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TITLE:

STUDIES OF STABILITY AND HANDLING FOR BUS EQUIPPED WITH ESP SYSTEM IN BRAKING MODE

Topic:

● FUTURE AUTOMOTIVE TECHNOLOGY
○ INTELLIGENT TRANSPORTATION SYSTEMS
○ USER FRIENDLY AUTOMOBILE
○ ADVANCED PRODUCTION AND LOGISTICS
○ VEHICLES & THE ENVIRONMENT

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National Society: ● YES ○ NO

Name of the National Society: Academic Automotive Association

Abstract:

The proposed research has been done for bus (28 passengers capacity) and consists of the following parts:
- Dynamical ADAMS model,
- ESP algorithm in MATLAB/Simulink 6.5
- 3D-model of bus body in Unigraphics software.

The virtual simulation allowed the investigation in the main characteristics for the traction and braking modes of vehicle movement. The created complex model gives the possibility for integrate analysis of bus dynamics.

Place / Date: Minsk, 12 / 02 / 2004

INTRODUCTION

The tendency to improve the passenger's safety, stability and handling initiates the development of new algorithms for vehicle control systems. Within the framework of this problem the perspective bus for 28 passengers producing with Minsk Automobile Plant was researched in the presented work, Table 1.

Table 1. Technical characteristic of bus

Full mass, kg	9670
Mass reduced to driving wheels, kg	6220
Engine	
- maximum power, kW	114,8
at rotating speed, min^{-1}	2400
- maximum torque, H*m	567
at rotating speed, min^{-1}	1500
Tires	235/75 R17.5
Total inertia moment of wheels, $kg \cdot m^2$	6,86

Particular features of the subject of inquiry from the point of stability and handling are:

- Advanced requirements for active safety concerned with passengers transportation
- Short chassis frame, high location of centre of mass (gravity) that makes the special requirements by stability supplying.

The aim of the research work was to create the conception of virtual proving ground (VPG) for vehicle tests connected with active safety of the subject of inquiry. The necessity of creation of virtual proving ground associated with the following theses:

- Rapid prototyping
- Decreasing of time and costs for carrying out road tests
- Possibility to analyze the models of complete bus and single bus components at the simulation stage
- Possibility to optimize bus assemblies.

During creation of virtual proving ground conception the following previous investigations were taken into account:

- ADAMS simulation for closed-loop systems and vehicle control systems [1, 2]
- Investigation in Virtual Proving Ground [3]
- Control systems for trucks [4, 5]
- Development of vehicle control strategy [6-8]
- Simulation of processes into brake system [9, 10].

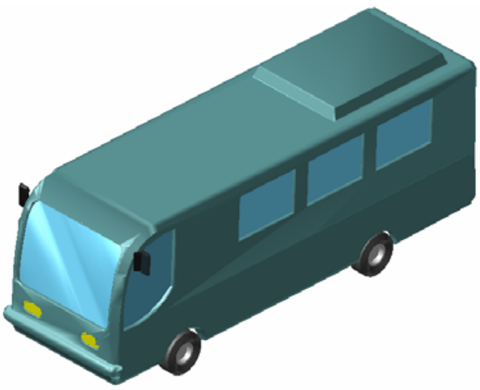
CONCEPTION OF VIRTUAL PROVING GROUND

The virtual proving ground under discussion is based on various computer applications. The following demands should be realized for creating virtual proving ground:

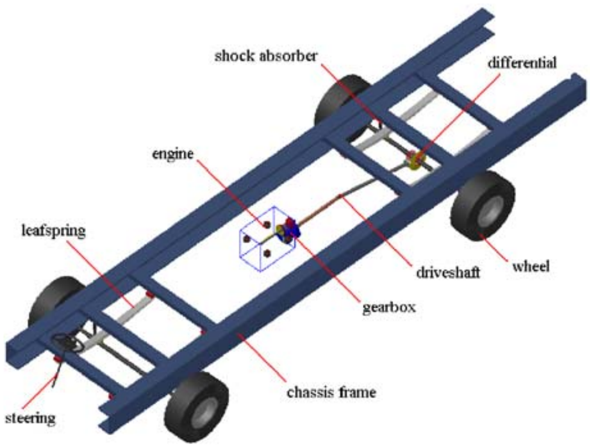
1. Bus simulation model should be created in ADAMS to provide maximum approximation to real mechanical system.
2. Active safety control system should be realized in MATLAB, because this software gives the best fit for such algorithms.
3. Solid models of framework and body should be engendered in Unigraphics, which allow to appreciate mass and inertia parameters and configuration decision.
4. Co-simulation of the subject of inquiry in ADAMS and MATLAB

