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RESEARCH OF THE INFLUENCE OF TIRE HYDROPLANING ON DIRECTIONAL STABILITY OF VEHICLE

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Abstract. Vehicle use is inherently linked to the risks. While transport means are being constantly improved, active and passive safety issues appeared to be more and more complex what makes experimental testing and numerical modelling problems of safety – sensitive structures considerably actual. In case of hydroplaning phenomenon to keep the vehicle's stable direction its movement becomes more difficult. Selection of the safe speed is one of the main objectives in order to ensure greater traffic safety and reduce the possibility of an accident. The aspects of tire simulation by finite element method were revealed and analysis of the impact of a vehicle's speed on the appearance of hydroplaning process was performed. The peculiarities of Euler–Lagrange formulation of dynamical problems and modelling of fluid – structure interaction by finite element method are presented in the research. The article describes preliminary models developed using the PATRAN and DYTRAN software packages. On the basis of these models, numerical calculations have been performed, in consequences the values of critical speed of the tire hydroplaning was obtained.

Keywords: tire, hydroplaning, fluid–structure interaction, traffic safety, safety speed, PATRAN, DYTRAN.

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Introduction

Motion of a vehicle is based on its grip with pavement. As tires are in direct contact with the pavement, the vehicle is controlled directly due to its tire grip with the pavement, and parameters of the tires have a great influence on controlling stability and ride safety of the vehicle. In order to ensure traffic safety, controllability of a vehicle at all seasons and weather conditions is of special importance.

The application of tires for coaches had the aim to increase ride comfort. A tire should ensure perfect automobile – tire grip, support all the forces acting on the automobile and minimize their transfer to other elements of suspension and the vehicle body. This has direct influence on motion safety and comfort possibilities of the automobile. Although the principal idea of the tire structure – air inflated reinforced rubber envelope – still remains not changed, structure of the tires and the applied materials are in constant change. Typical requirements for the tire performance are the following (Buhin 1988; Sapragonas, Dargužis 2011; Sokolovskij *et al.* 2007; Pacejka 2012; Kravchenko *et al.* 2012):

- good power transfer between the road and tire;
- good parameters of force transfer between road surface and the tire;
- the ability to maintain its regular shape when moving on a straight line and curved path in order to ensure motion stability;
- sufficient stiffness and strength at high speed motion;
- reliable attachment of the tire to the rim;
- long service life;
- good shock absorbing properties;
- low noise generation.

Researches show that with the improvement of transport means and increase of their speeds, the risk of traffic accidents does not decrease (Seiffert, Wech 2007). The problem of road fatalities still remains an actual one in Lithuania. In the year 2010, 299 persons were killed in road accidents in Lithuania, 2011 – 296; 2012 – 301.

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The problem of safety and security is deepened by increased level of auto mobilisation in Lithuania – from 98 veh/1000 inhabitants to 560 veh/1000 inhabitants while majority of the transport systems are designed for 250 veh/1000 inhabitants (Accident Rate Information 2012). Researchers of transport systems (Bazaras *et al.* 2013; Jasiūnienė *et al.* 2012, etc.) predict that traffic flows in the territory of Lithuania will be increased several times what will inevitably increase the accident rate.

Although modern methods of numerical analysis, computer aided design and the possibilities of modern materials application provide the possibilities of fast, though not always cheap solutions of the faced problems, just the fact of their appearance indicates that safety issues are extremely complicated. The problems attracting the greatest attention within society usually are related to stability in critical situations and reliability issues, but they are highlighted as a rule by the increasing number of traffic accidents.

One of the possible actions in the area of transport safety is also the analysis of European dimension (European Commission 2011) which is harmonization and implementation of road safety technologies such as intelligent speed limiters which limit the speed according to the road condition, e.g. currently independently on the road condition, wet or dry is the pavement, speed limits remain the same. Selection of the safe speed is left for the driver (Maurya, Bokare 2012; Kravchenko *et al.* 2012).

In this context the research of the accident rate, reduction of losses and road deaths are of special importance. In the area of road users' behaviour, environmental impacts and technical technological measures the research based solutions enabling to eliminate these problems are necessary.

