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Improvement Stability Control Theories for Agricultural Transport Systems

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Abstract

The design and management of farming transport systems is facing a series of defy. The target of growing vehicle mobility and reduction soil stress has always been in the center of notice. Comprising trailer wheels in the generate of pulling force could be beneficial in both cases. In this way, the mobility of the transport system could be secured even in heavy soil situation, and the soil damage could be reduced.

In spite of the potential features, trailer bump is not presently practical. The cause for this is the shortage of proper integrity measures. The origin of this problem is the force produced by the trailer protrusion effective on the drawbar, which can bring the tractor into an unstable state, causing the tractor to curl over or the vehicle train to jack-knife.

To avert such incident, a control system must be advanced which can realize the beginning of unstable vehicle behavior and either by admonition or intervention help to keep the stable state of the vehicle.

Keywords: *Vehicle-train; agricultural transport systems; stability.*

1. Introduction

The aim of this paper is the stabilization analysis of transport vehicle combinations include agrarian tractors and propelled axle trailers, and the lessening of an incident related to the trailer drive. Special solicitude has been paid to the accidents caused by the trailer protrusion. In order to accomplish the stability growing, I have progressing a computer paradigm of a transport vehicle park, which is capable of perform dynamical simulations of transport vehicle trains and which can be the basis for improve stability control notions. Propelled axle agricultural trailers, and the related problems:

Tractors implicated in weighty agricultural transporting tasks are ballasted by additional weights in order to make it tolerable to produce the pulling force which is required to shift the trailer in heavy soil situation. In my estimation instead of ballasting the tractors, it could be more useful to involve the wheels of the trailer in the force improve to move the train.

This could secure the mobility of the transport system in heavy soil status, and the soil harm could be reduced as well.

Include the wheels of the trailer in the produce of the dragging force has the following conceivable advantage:

- Despite the public tendency towards growing power in agricultural machinery, the weightiness of the tractor can be reduced.

- By means of optimized weightiness and driving torque allocation, soil harm, environmental defilement and process costs can be minimized.

- By making the transport system more autonomous from soil conditions, harvest losses can also be minimized.

In spite of the potential features, because of the shortage of safety measures, trailer protrusion is not part of feasible life. The radix of the problem is that the trailer can produce a side force on the posterior wheels of the tractor, which under confirmed conditions can get the tractor into an unstable case. The trailer can reason the tractor to roll over or to jackknife.

The inference can be drawn, that the tractor-trailer vehicle set can only be applied when it is prepare with a control system that can avert the trailer drive created accidents to happen.

The goals of this paper can be concise as follows

– To Preparation a computer simulation model of an agricultural transport vehicle-park include different dynamical models of tractors and trailers.

The goals of this model parkis to accomplish stability analysis of tractor – propelled hub trailer vehicle set.

– To introduce stability criteria equations for future stability control programs which can determine different unstable states, and by interaction can re-stabilize the vehicle combinations.

2. The Models Used for improving the Stability-Programs

The models I have advanced in Mat lab/Simulink milieu are formed for this work. The models are progressing in a modular system so that they can be applied for the simulation of other kinds of vehicles in addendum to agricultural transport systems. Pending the evolution phase, special anticipation of agricultural transport systems have been taken into regard.

2.1 The Vehicle Model Park advanced for the Task

In order to model agricultural transport systems, I have advanced dynamic models of various tractors and trailers. From the model, vehicle collections can be created as in the truth.

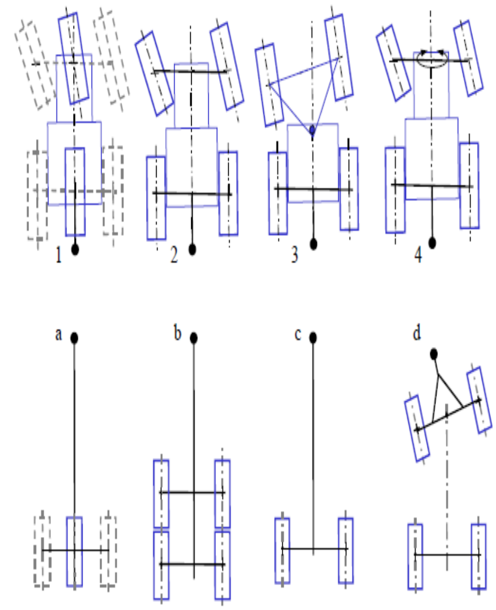

Figure 1: Vehicle Model Park

Figure 1 shows the paradigmed agricultural transport vehicle park. Available tractorsare a single-track tractor (1), a system-tractor (2), a joint-tractor (3), and acommon ploughing tractor (4). The trailers available are a single-track trailer (1), asemi-suspended tandem axle trailer (2), a semi-suspended single axle trailer (3),and a pulled trailer (4).