VPG Elements in Unigraphics

With the help of interactive design system Unigraphics were elaborated solid geometric models of bus framework and body, Fig. 1a. This allowed to apply and evaluate different layout decisions, also this gives the possibility to create finite element model of framework for more precise estimation of bus dynamics.



a)



b)

Figure 1. Bus Model
a) body; b) framework and chassis

VPG Elements in ADAMS

In ADAMS worked out the simulation model of bus chassis, Fig. 1b, which includes:

- Front and rear suspension (leaf spring, shock-absorber)
- Transmission (gearbox, differential)
- Steering
- Brakes
- Engine.

VPG Elements in MATLAB

With the help of MATLAB the ESP control algorithm for braking mode and electro-pneumatic modulator were created.

On the base of brake scheme, Fig. 2, control model in MATLAB was created, Fig. 3.

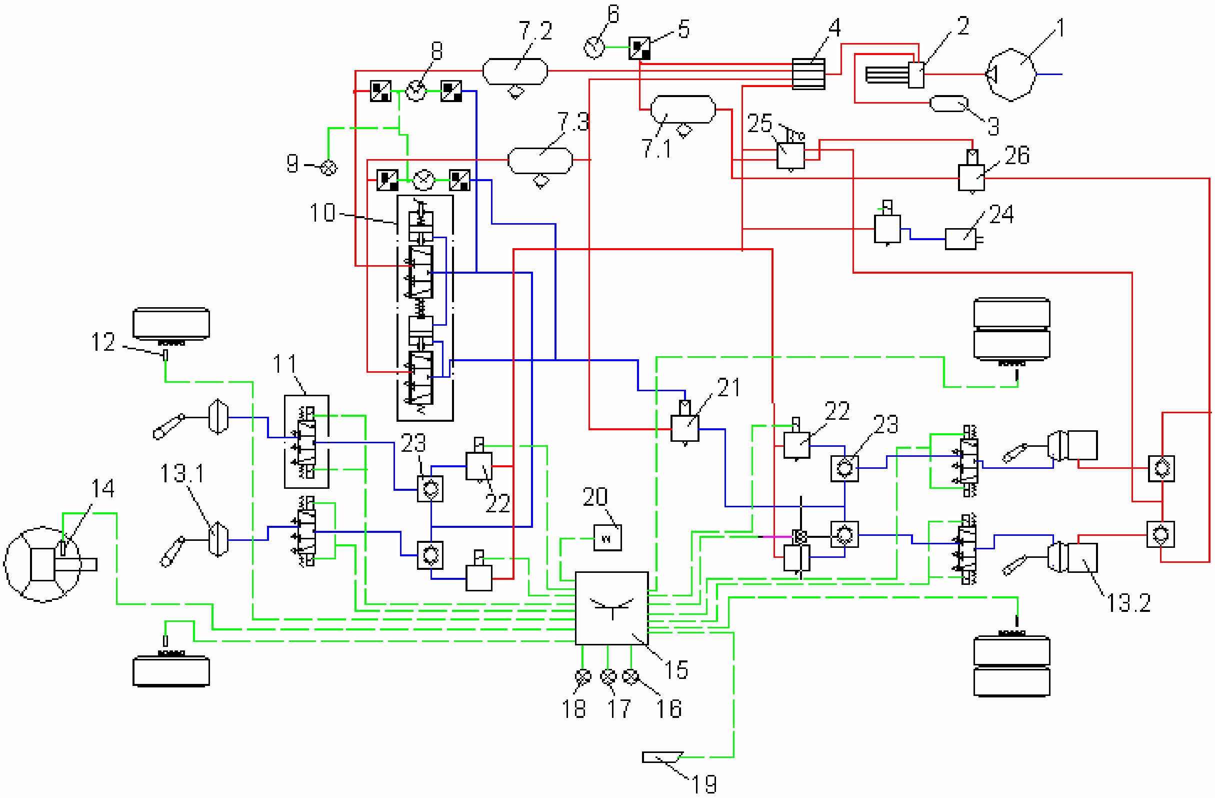


Figure 2. Scheme of air-operated brake system with ESP

1 *- compressor;* ***2*** *- drier;* ***3*** *- receiver;* ***4*** *- 4-circuit valve;* ***5*** *– pressure-tension transformer;* ***6*** *- gauge;* ***7*** *- receivers;* ***8*** *- manometer;* ***9*** *– pilot light for pressure decrease;* ***10*** *– brake valve;* ***11*** *– ABS modulator;* ***12*** *– wheel sensor;* ***13*** *– brake chamber;* ***14*** *– steering sensor;* ***15*** *– electronic control unit;* ***16*** *– ABS pilot light;* ***17*** *– TCS pilot light;* ***18*** *– ESP pilot light;* ***19*** *– lateral acceleration sensor;* ***20*** *– yaw rate sensor;* ***21*** *– relay valve;* ***22*** *– electronic valve;* ***23*** *– two-line valve;* ***24*** *– retarder control cylinder;* ***25*** *– parking brake valve;* ***26*** *– relay valve for engine management.*