In majority of cases experimental research methods of complicated phenomena are much more reliable than the numerical ones; nevertheless they are relatively expensive and time consuming. Therefore, in order to research even more deeply such complicated phenomena as hydroplaning of a vehicle tire it is reasonable to perform numerical experiments which are faster and significantly cheaper. The objective of this research is to develop computational models of the tire, the application of which would give the possibility to make fast and reasonably reliable analysis of hydroplaning phenomena at different speeds of the vehicle and its tire tread depth. Although such modelling problem is large in its volume and time consuming, its results can be applied for the solution of a number of other problems – simulation of the tire rolling on deformable soil, sand, wet snow or ice-covered pavement; determination of critical speed at which hydroplaning is initiated; determination of optimal tread pattern for the tire; and defining of recommended mechanical characteristics of shoulder or belt materials.

1. Hydroplaning Process

One of the first problems associated with the tire's influence on active safety of a car was the hydroplaning problem.

It is noted that the wheel interaction with water covered road, the time to squeeze water from the contact area is enough until the wheel turns slowly. The tire's front is filled with water and the resulting pressure lifts the tire. The speed when the tire is completely separated from the road is called the critical hydroplaning speed. Under these conditions, the car starts to slide affected by the inertia force, the brakes stop working and the car gets uncontrolled. Minimal water level, likely to lead to hydroplaning, depending on the road surface, the tire and the speed can be from 2.5 to 10 mm. The phenomenon has been observed first with aircraft tires. The first fundamental research on tire hydroplaning has been performed in NASA (Horne, Dreher 1963). In primary overviews physical origin of appearance of hydroplaning phenomenon in aircraft tires, when the tire is moving on wet road is presented. The tire total dynamic hydroplaning speed v_p is:

$$v_p = \sqrt{\frac{2 \cdot p}{\rho \cdot C_{Lh}}}\,, \qquad (1)$$

where: C_{Lh} – the hydrodynamic lift coefficient; ρ – density of the fluid; p – the tire inflation pressure. For a free rolling tire C_{Lh} is about 0.7 and for a sliding tire C_{Lh} is about 0.95.

Analysis revealed some additional aspects for determining further trends of active safety measures. It was searched for the ways to remove water from the tire and the road contact area (Fig. 1). The attempts to adapt the tread grooves and the other part to splash out were made. And while the film of water is being destructed and the splashing process accelerates as a wave forms in front of the tire, however, with increasing driving speed, water fails to flush out sideways while the volume of tread grooves remains constant. Because of not flushed out water from the contact, according to the principle similar to that of lubrication in hydrodynamic bearings the water begins to form a wedge, resulting in pressure and lifting the wheel.

Tests confirmed that, depending on the thickness of the water layer, there is a speed limit, above which the front wheels of cars of classical composition stop spinning at all, because grip strength is not enough to turn even the wheel, the possibility of the vehicle to change its direction even cannot be mentioned.

Examining circumstances of movement on wet road it was noticed that besides water layer thickness,

a) b)

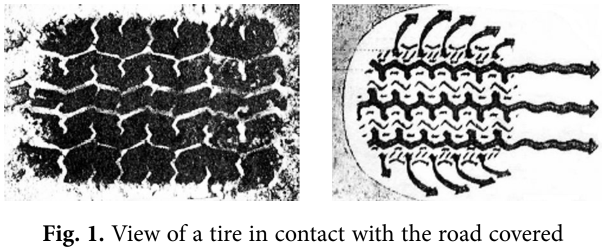

Fig. 1. View of a tire in contact with the road covered with a layer of water (a) and a scheme of water removal from the contact (b)

the tread depth has strong influence. If the safe grip coefficient is equal to 0.75, and while driving on wet road a tire with tread depth of 1 mm has safe speed of 45 km/h, and when using the tire with tread depth of 4 mm the speed limit would increase to 100 km/h (the data is approximate, there will be no such a significant dependence for modern tires). About the seventieth of the last century discussions about what should be the tread pattern – whether the grooves must be longitudinal or transverse were going. Longitudinal grooves – the ordinary way to ensure directional stability, transverse ones – the ordinary way, as well, to destroy the water film causing hydroplaning. Inclined grooves better remove the water. While you are absolutely sure that the pattern affects grip with the wet road, there are no united guidelines. Manufacturers choose a different pattern, often its design principles, too.