The models are formed in a Matlab/Simulink environment and determined in a modular system. This warranty that different sub-models can be varied within models, and modern model units (like a trailer behind a car, a plough behind an agriculturaltractor, or a diverse tractor) can be inserted in the vehicle model if the simulationgoals require it.

I have formed an animation-window, which helps via simplified schemas of the vehicles to pursue the motion of the vehicle train. It has allusion for the state of the stability control system, and helps to produce animations for demonstration purpose.

2.2 placement of the Pulling Angle

Pulling angle: (Also two angle (ProPride Inc.)) The horizontal compound of the angle between the pulling and the pulled vehicle. Notation: γ (o or rad)

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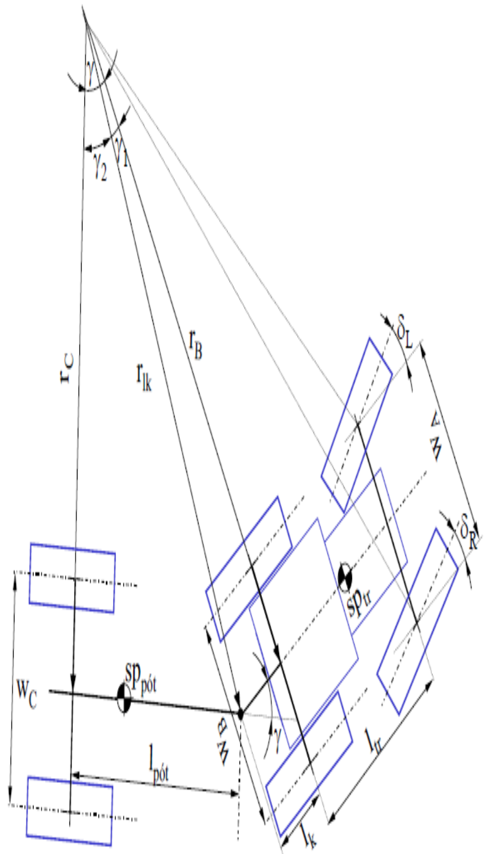

Figure 2: The extended Ackermann-condition of vehicle trains

One mode of determining the status of the vehicle is rely on scale the pulling angle and contrast its value to the expected one. To determine the expected value of the pulling angle, I have inserted the extended Ackermann conditions of drove wheel angles to vehicle trains. Figure 2 shows a tractor and trailer connected to it. The angles of the steered wheels (δL,δR) are calculated in the conventional manner of Ackermann's method (Ackermann, 1990).The Ackermann provision of vehicle train is accomplish when not only the axles of the wheels of the tractor but also the wheels of the trailers are formulation in the theoretical turning center (moment an Centrum). The stat pull-angle in the fixed.

Curving can then be studied using the notations of Figure 2 as follows:

$$\gamma_{stat} = \gamma_1 + \gamma_2 \tag{1}$$

Where

$$\gamma_1 = \arctan\left(\frac{l_k}{r_B}\right) \text{ and} \tag{2}$$

$$\gamma_2 = \arcsin\left(\frac{l_{pót}}{r_{lk}}\right) = \arcsin\left(\frac{l_{pót}}{\sqrt{(l_k^2 + r_B^2)}}\right). \tag{3}$$

Equations (2) and (3) substituted in eq. (1):

$$\gamma_{stat} = \arctan\left(\frac{l_k}{r_B}\right) + \arcsin\left(\frac{l_{pót}}{\sqrt{(l_k^2 + r_B^2)}}\right) \tag{4}$$

The turning radius of the rear axle is:

$$r_B = \frac{l_{tr}}{\tan(\delta_L)} + \frac{w_A}{2} \tag{5}$$

The calculated steady state pulling angle is equivalent only in steady curving with the real pulling angle. The cause for this is that in contrast to the δL, δR steering angles of front wheel of the tractors, which promptly occur as the steering wheel is upset, the pulling angle is unceasingly variable as the vehicle moves. To arrive its steady state value, the vehicle has to nomad a certain distance.

My aim was to establish a model or equation which depict the actual value of the

Pulling angle, not only in steady but also in transient state.