– electrical signal
– supply line
– atmospheric pressure line

THE PRELIMINARY TEST RESULTS AND THEIRS ANALYSIS

The proposed research has been done for several test modes by braking:

- straight-line motion of bus on dry and wet asphalt
- curvilinear motion (turning movement of bus)
- “Slalom” mode motion.

For modes under discussion the strategy for test performance was created. The main aim of this strategy: to examine the wheel blocking, because this process is very undesirable and brings for increasing braking distance and occasion of skidding. The wheel blocking is characterized by slip coefficient, which can vary from 0 to 1. So when slip coefficient equal 1, the skidding happens, and when values of slip coefficient equal 0,1…0,15, the coefficient of longitudinal road force reaches maximum values.

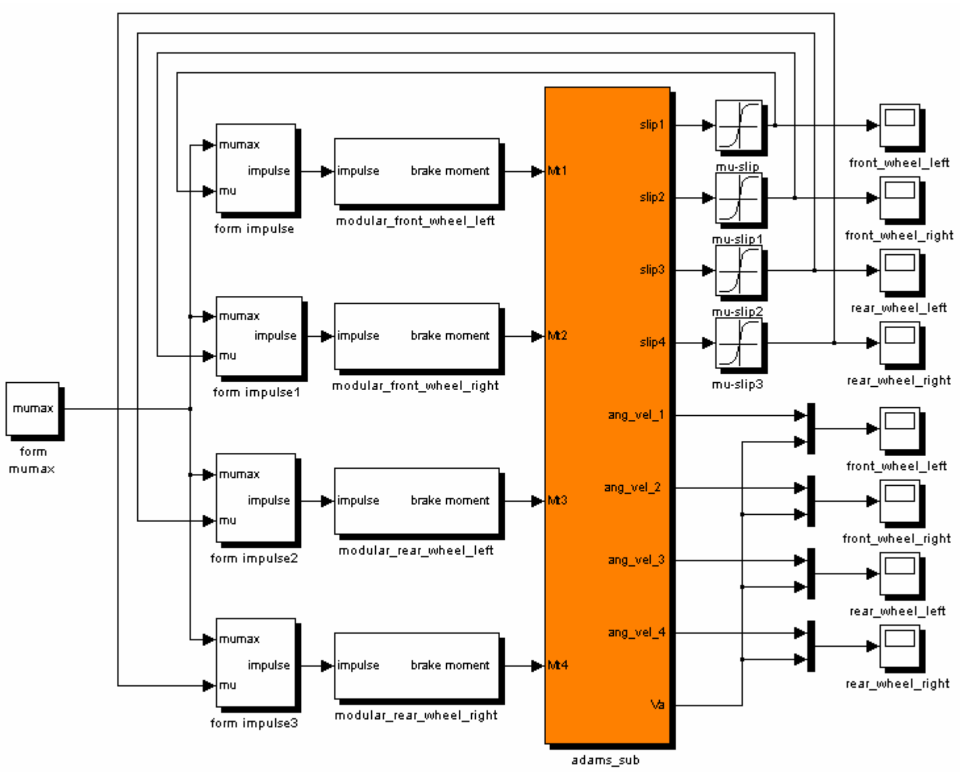


Figure 3. ESP Simulation (for braking mode) in MATLAB

Analysis of research works dedicated to wheel operation showed that dependence "coefficient of longitudinal force – wheel slip" depends on many different parameters: type and condition of road surface, tire parameters, inflation of tire pressure, wheel load, velocity, temperature conditions and slip coefficient. As a part of parameters has environmental description, then the main adjustment parameter is the slip coefficient.