For water removal problem from the contact zone, designers are facing another – grip optimization problem. The grooves intended to remove water change deformation features of the tread and at the same time grip conditions (Sapragonas, Dargužis 2011). When tilted a tread pattern element (a separate unit, restricted by grooves), adheres to the road other way than when the load is perpendicular to the surface of the block, in contact with the road. Longitudinal grooves worsen the grip in lateral directions, transverse – in longitudinal ones. Optimizing of the tread is rather complex task because requirements to today's tires are mutually exclusive. Grip tests in the longitudinal direction and the transverse direction are performed on dry and wet roads. On wet roads usually the tires are tested when braking from 80 km/h to 20 km/h, and then the result is recalculated. For the wet road (more precisely – in the case where the road surface is covered by water layer) additionally the speed limit is defined, for which hydroplaning start is captured (usually 15% of the wheel slip is fixed). For high-speed tires the process begins already from 60 km/h. Vehicle directional stability and response to the driver's movements, adjusting the trajectory, is evaluated by the speed of overcoming a tortuous road track ring. Many of the parameters are highly dependent on the car and driver, so test results have only a comparative value (Huang 2002; Seiffert, Wech 2007).

2. Fluid Structure Interaction Modelling

DYTRAN software package is a three-dimensional analysis code for analysing the dynamic, nonlinear behaviour of solid components, structures and fluids. Lagrangian and Eulerian solvers are available to enable modelling of both structures and fluids (DYTRAN: User's Guide 2012). Lagrangian formulation items are for solid geometrically non-linear dynamic tasks. For modelling of fluid or gas tasks Eulerian elements are designed.

Main differences in Lagrangian and Eulerian formulation are those (Fig. 2):

- always constant weight in Lagrangian formulation;
- always constant elements volume in Eulerian formulation;

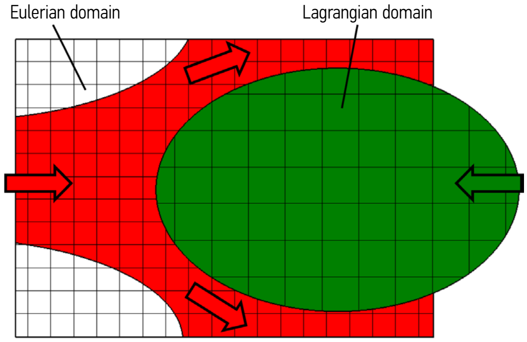

Fig. 2. Lagrangian and Eulerian coupling technique

- finite element mesh are fixed in space and time;
- mesh nodes have no degrees of freedom;
- the material moves from item to item.

Eulerian material state is defined by these four variables (DYTRAN: Theory Manual 2012):

- speed at point *P* during time *t*;
- $\rho(P,t)$: density at point *P* during time *t*;
- $e(P,t)$: specific inner energy at point *P* during time *t*;
- $\sigma_{ij}(P)$: stresses at point *P* during time *t*.

Four equations linking these four variables:

- constant weight → continuously;
- constant acceleration → the second law of dynamics;
- constant energy → the first law of thermodynamics;
- state of equations.

In addition, the Eulerian processor problem is solved in two steps, i.e. in the first step Lagrangian cycle is performed, in the second – variables are adjusted and Eulerian the solver is run again. Therefore, Eulerian method is suitable for simulation of large deformation and fluid movement (Doroševas 2007).

3. The Description of Finite Element Model

The simplified finite element model of the tire 175/65/R14 is designed on the basis of universal pre-processor PATRAN environment. DYTRAN software package is used as the solver, enabling solving Lagrangian and Eulerian equations. For this unique reason, it is possible to effectively model and solve fluid and elastic body interaction tasks. In reality, the wheel rotates and rolls on the way forward. In finite element model the wheel is pressed to an absolutely rigid road and is spined up to a constant angular velocity, but does not move forward (Kumar *et al.* 2012; Fwa *et al.* 2012). Absolutely rigid road and water film flows around the wheel at linear velocity in the wheel movement direction (Fig. 3).

