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Ph. D. THESIS

-Abstract-

STUDIES AND RESEARCH REGARDING THE EFFECTS OF BRAKING ON THE BRAKING SYSTEMS OF MILITARY TRUCKS

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ABSTRACT

Braking is the process that partially or completely reduces a vehicle's speed. During this process, part of the kinetic energy accumulated by the vehicle turns into caloric energy by friction, and some is lost to defeat resistances that oppose to movement.

Enhancement of the acceleration and speed performances of a vehicle in safe condition depends to a large extent on its braking capacity. The braking system is more efficient, the medium movement speeds increase and mining indices of the vehicle have higher values. Also, good braking qualities help to avoid accidents, even at a relatively low speed, caused by the unexpected appearance of an obstacle.

In the military field, to transport materials, technical, personnel, special transports, small and medium capacity vehicles are often used for transport, with 2 or 4 drive axle. Most of them are derived from civil transport vehicles to which some constructive changes have been made to enhance the mobility indices, such as: engine power was supplemented, the front axle was replaced with the drive axle, tires were equipped with a profile that provides a higher coefficient of adhesion on a deformable soil and a lower medium pressure on the ground, etc. Consequently, some systems, including the braking system, are the same as the ones on general use vehicles. This observation is based on the more and more obvious tendency of civil technology transferred in particular applications, in order to reduce costs and capitalize on technological developments already tested and manufactured in series.

Because of long life cycle of military transport vehicles (typically 20...25) is insisted on the use of large car parks of vehicles that are equipped with classical braking systems. For these reasons, this paper focuses mainly on analyzing classical braking systems that equip military trucks (RD-10215 FA şi DAC 665 T/G) operating in different conditions: on road and on deformable ground, urban, extra urban and interurban environments, uphill and downhill.

Studying specialized literature as well as the braking systems domain analysis, allowed the formulation as a general objective of the paper the investigation of the processes that accompany the vehicle braking in typical situations that require action of braking system: movement on the road, moving uphill, horizontal movement on the road, moving on a deformable terrain. To achieve this objective and having into consideration the particular case of military truck movement, theoretical research will be required (analytical, numerical modeling and simulation) and experimental on the following aspects, considered specific objectives:

• evaluation of the braking force limitations due to the modification of the vehicle’s weight distribution on decks;
• evaluation of the influence the coefficients of adherence and tire rolling resistance have on the braking process;
• evaluation of the need of braking by determining the statistical distributions of the truck’s cinematic parameters when moving in an urban environment and on the road, both orizzontally and on a slope;
• study of thermal phenomena occurring in the braking system’s frictioning parts;
• identification and use for simulation of calculation models to enable study of the vehicle’s braking process while moving on a deformable soil.
Due to the development of advanced computing methods using finite element theory, it is possible to constructively and functionally optimize the braking system, taking into account its requests, statistically determined based on a scenario of a transport vehicle use.

Research efforts will be directed to study the longitudinal dynamics of the braked vehicle so that you can make specific requirements in accordance with the actual conditions of exploitation of the vehicle.

The paper is structured on five chapters, developed in a proper succession so that exposure would be logical and systematic.

Chapter 1 presents the current stage in the construction and evolution of the braking system.

Chapter 2 (THEORETICAL ANALYSIS OF THE DYNAMICS OF BRAKING VEHICLE) deals with cinematics and dynamics of the military transport truck and the braking system’s dynamics, cinematics and dynamic models are transposed in analytical simulations with which the behavior of the braking system is analyzed.

Chapter 3 (EXPERIMENTAL RESEARCH ON VEHICLE EVALUATION BRAKING PERFORMANCE) contains the results of experimental research performed in order to evaluate the braking system of trucks; experimental equipment, conditions under which the experiment was conducted, experimental data recording systems are presented and a series of processing and interpretation of the data obtained are made.

Chapter 4 (MODELING AND SIMULATION MECHANICAL AND THERMAL BRAKES) developing models and simulations of the mechanical and thermal requisitions that appear on the braking system for different operating modes of it. Finite element method (FEM) is used to obtain the contact pressure expression based on the location of the contact surface, thermic transfer taking place on the surface of contact between shoe and the drum, observed experimentally, is used for model parameterization of heat transfer inside the active elements of the braking system.

Chapter 5 (GENERAL CONCLUSIONS. PERSONAL CONTRIBUTIONS) summarizes the conclusions of the study, by combining theory of braking systems with a series of experiments on military trucks braking systems, it allowed the development and parameterization of the physical processes models that occur during braking, the simulations obtained with models are consistent with experimental observations; a series of conclusions and recommendations have detached, regarding braking systems for both general use vehicles and military trucks.