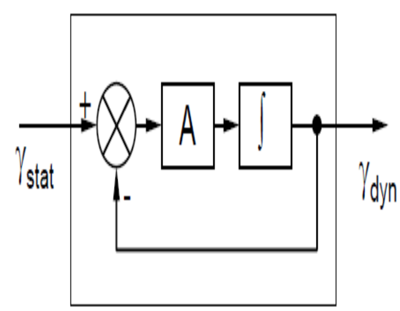

Figure 3: Determination of γdyn actual pull-angle based on the γstat steady-state pull-angle

Determination. In this situation, the matrix A is simplified to scalar, and its value is the

Alternative of the time desired by the rearward axle of the trailer to reach the position of the rear axle of the tractor.
In equation:

$$A = \frac{v_x^{tr}}{l_{pót} + l_k}, \qquad (6)$$

Wherever X is the speed of the tractor (in m/s), pót k l + l is the range of the axles of the tractor and the trailer (in meters).
The factual value of the pulling angle in a differentiation equation form:

$$\frac{1}{A}\frac{d\gamma_{din}}{dt} + \gamma_{din} = \gamma_{stat} \qquad (7)$$

The settling of the equation count on the input function (γstat). Employ a step
Input function with the gage of γstat, the equation of γdin output will be:

$$\gamma_{din} = \gamma_{stat}\left(1 - e^{-At}\right). \qquad (9)$$

2.3 Stability Determination

The stability limiting functions are logical standard functions of which the amount is 0 if the vehicle behaves as prospective, and 1 if instability is adjusted.
The general compose of the criteria an equation is:

$$stab = \begin{cases} 0.\mathit{if}\ expected < expected_{min} \vee measured \in \left[expected_{low} \ldots expected_{high}\right] \\ 1.\mathit{if}\ expected > expected_{min} \wedge measured \notin \left[expected_{low} \ldots expected_{high}\right] \end{cases} \qquad (10)$$

Where:
- For useable is the studied value of the stability limiting parameter.
- expected min is the beginning value of the expected parameter. If measured
Lower is prospective, then no stability effectiveness is done,
- Expected low is the minimize limit of the reference band applied in the arbitrage of
Expected and measured values,
- Expected high is the maximum limit of the reference band applied in the arbitrage of
Expected and measured values.
The expected values and the stability setting method can then be established

In vehicle and Fuzzy logic controller designing, and its implementation as an embedded system can be deemed as well.

3. Validations by Field Measuring

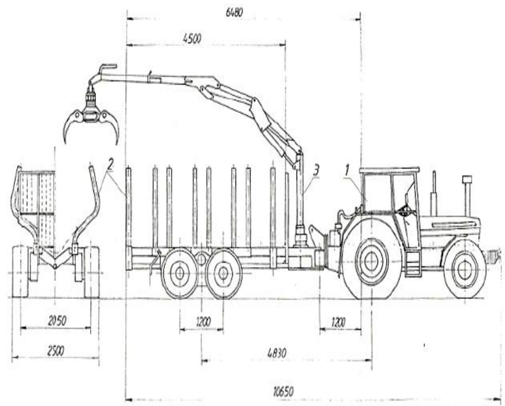

Figure 4: Schematic design of the measured tractor-trailer set

3.1 Combined Braking and Steering Test

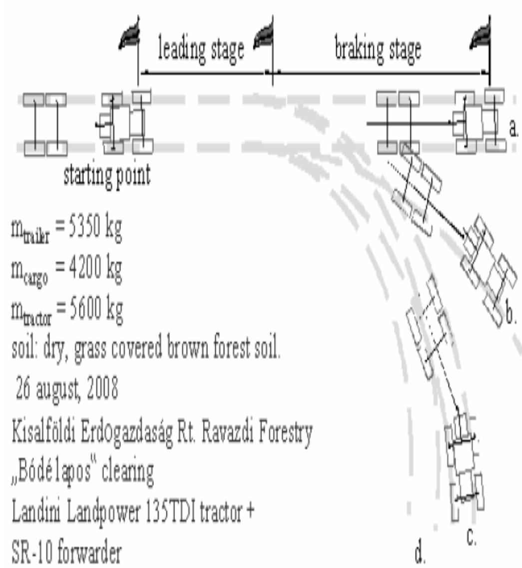

Figure 5: Measuring stages of the joint braking and steering test

I have done the effectiveness using a vehicle set consisting of a Hungarian made SR-10 kind propelled axle forwarder connected to a Landing power agricultural caterpillar.
The measures were performed on the lands of the forestry the measuring track is shown in the

Figure 5. The steady-state phase is 30 lengthy, and the brake stage is also 30 meters.

The steering angles are from a to d 0, 7, 15, and 28 degrees.