<u>Examples of Tests</u>

As a case in point let's analyze the most frequent case of tests – braking of vehicle on straight-line section of road with dry asphalt. Main characteristics – velocity cyclogram and "slip-time"-dependence showed on Fig. 4 and Fig. 5.

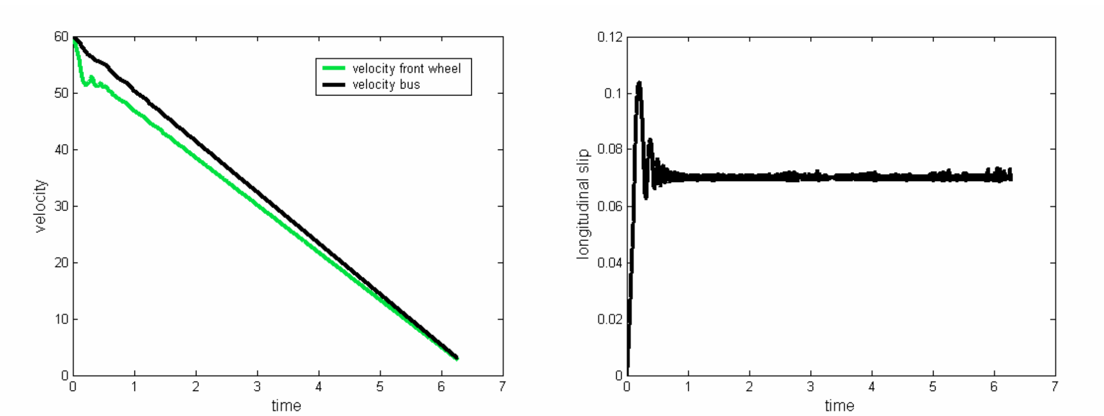


Figure 4. Velocity Cyclogram and "Slip-Time"-Dependence for Front Wheel

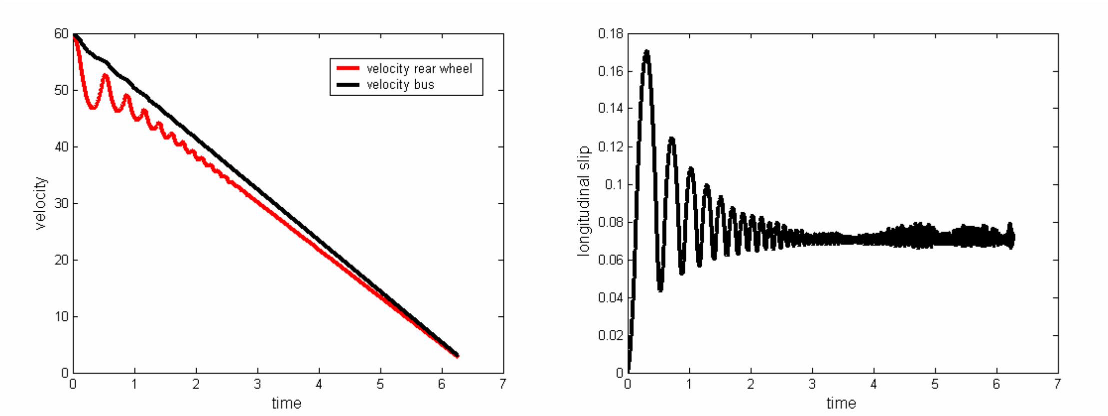


Figure 5. Velocity Cyclogram and “Slip-Time”- Dependence for Rear Wheel

Simulation of ESP for bus showed that the algorithm with regulation by coefficient of longitudinal force within tire-road contact could be used for braking control. As the result tire revolving supplied in restricted area of slip with at the same time supplying high braking efficiency, Table 2. Maximum values of slip and slipping velocity show that selected control algorithm doesn’t occur wheel blocking and supplies almost maximum coefficient of longitudinal force. Averaged extent of coefficient of longitudinal force using also is in optimal range. For example, for most of active safety systems it’s equal 0,9…0,95.