Such the model enables the use of Eulerian net of the finer elements, which is especially true in the tire and road contact area and allows to save computational time. The wheel pressing force is chosen to be equal to the quarter of car weight, and linearly increases from 0 to 3500 N during an initial 0.05 s calculation period. The tire is inflated to the inner pressure of 200 kPa, which is

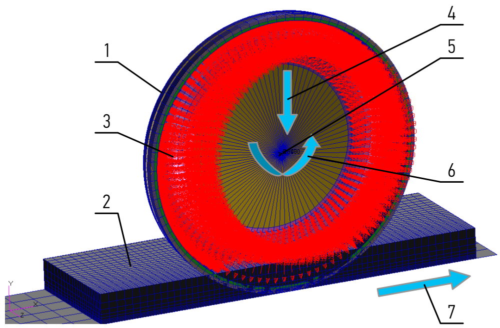

Fig. 3. Tire boundary conditions scheme: 1 – Lagrangian elements; 2 – Eulerian elements (water film and void); 3 – tire inflation air pressure; 4 – weight of quarter of vehicle; 5 – grounded damper element; 6 – rotation of the tire; 7 – linear movement of rigid road and water film

linearly increasing in the same time interval. Since the rim is absolutely rigid body, the TLOAD1 card is used to describe the boundary conditions. The wheel is free to move only in the vertical direction and rotate around horizontal axis. The remaining four degrees of freedom of the rigid body are constrained by selecting zero rotational and linear velocities.

The simplified tire models are recommended to use at initial stages of the simulation. If it is necessary, a detailed model, which slightly lengthens the computation time, can be used. The simplified tire model is presented in Fig.4 and mechanical properties of the materials in Table.

Depth of longitudinal grooves of the tread in the simplified model is 10 mm. Longitudinal grooves are intended for maintaining directional stability of a vehicle. Shoulder and rim of the tire are simulated by shell-type elements; all other parts are brick elements. Node-to-surface contact is used to describe tire and simplified absolutely rigid road surface.

Properties of the tire's rubber are described using Mooney–Rivlin hyper elastic model. Thus, the form of strain energy potential for a Mooney–Rivlin material is given as (DYTRAN: Theory Manual 2012):

$$W\left(I_1,I_2,I_3\right)=A\cdot\left(I_1-3\right)+B\cdot\left(I_2-3\right)+ C\cdot\left(\frac{1}{I_3^2}-1\right)+D\cdot\left(I_3-1\right)^2, \quad (2)$$

where: constants A, B, C, D and Poisson's ratio n are the input parameters for the model; I_1, I_2 and I_3 are strain invariants in terms of stretches. The constants C and D are related to the input parameters as $C=\frac{A}{2}+B$ and $D=\frac{A\cdot\left(5\cdot n-2\right)+B\cdot\left(11\cdot n-5\right)}{2\cdot\left(1-2\cdot n\right)}$.

Second Piola–Kirchhoff stress tensor:

$$\sigma=\frac{2\cdot\delta W}{\delta C}. \quad (3)$$

The region of Eulerian formulation elements consists of a water layer. The rest is emptiness (air). An important condition for modelling is that the edges of

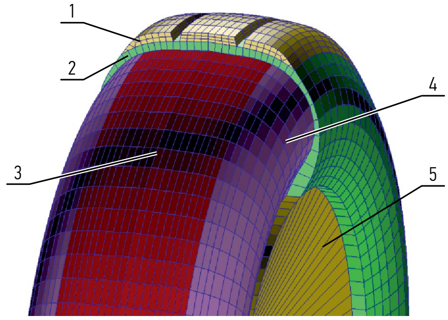

Fig. 4. Simplified model of tire175/65/R14: 1 – protector; 2 – rubber; 3 – belt; 4 – shoulder; 5 – rim

