual terrain irregularities, appearing also vibration of the gears axes and of the tractor chassis.

Starting from these considerations, the paper presents results of experimental tests to move on agricultural land of a aggregate consists of a U-650M tractor and of a trees vineyard attachment RPV-2, on the push force of the attachment on the gear-shift bar to the tractor, traction force, vibration acceleration in three points on the tractor and tractor skidding for three different speeds of travel.

It shall, also the testing equipment and how to catch the gage for acquisition the necessary data records.

Using known relations in the study of the dynamics of the mobile aggregates, was achieved a modelling program of the traction parameters, in MathCad program, with which help were determined and set graphic the variations of the push force on the gear-shift bar, the traction force and the vibration acceleration to the steering wheel of the tractor. Based on experimental results obtained, the calculation program was checked and improved.

The results presented in the paper are of interest to specialists in the study of the dynamic agricultural mobile aggregate, and the modelling program developed can be used to determine the parameters for the traction and for other types of aggregates to the movement on land with other features than used and tested.

Keywords: mobile agricultural aggregate, tractor, attachment, data acquisition sheet, experimental tests, time, velocities, accelerations.

INTRODUCTION

The main objective of experimental testing, constitute the checking and the rectification of the programmer of modeling from the study of the dynamics of mobiles agricultural aggregate.

The modeling of mobiles agricultural aggregate will achieved considering the traction force that is necessary to displace the mobile agricultural aggregate is constant. In reality, this traction force is variable because of the irregularity of the field. In time of the experimental testing is recorded the variation of traction force when the aggregate is moving. This variation will be approximate with a function that is a sinusoidal shape and in the programmer of modeling of the mobile agricultural aggregate are introduced the relations of calculation of the traction forces for three rates of travel of the aggregate.

It checked if the experimental values of the steering wheel accelerations and of the driving wheel accelerations of the tractor correspond of the calculated values with the programmer of modeling.
From the rectified the programmer of modeling the dynamics of mobiles agricultural aggregate, who moved on the field with known parameters, will be determinate, for each velocity stage. The following parameters: the traction force, slipping coefficient, real velocity of move, time consumption and the effective specific fuel consumption, the accelerations and the oscillations amplitudes of the steering wheels and the driving wheels of the tractor.

THE DESCRIPTION OF THE EXPERIMENTAL INSTALLATION

For performed the experimental testing we used a mobile agricultural aggregate formed by U-650 M tractor and the agricultural attachment RPV – 2 (fig. 1).

![Mobile agricultural aggregate](image)

Fig. 1. The mobile agricultural aggregate used at the experimental testing

For measurement and recording the parameters who define the dynamic behaviors for the considered mobile agricultural aggregate we used the following equipment:

- 486 DX Professional Computer;
- Data acquisition sheet;
- Inductive accelerometer type B 12/200 (Hottinger);
- Draw bar for U – 650 M tractor;
- Fifth gear for establishing of predicted rate of movement of aggregate.

In Fig., 2 are presented the assembly of the accelerometers for recording of the acceleration of the steering wheel and the driving wheel of the tractor.

In Fig., 3 are presented the assembly of additional wheel for the determination of a predicted rate of movement of the tractor.

In Fig., 4 are presented the draw bar with measuring head of the traction force and the pressing force of the attachment, as well as the mount of the data acquisition system.
Fig. 2. The mount at the measuring head of the acceleration of the steering wheel and driving wheel of the tractor.

Fig. 3. The mount at the additional wheel.

Fig. 4. Draw bar with the force cells and the mount of the data acquisition system.
THE MANNER OF THE PROGRESS OF THE TESTS

The experimental tests were in November 2006 on the field path with the following parameters:

- The amplitude of the dishevelment: 0.06 m;
- The length for the dishevelment: 0.039 m.

The predicted rates for the movement at the mobile agricultural aggregate were: 6.54 km/h, 8.95 km/h, 12.32 km/h. The mobile agricultural aggregate it was started in one of the predicted rates who was mentioned and after the aggregate reached the stationary regime of working (after 15 – 20 seconds) it was done, for a 15 seconds length, the following recordings:

- The traction force;
- The pressing force of the tractor attachment;
- The acceleration of the front bridge of tractor;
- The acceleration of the back axle of tractor;
- The acceleration of the mass point of tractor;
- Number of rotations of steering wheel;
- Number of rotations of fifth gear.

Results are presented in graphs and tables. The mobile agricultural aggregate, for each rate of travel made two successive of tests.

PROCESSING AND INTERPRETING OF THE EXPERIMENTAL TESTS

In table, 1 are presented the recordings performed for determination of the real velocity of movement, of predicted rate and of the skidding of steering wheels of the tractor.