Table 2. Results of Preliminary Tests

Parameter	Front left wheel	Front right wheel	Rear left wheel	Rear right wheel
Maximum value of slip	0,105	0,107	0,175	0,172
Maximum slip velocity	8,5	8,7	13,4	13,2
Minimum usage grade of coefficient of longitudinal force	87,1	86,9	85,2	85,5
Average usage grade of coefficient of longitudinal force	92,55	92,45	91,15	91,3

<u>Preliminary Conclusions</u>

1) Created virtual proving ground gives the possibility to equivalent simulation of difficult dynamic systems and different control algorithms, which helps to give estimation of system characteristics at the designing stage.
2) Appropriately to integrate MATLAB and ADAMS software for valid debugging of control algorithms for subject of inquiry.
3) Created simulation model gives the possibility to evaluate dynamic characteristics not only the complete bus but its single components and also theirs effect on whole system behavior.
4) It’s possible to carry out tests not only for dynamic characteristics but also for fatigue tests of bus components with the help of created model.

5) Created in Unigraphics body and chassis of bus gives the possibility to evaluate influence of their mass and geometry parameters on bus dynamics, and also deflected mode of chassis in motion.

FURTHER INVESTIGATIONS

During the investigations the problem with determination of real coefficient of longitudinal force of tire with road appeared, because we don't know in which road the bus is moving, Fig. 6.

The following possible decision can be proposed. Let's bring in coefficient, which defines rate of vary of slip coefficient:

$$ts = \frac{a_A - \varepsilon_w \times r_d}{a_A}$$

Where $\mathbf{a_A}$ is acceleration of centre of mass, $\boldsymbol{\varepsilon_w}$ is angular acceleration of wheel and $\mathbf{r_d}$ is wheel radius.

Let's analyze the implementation area of coefficient of longitudinal force, Fig. 6: let us suppose that we know current slip coefficient, therefore, coefficient of longitudinal force represents one-dimensional array – value by green line from low bound (blue) to up (red). Then with the help of FUZZY CONTROLLER, in which adjustment parameter is **ts**, determine current value of coefficient of longitudinal force, Fig. 7.

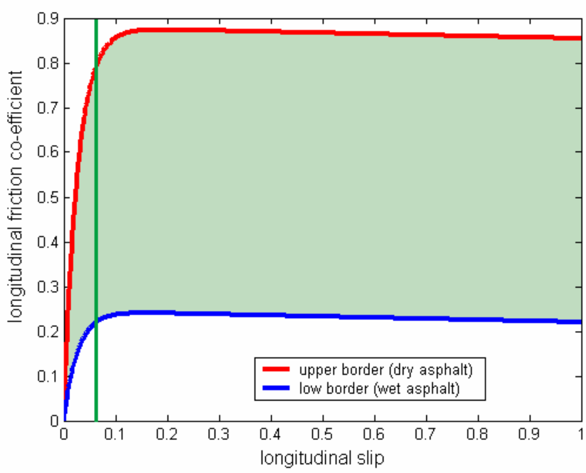


Figure 6. Implementation area of coefficient of longitudinal force of tire with road

Further adjustment of offered alternative strategy of control for active systems of safety with the help of virtual proving ground is intended. The authors hope to cover more detail this question in consequent works.

ACKNOWLEDGEMENTS

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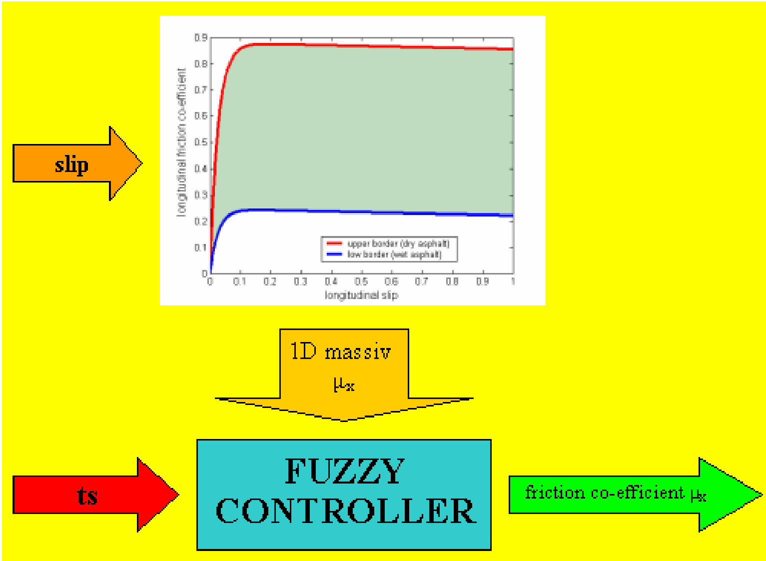

Figure 7. Diagram of Determination Coefficient of Longitudinal Force Based on Fuzzy Logic

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