Bibliographical research has shown that there is a major deficit in the research activities regarding the investigation of the braking process on logistic transport trucks particularities. Most reference papers in the computing and construction vehicles field approach the braking process based on severly simplifying assumptions, aimed to obtain simple calculation relations, able to only highlight the major factors influencing the braking process.

The calculation pattern based on relations from specialty literature, but also based on original approaches proved to be robust and useful. Formulations have been identified which finally led to an analytical algorithm implemented in an application made using Mathcad program. Developed computer simulation models allow horizontal movement of the vehicle both on the ground and in a slope/ramp. Thus, it is possible to determine by the calculation of the tensile strength’ characteristic, of the dynamic feature and of the starting characteristics. The established relationships allow the assessment of the braking deceleration while the wheels are running (without being blocked). The accuracy of the simulation’s results crucially depends on the adoption of appropriate values for rolling resistance coefficient, the coefficient of inertia masses reduced to the wheel axis, the coefficient of adherence, etc.

The validation of the calculation model was done by conducting experimental studies that showed the dynamic characteristics of vehicle movement on different types of terrain and according to predetermined test scenarios. Making experimental research has allowed the evaluation of the masses of inertia factor reduced to the wheel axis, but also the characteristics of
moving on a deformable terrain (total coefficient of rolling resistance \( f \), coefficient of adherence \( \varphi \), traction force to the hook \( F_{tc} \)).

From the experiments carried out and by making calculations, a number of essential parameters were obtained. So, the experiments have enabled the determination of average values of the speed at which braking starts (35.5 km/h), braking deceleration (-0.2113 m/s²), braking space (104.104 m). Relative frequencies of these parameters indicate a prudent style of truck driving. The average time between the end of an immobilization braking and the beginning of the next brake (108 seconds) is sufficient to evacuate the heat accumulated in the friction elements of the braking system.

Measurements of temperature have shown that in urban areas there wasn’t any overheating of the friction elements in the braking system; the capacity of dissipating thermal energy is high, so the kinetic energy flow is easily dissipated. The temperatures recorded during the measurements have varied between 48°C and 79°C, and those recorded on the metal side of the brake shoe were varied between 27°C and 55°C for an air temperature of 18°C inside the drum during measurements, the temperature rises from 8°C and 26°C.

The procedures used in the experimental research have proven to be the right ones for the paper’s objectives. The equipment used allowed measurements within fully acceptable errors. The number of satellites used (8) was an indicator of the accuracy of the GPS system. The use of VC 3000 VERICOM DAQ is recommended, intended primarily for measuring braking characteristics to determine starting characteristics and the evolution of the car in turns. The Racelogic Vbox Mini system is also recommended, which uses a GPS system and a small accelerometer perpendicular to the direction of travel, which determines the side slip angle during braking, the absolute speed and trajectory of a vehicle. In addition you can record information on wheel speed, the temperature indicated by thermocouple sensors.

Making experimental research has shown the basic elements of the driver’s behavior while braking, especially those regarding the decisions made on braking while maintaining the truck’s speed safe during downhill movement: the speed at the start of braking, estimating the space required for braking, the braking intensity etc.

Recorded data analysis determined the main statistical characteristics of the kinematic parameters of the braking process and the statistical correlations between them and the tread characteristics. Experimental research program developed and executed with satisfactory results that are presented in the thesis is recommended.

Making experimental research in real traffic conditions showed a tendency to maintain the speed limits safe by repeatedly operating the braking system and not by its continuous operation, therefore, long downhill movement is a succession of accelerations and brakings to restore a proper speed.

Making a significant volume of modeling through finite element method (FEM) allowed the simulation of the processes take place at the level of shoe, liners friction and drum, thermal wise. Simulation results were confirmed by experimental investigations which included measurement of temperature and friction on the metallic side of the shoe. It showed that intermittent braking of the vehicle leads to the reduction of the thermal regime of the components, with the possibility of uniformizing the thermal fields by transmissibility, but also of reducing the thermal regime by heat dissipation by convection.

In case of movement on deformable terrain, the increase of the tire rolling resistance coefficient favours the braking, especially in soft soils and on low angles of the slope. However, there is a decrease in the wheel’s grip to the ground, which blocks the wheel, resulting in loss of vehicle stability. In this case, the use of electronic brake assisting systems and traction becomes absolutely necessary.
In the final part of the work a large bibliographical list can be found, containing all of the studied papers (165) from all chapters. The bibliographic material is grouped alphabetically and contains specialty books, scientific research, contracts, catalogs, execution documents, exploitation manuals, web pages.

The authors’ CV, the list of published works and also 2 representative works (in the research field) published at several scientific manifestations can also be found at the end of the paper.

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