The measurements were performed on a dryish, sunny day, with temperatures in the extent of 20-23oC. The soil was a brown forest soil, always maintained, grass enveloped clearing. Pending the taking of the measurement, data were partly manually and partly electronically registered. The measuring combination became a code for further pairing of the identical manually and instrumentally registered data.

The vehicle-train, after pre-stage journeys, at the second stage either advanced straight ahead or took a curve with the steering wheel overturned to 7, 15 or 18 degrees (a-d difference in the Figure 5), whilst at the same time decelerating to still-pause by the smooth implementation of the brakes. The measurement is persistent till the still-stand of the vehicle. Pending the measurement, the steering-wheel angle, the pulling angle, and the acceleration were registered by a data registering system, and the number of the rotations of the wheels, the time wanted to pass stages 1 and 2,the speed of the tractor, and a trigger signal were registered manually. Having finished the first series of measure, two similar combinations of measurements followed. In this way three recurrences were performed.

The target of the test is to locate the accelerations, wheel slips and curving stability while braking and joint braking and steering.

3.2 Roundabout Test

One of the stability approaches is based on measuring the pulling angle among the tractor and the trailer. The roundabout test is to confirm the determination of the foreseeable value of the pull angle in steady and transient states. The first stage is a leading up, whilst the second stage is a roundabout at the maximum steering angle of the tractor. Figure 6 shows the plan of the test and specifics. In this test only the trailer drive was utilized.

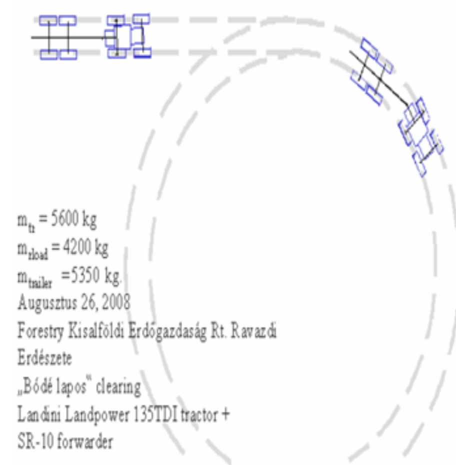

Figure 6: Plan and data of the roundabout test

3.3 Validation Test

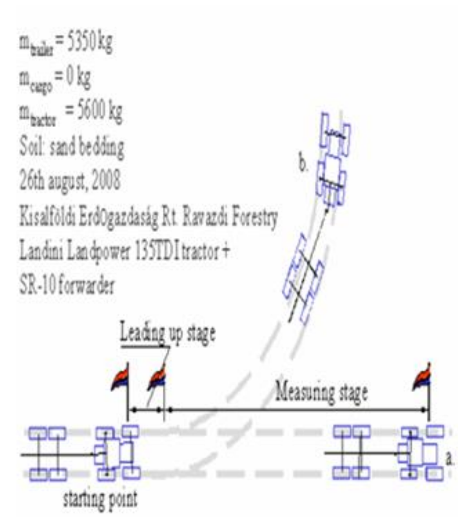

Figure 7: Plan and data of the validation

The validation tests were completed in an empty barn, which was under structure. The barn had fine grit and level bedding, which seemed ideal and readily reproducible. In the bedding noteworthy a short stage to achieve a nearby steady-state running of the vehicle set, followed by either a 20-meterlongstraight track, or a left turning one. The same data sets were registered as incase of the joint braking and steering test.

The target of the measuring was to fruition the functionality of the measuring tools, and to implement measurements to validate the pull-angle and yaw-rate determinations.

4. Processing the Measuring Data and Results

4.1 Evaluation of the Braking and Steering Test

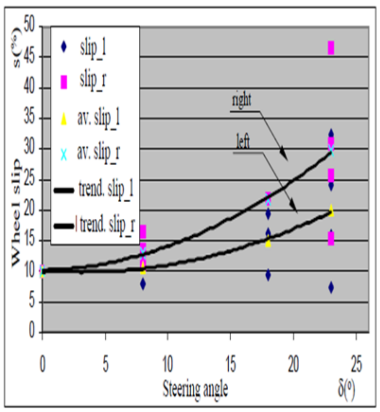

Figure 8: Wheel Slips as Function of Steering Angle

Figure 8 shows the dependency of the slip of the driven wheels as a function of the steering angle. The persistent line is a inclination curve drawn over the medium calculated slip at the set steering wheel angles. It can be seen that the slip differentiates between inner and outer wheels in the regard of turning direction.
The sliding of the inner wheel is proportionally upper than the outer, count on the steering angle. The middle of the slip values rise proportionally with the steering angle. The cause for this is that the travelling casualties increase with the steering angle, and the increased casualties indirectly reason increased slip values.