![Table 1](image)

For each stage, velocity had done two experimental tests on 15 seconds time. The tests performed it done the following recordings:

- Number of rotations of steering wheel (N);
- Number of rotations of fifth gear (Ns);
- The experimental test time: 15 seconds.

For each experimental test it was calculated the real velocity of movement with the relation:

$$v_r = \frac{2 \cdot \pi \cdot N \cdot r}{l}$$

and the predicted rate of movement:
\[ v_t = \frac{2 \cdot \pi \cdot N_s \cdot r_s}{t} \]  

(2)

where:  
- \( r \) - is the dynamic radius of the steering wheel;  
- \( r_s \) - is the radius of the fifth gear;  
- \( t \) - time of experimental test.

For the calculation of skidding of steering wheel of tractor it was used the relation:

\[ \delta = \frac{v_f - v_r}{v_f} \cdot 100 \quad [\%] \]  

(3)

From each of the six experimental tests are recorded the acceleration of the steering wheel, the acceleration for the driving wheel, the traction and the pressing force. For each of the six tests with 15 seconds time, had done 15000 recordings for each of the measurements amounts.

For a measuring fault of acceleration of 0, 65 and a degree of reliability of 90% were selected 76 values that are corresponded at the done tests at an interval of time of 0, 2 seconds. For the mobile agricultural aggregate velocity of 12,321 km/h presented in figure 5 the variation of the pressing force of agricultural attachment on the coupling eyelet with the tractor and the variation of the traction force.

For the traction and pressing force on the coupling eyelet of the agricultural attachment, have followed to obtain some function that approximated the variation of these.

For the three predicted rates of movement of the mobile agricultural aggregate who was tested, we calculated the medium values, the amplitude, the period and the oscillatory pulsation of the traction force and the pressing force presented in tables 2 and 3.

The mathematical relations who approximate the variation of traction force necessary to movement of mobile agricultural aggregate are:

\[ v = 6,54 \text{ km/h} \quad F_t = 118.4 + 95.37 \cdot \sin(8.64 \cdot t) \quad [\text{daN}] \]  

(4)

\[ v = 8,95 \text{ km/h} \quad F_t = 162.8 + 145.12 \cdot \sin(9.67 \cdot t) \quad [\text{daN}] \]  

(5)

\[ v = 12,32 \text{ km/h} \quad F_t = 133.55 + 144.88 \cdot \sin(9.89 \cdot t) \quad [\text{daN}] \]  

(6)

The calculation relations of the pressing force are:

\[ v = 6,54 \text{ km/h} \quad F_a = 267.5 + 38.45 \cdot \sin(9.04 \cdot t) \quad [\text{daN}] \]  

(7)

\[ v = 8,95 \text{ km/h} \quad F_a = 246.15 + 55.2 \cdot \sin(9.82 \cdot t) \quad [\text{daN}] \]  

(8)

\[ v = 12,32 \text{ km/h} \quad F_a = 232.55 + 80.68 \cdot \sin(10.06 \cdot t) \quad [\text{daN}] \]  

(9)

The calculations of the traction and pressing force on the coupling eyelet are introduced in modelling programme of the dynamic mobile agricultural aggregate.

With the modelling programme of an mobile agricultural aggregate, particularized for RPV 2 attachment, are calculated the acceleration of steering wheel and the acceleration of the driving wheel for the three predicted rates of movement.
Fig. 5. The variation of the pressing force of the RPV – 2 attachment on the coupling eyelet and the tractio force for $v = 12.32$ km/h

The parameters of the traction force determinate on base of experimental dates

<table>
<thead>
<tr>
<th>Velocity [km/h]</th>
<th>Average [dan]</th>
<th>$\sigma$ [daN]</th>
<th>Amplitude [daN]</th>
<th>Period [s]</th>
<th>$\omega$ [rad/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.54</td>
<td>102.1</td>
<td>142.1</td>
<td>88.827</td>
<td>0.764</td>
<td>8.224</td>
</tr>
<tr>
<td></td>
<td>134.7</td>
<td>189.5</td>
<td>101.928</td>
<td>0.694</td>
<td>9.053</td>
</tr>
<tr>
<td>8.95</td>
<td>141.5</td>
<td>208</td>
<td>153.188</td>
<td>0.708</td>
<td>8.87</td>
</tr>
<tr>
<td></td>
<td>181.1</td>
<td>254.6</td>
<td>137.066</td>
<td>0.6</td>
<td>10.47</td>
</tr>
<tr>
<td>12.32</td>
<td>119.7</td>
<td>197</td>
<td>144.472</td>
<td>0.682</td>
<td>9.213</td>
</tr>
<tr>
<td></td>
<td>147.4</td>
<td>240.9</td>
<td>145.303</td>
<td>0.594</td>
<td>10.577</td>
</tr>
</tbody>
</table>