Table. Material properties of the tire components (Park *et al.* 2006)

Component	DYTRAN software package constitutive material models
Protector and Rubber	Mooney–Rivlin rubber (RUBBER1); *A* constant – 62500; *B* constant – 18200; Poisson's ratio – 0.49
Belt	Linear elastic (MAT1); *E*-modulus – $3.6\cdot10^9$ Pa; Poisson's ratio – 0.49
Shoulder	Linear elastic (MAT1); *E*-modulus – $2.1\cdot10^8$ Pa, Poisson's ratio – 0.49
Rim	Rigid material (MATRIG); *E*-modulus – $2.1\cdot10^{11}$ Pa; Poisson's ratio – 0.29

Eulerian formulation elements coincide with the global coordinate system. This is necessary in order to use in the solver Fast Coupling algorithm, resulting in shorter time of task solution. In addition, to use this algorithm it is necessary to form a closed distinctive surface of fictitious elements of shell type between the Lagrangian and Eulerian formulation elements. FLOW BC IN card and one front surface are used for water inflow, and FLOW BC OUT card and end and side surfaces of finite elements are used for water outflow.

The inertial loads used to get uniform flow of water are described by HYDROBOD card – longitudinal acceleration is given to water film and it is loaded with a constant force of gravity.

4. Evaluation of Tire Hydroplaning Finite Element Method (FEM) Results

For the calculation by FEM the following tasks were chosen:

- develop the tire finite elements model;
- perform calculations for verification of the tires and the road model without a water film;
- perform calculations for verification of the water film;
- compare tire and the road contact forces and wheel axial displacements at different driving speeds.

A numerical test is carried out in these stages:
- the tire is inflated and the wheel is pressed to an absolutely rigid road by vertical axial force;
- the wheel is rotated at an angular velocity and at the same time, road and water film starts moving at the linear speed.

At the initial phase besides the tire simulation particularities, the influence of extreme conditions on stability of the problem solution course was also analysed. The numerical tests showed that system damping is important for the stability of solutions. In some cases it is recommended the use of viscoelastic α or β critical damping, but in the model brake forces appear and the wheel's rotation is slowing down.

For this purpose an axial grounded damping element to suppress vertical displacements of the wheel, an axial grounded damping element, which simulates shock absorber, was used in the work. Calculation results for systems without water with depression element and without it are presented in Fig. 5.

For numerical research the following simulation variants were selected:
- thickness of water film – 5 mm and 10 mm;
- tire velocity – 65 km/h, 95 km/h, 105 km/h and 110 km/h.

Besides, in numerical model the attempts were made to change FBLEND and DELCLUMP cards, having a direct impact on Eulerian formulation elements, i.e. destruction of water film and spatter removal. The numerical studies are performed to allow a more accurate assessment both for the numerical model and decide how for all the cases of calculating the wheel axis shift and contact force between the tire and for the road as absolutely rigid surface various FE mathematical models correlate.

For all the cases of calculations the wheel axis shift and contact force between the tire and absolutely rigid road surface were measured. Calculation results are given in Fig. 6. At the initial numerical research in the model with water film thickness of 5 mm and the depth of longitudinal grooves of 10 mm the wheel rotation velocities mentioned earlier were tested.

At the velocities 65 km/h and 95 km/h considerable axis shift and reduction in contact force was not fixed. At the velocity of 110 km/h, both axis shift and contact force decrease, but vertical displacement of the tire was not big. Considerable changes of axis shift and contact force occurs in the model with water film of 10 mm. At the velocity of 95 km/h, the contact force starts decreasing. When the wheel is rotating at velocity of 110 km/h, a significant reduction was fixed after 150 ms. When water film and the wheel achieve the final acceleration, and after another 100 ms the tire completely loses grip (Fig. 7).

The fluid motion and numerical noises due to the fluid–structure interaction causes oscillations of the tire vertical and contact force. The expression was not obtained in the model without water (Fig. 5).