4.2 Evaluation of the Roundabout Test

The aim of the roundabout test is to bring the vehicle train to an utmost state in order to confirm the stability program and the calculation process of the pulling angle. While the test only the trailer drive was applied with the steering angle set at 28 degrees to the right.
Data recorded while the tests were:

- Numbers of turnover of the trailer tires (nb, nj)
- Accelerations of the trailers body (aA1x- aA4y)
- Steering angle (δ)
- Pulling angle (γ)
- Travel speed of the train (vh)

Figure 5 summarizes the result of the validation of the pulling angle calculation.
Measured and calculated pull-angles

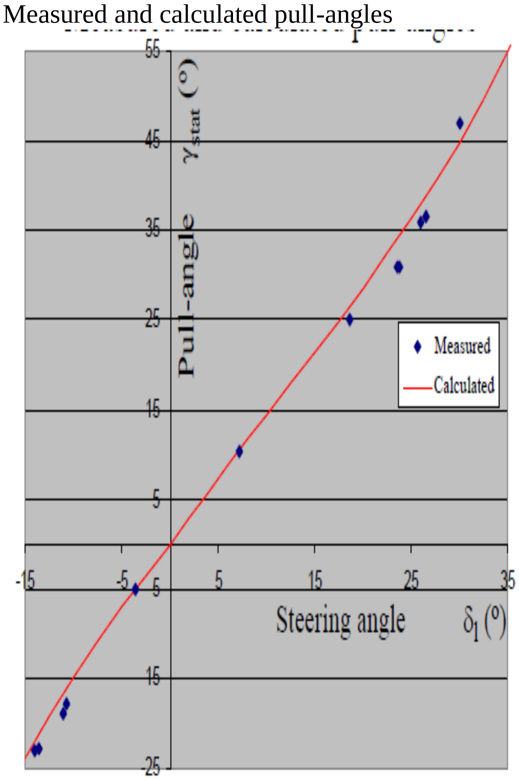

Figure 9: Comparison of measured and simulated pulling angle

Figure 9 shows the comparison of the calculated and the measured steady-state pulling angles. The persistent line shows the function of equation 4, and the squares are the date gained from the field measuring. This result validates the determination of the steady-state pull-angle determination.
From the registered measurement data, the steering and pull angle data have been taken (Figure 10 upper part). I have established a computer model of the vehicle train and adjust the parameters in conformity with the measured vehicle. Using the registered speed and steering data, I have reproduced the simulation with the model. The pull angle created by the simulation then was compared with the measured one (Figure 10 lower part), after which after I draw

the following epilogue. The model applied for determining the transient state of the pulling angle grants satisfactory results; therefore, it can be applied as the parameter of vehicle stability determination.

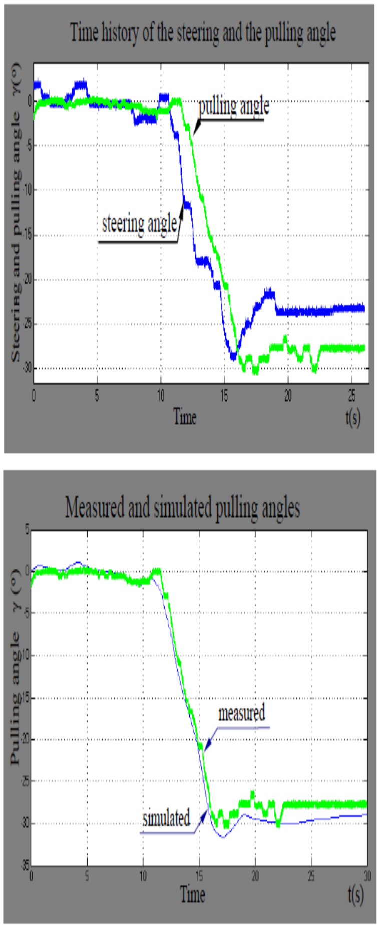

Figure 10: Comparison of measured and simulated pulling angle

5. Conclusions

Stability determinations were advanced using a self-developed model park of agrarian transport vehicles. Through the stability determination methods, the pulling angle based determination set to be the most accurate, and the simplest to measure its determination parameter. The pulling angle determination model was proved by a series of field measurements. The expected pulling angle can be liken with the measured one, and from the variation the stability of the vehicle train can be determined. The feature of this method is that the pull angle deviation can be rise both by the pulling vehicle and the trailer; in this way abnormal conduct of either of them can be determined.

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