The parameters of the pressing force determinate on base of experimental dates

<table>
<thead>
<tr>
<th>Velocity [km/h]</th>
<th>Average [dan]</th>
<th>$\sigma$ [daN]</th>
<th>Amplitude [daN]</th>
<th>Period [s]</th>
<th>$\omega$ [rad/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.54</td>
<td>263.4</td>
<td>266.5</td>
<td>36.534</td>
<td>0.724</td>
<td>8.678</td>
</tr>
<tr>
<td></td>
<td>271.6</td>
<td>275.9</td>
<td>40.371</td>
<td>0.668</td>
<td>9.406</td>
</tr>
<tr>
<td>8.95</td>
<td>257.3</td>
<td>269.4</td>
<td>60.676</td>
<td>0.644</td>
<td>9.756</td>
</tr>
<tr>
<td></td>
<td>235</td>
<td>243.8</td>
<td>49.737</td>
<td>0.636</td>
<td>9.88</td>
</tr>
<tr>
<td>12.32</td>
<td>207.1</td>
<td>223.9</td>
<td>80.539</td>
<td>0.658</td>
<td>9.549</td>
</tr>
<tr>
<td></td>
<td>258</td>
<td>277.1</td>
<td>80.829</td>
<td>0.594</td>
<td>10.577</td>
</tr>
</tbody>
</table>

In table 4 are presented the amplitudes of steering wheel and of driving wheel experimental determinate and calculated with the modeling programmer of mobile agricultural aggregate.
The experimental and calculated acceleration of the steering wheel and of the driving wheel of a tractor are presented in table 4.

<table>
<thead>
<tr>
<th>Velocity [km/h]</th>
<th>Acceleration of steering wheel [m/s²]</th>
<th>Acceleration of driving wheel [m/s²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exp.</td>
<td>Calculated</td>
</tr>
<tr>
<td>6.54</td>
<td>3.874</td>
<td>3.39</td>
</tr>
<tr>
<td>8.95</td>
<td>4.213</td>
<td>4.56</td>
</tr>
<tr>
<td>12.32</td>
<td>4.761</td>
<td>4.4</td>
</tr>
</tbody>
</table>

The real medium velocity of movement of the mobile agricultural aggregate and the medium coefficient of backlash, experimental and calculate determinate with the modelling programmer are presented in table 5.

<table>
<thead>
<tr>
<th>Predicted rate [km/h]</th>
<th>Medium real velocity [km/h]</th>
<th>Medium backlash coefficient [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exp.</td>
<td>Calculated</td>
</tr>
<tr>
<td>6.54</td>
<td>6.5</td>
<td>6.47</td>
</tr>
<tr>
<td>8.95</td>
<td>8.885</td>
<td>8.81</td>
</tr>
<tr>
<td>12.32</td>
<td>12.235</td>
<td>12.25</td>
</tr>
</tbody>
</table>

CONCLUSIONS

At least of the experimental tests of the mobile agricultural aggregate are done the following conclusion:

• The recording of the variation of the traction force and of the pressing force of the agricultural attachment on the coupling eyelet permitted determination of relations who permit the calculation of these for each moving velocity of aggregate;
• Frequency of the traction and pressing force oscillation are 1,3–1,68Hz
• The programmer who permit the calculation of the dynamic parameters of the mobile agricultural aggregate corrected with the mathematic expressions of the traction and pressing force determinate from the experimental tests, permit the calculation of the real velocity, the backlash of the driving wheel, the accelerations of the steering wheel and driving wheel;
• The miscalculations of the accelerations of the steering wheel are in 7,58-12,5% limits, and the miscalculations of the accelerations of the driving wheel are in 4,4-13%;
• The miscalculations of the movement at the real velocity of the mobile agricultural aggregate are smallest for 1% given at the medium values experimental determinates and the miscalculations of the backlash coefficient given at the experimental determinates medium value is in 4,9-18% limits;
• Are estimated that the values obtain with the modeling programmer of the mobile agricultural aggregate for the oscillations amplitude of the steering wheel, and driving wheel are very close of the experimental values;
• The modeling programmer permits the determination of time consumption and the effective specific fuel consumption for can appreciated the economic of using at the mobile agricultural aggregate;
The modeling programmer of the mobile agricultural aggregate, particularized for a special tractor and an agricultural machine at the movement for a custom field, will be use when the movement at the aggregate is done for other type of field. In this way are determinate the dynamics and economics parameters of the aggregate without be necessary the performance of other tests.

REFERENCES