The problem of water splashing and dripping water removal from the model was addressed in the second re-

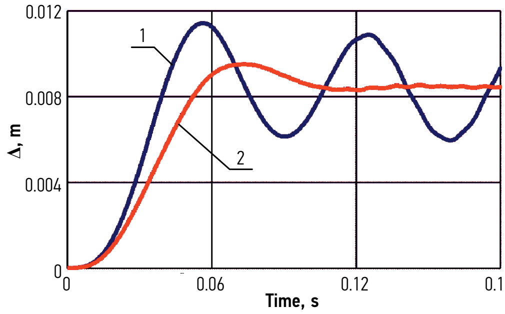

Fig. 5. Calculation results of vertical axis displacement Δ in the model without water: 1 – not damped tire system; 2 – damped tire system

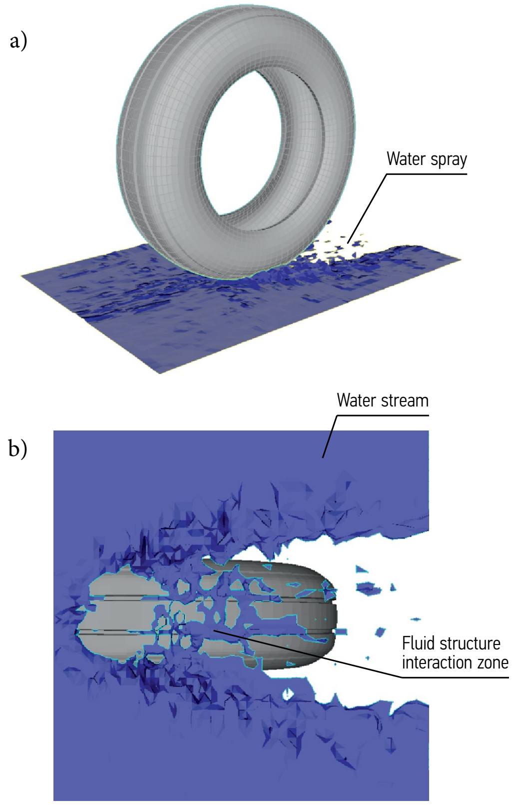

Fig. 6. Tire hydroplaning results: a – isometric view; b – bottom view

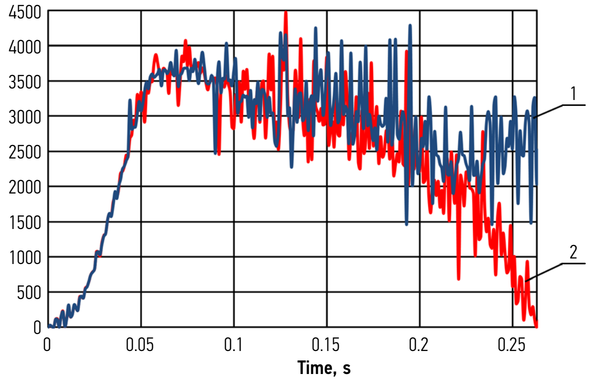

Fig. 7. Calculation results of the tire – road contact force F_c in the model with water, when driving speed is 110 km/h: 1 – thickness of water film is 5 mm; 2 – thickness of water film is 10 mm

search stage. In this case, changing values of parameters, we deal with the stability of progress of the problem solution. Randomized for some parameter values it is impossible to identify solutions. Using the recommended values the task is stable, but the accuracy of the solutions is questionable. From the model, rather massive water volume is removed, that is why the fluid and structure interaction remains unclear and may change.

Performed tire design simplifications did not significantly affect the results. In all calculation cases boundary conditions, the materials and the characteristics of the elements of the finite elements used were selected the same. To adjust the solutions, additional studies should be performed by appropriately selecting the wheel camber and alignment angles. In this case, the possibilities of water removal for front and rear wheels are different and require additional analysis.

Conclusions

The concept of hydroplaning is defined and the influence of different factors on it is analysed in the research. A simplified model of a tire water interaction was developed in PATRAN software package environment and the simulation was carried out applying DYTRAN software package.

Approximate computational model of the tire was developed, applying it to the rolling motion of vehicle's tire on wet pavement of a road was analysed and critical speeds at which according the simplified model hydroplaning (aquaplaning) starts with direct influence on directional stability and active safety of the vehicle were determined.

The simulation results indicate that for the simplified tire model the contact force starts decreasing when the speed exceeds 95 km/h and at water film of 10 mm thickness and the speed of 110 km/h the tire totally losses grip on the pavement. The main advantage of the solutions of numerical problems of this type is the possibility to make sufficiently deep description of the tire-pavement contact zone and perform hydroplaning simulation what is not so easily done applying conventional analytical or experimental methods.

The obtained results confirm the predictions and greatly depend on boundary conditions, the coefficients applied for Eulerian formulation elements and mechanical characteristics of the tire materials.

In order to make more accurate and precise analysis of the vehicle's tire movement on wet pavement and the overall behaviour of the deformed tire structure it's advisable to perform more analysis combinations of the water film thickness and tire velocities. Also it is recommended to do more detailed design analysis and numerical modelling, to check the influence of tread pattern, camber and toe angles of the front wheel, to determine experimentally the mechanical characteristics of the tire elements, and to analyse parameters used in DYTRAN software package mathematical models, as well.

References

Accident Rate Information. 2012. The Lithuanian Road Administration under the Ministry of Transport and Communications of the Republic of Lithuania. Available from Internet: http://www.lra.lt/en.php/traffic_safety/accident_rate_information/106

Bazaras, D.; Batarlienė, N.; Palšaitis, R.; Petraška, A. 2013. Optimal road route selection criteria system for oversize goods transportation, *The Baltic Journal of Road and Bridge Engineering* 8(1): 19–24. http://dx.doi.org/10.3846/bjrbe.2013.03

Buhin, B. L. 1988. *Vvedenie v Mehaniku Pnevmaticheskih Shin*. Himija, Moskva. 224 s. (in Russian).

Doroševas, V. 2007. *Impulsinės Apkrovos Veikiamų Nehomogeninių Mechaninių Sistemų Dinamika*: Monografija. Kaunas: Technologija. 212 p. (in Lithuanuan).

DYTRAN: User's Guide. 2012. The MacNeal-Schwendler Corporation. 274 p.

DYTRAN: Theory Manual. 2012. The MacNeal-Schwendler Corporation. 166 p.

European Commission. 2011. *White Paper: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*. 30 p. Available from Internet: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0144:FIN:EN:PDF

Fwa, T. F.; Pasindu, H. R.; Ong, G. P. 2012. Critical rut depth for pavement maintenance based on vehicle skidding and hydroplaning consideration, *Journal of Transportation Engineering* 138(4): 423–429. http://dx.doi.org/10.1061/(ASCE)TE.1943-5436.0000336

Horne, W. B.; Dreher, R. C. 1963. *Phenomena of Pneumatic Tire Hydroplaning*. NASA Technical Note D-2056. National Aeronautics and Space Administration, Washington, D.C. 52 p.

Huang, M. 2002. *Vehicle Crash Mechanics*. 1st edition, CRC Press. 504 p.

Jasiūnienė, V.; Čygas, D.; Ratkevičiūtė, K.; Peltola, H. 2012. Safety ranking of the Lithuanian road network of national significance, *The Baltic Journal of Road and Bridge Engineering* 7(2): 129–136. http://dx.doi.org/10.3846/bjrbe.2012.18

Kravchenko, A.; Sakno, O.; Lukichov, A. 2012. Research of dynamics of tire wear of trucks and prognostication of their service life, *Transport Problems – Problemy Transportu* 7(4): 85–94.

Kumar, S. S.; Anupam, K.; Scarpas, T.; Kasbergen, C. 2012. Study of hydroplaning risk on rolling and sliding passenger car, *Procedia – Social and Behavioral Sciences* 53: 1020–1028. http://dx.doi.org/10.1016/j.sbspro.2012.09.951

Maurya, A. K.; Bokare, P. S. 2012. Study of deceleration behaviour of different vehicle types, *International Journal for Traffic and Transport Engineering* 2(3): 253–270 http://dx.doi.org/10.7708/ijtte.2012.2(3).07

Pacejka, H. 2012. *Tire and Vehicle Dynamics*. 3rd edition, Butterworth-Heinemann. 672 p.

Park, S.-J.; Yoo, W.-S.; Kim, M.-S.; Ok, J.-K.; Kim S.-J. 2006. Comparison of tire contact pressure between physical experiment and computer simulation, in *Proceedings of the Third Asian Conference on Multibody Dynamics 2006 (ACMD2006)*, 1–4 August 2006, Tokyo, Japan. (CD).

Sapragonas, J.; Dargužis, A. 2011. Model of radial deformations of protector of vehicle tire, *Mechanika* 17(1): 21–29. Available from Internet: http://dx.doi.org/10.5755/j01.mech.17.1.199

Seiffert, U.; Wech, L. 2007. *Automotive Safety Handbook*. 2nd edition, SAE International. 306 p.

Sokolovskij, E.; Prentkovskis, O.; Pečeliūnas, R.; Kinderytė-Poškienė, J. 2007. Investigation of automobile wheel impact on the road border, *The Baltic Journal of Road and Bridge Engineering* 2(3): 119–123.

In Memoriam

Prof. Dr. Habil. Jonas Sapragonas (1942–2013)

In 2013, 21 January we lost a Professor Jonas Sapragonas of the Kaunas University of Technology (Lithuania) who was involved in the Research Journal TRANSPORT as the Deputy Editor-in-Chief since 2005.

A subtle Lowlander's character began to emerge in his native land Papilė (born in 1942, 19 August in Akmenės District), where people lacked neither diligence nor spirituality. In 1959 having graduated from Rietavas secondary school he became connected with the activities of engineer and scientist – having graduated from Kaunas Polytechnic Institute (Kaunas University of Technology now), the Faculty of Mechanical Engineering and acquired qualification of Mechanical Engineer (in 1964), he started working as an assistant in the Department of Strength of Materials, where during the period 1967–1970 studied the postgraduate course.

The talented and promising young scientist in 1970 defended his Science Candidate (Doctor) dissertation of technical sciences (PhD), in 1973 was invited to work in the Department of Machine Tools, since 1975 – in Associate Professor position.

Lowlands' perseverance and obstinacy like an engine drove into broader waters and unfamiliar fields – internship at the Paris Higher Industrial School of Physics and Chemistry (1977–1978, France), active scientific work in research of mechanical features of polymers and composites allows to achieve significant scientific results in this field – in 1993 he defended Habilitated Doctor's dissertation.

In 1995 he was granted academic rank of Professor, while entering a new phase of scientific work – the work in Faculty of Mechanical Engineering and Mechatronics at the Department of Transport Engineering (Kaunas University of Technology) bringing together the affinity group working in Transport Engineering and Technology field – Department of Transport Engineering (1998–2008), Director of the Institute of Transport Problems (Kaunas University of Technology).

As the Real Member of Lithuanian Academy of Sciences (Technical Sciences) he has been an active researcher in the research field of Transport Engineering, a member and an opponent of many Dissertation Defence Boards, a member of Habilitation Committees. Under his leadership eight doctoral students in 2000–2011 successfully defended doctoral theses in Transport Engineering field. He has been a supervisor of a number of undergraduate and graduate thesis, an active participant in the evaluation of these works.

The Professor published more than 120 scientific papers, six inventions, one monograph, was an author and co-author of nine textbooks and teaching aids. The professor was an active participant in improving the quality of learning process – Vice-Dean of the Faculty, a member of the Senate, Member of Faculty Council, as an expert of Assessment of Quality of Studies he participated in external evaluation of studies programs, was an author of regulation of Transport Engineering.

The legacy of respectable and full of creative impetus personality – the World built by wisdom and experience – impeccable academic activities and dedication to science, assistance to young colleagues when they enter complex way of scientific searches, wisdom and knowledge reflected in books, lectures, and other academic works.

The academic communities of the Kaunas University of Technology and the Editorial Board of the Research Journal TRANSPORT