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VIII MEĐUNARODNI NAUČNO-STRUČNI SKUP
O DOSTIGNUĆIMA ELEKTROTEHNIKE,
MAŠINSTVA I INFORMATIKE

8th INTERNATIONAL CONFERENCE
ON ACCOMPLISHMENTS IN ELECTRICAL,
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Mašinski fakultet
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LABORATORY RESEARCH OF INTERACTION BETWEEN STEERING AND SUSPENSION SYSTEMS OF VEHICLE

Danijela Miloradović[1], Jasna Glisović[2] -

Abstract: *This paper presents a part of the results obtained during investigation of interaction between the steering and the suspension systems of the passenger car in laboratory conditions. The objective of the research was to understand the different effects of interaction between these two vital vehicle systems, in static and quasi-static conditions. The results obtained during turning of the steering wheel following the given law and during the passing of the vehicle wheel over the obstacle shaped as a "step" function are analysed in the paper and corresponding conclusions are presented*
Key words: *vehicle, steering system, suspension system, interaction*

LABORATORIJSKO ISTRAŽIVANJE INTERAKCIJE IZMEĐU SISTEMA ZA UPRAVLJANJE I SISTEMA ELASTIČNOG OSLANJANJA VOZILA

Rezime: *Rad predstavlja deo rezultata istraživanja interakcije između sistema za upravljanje i sistema elastičnog oslanjanja putničkog automobila u laboratorijskim uslovima. Cilj istraživanja bilo je sagledavanje različitih efekata interakcije između ova dva vitalna sistema vozila u statičkim i kvazistatičkim uslovima. U radu su analizirani rezultati dobijeni pri zaokretanju točka upravljača prema zadatom testu i pri prelasku točka preko prepreke u obliku "step" funkcije i predstavljeni su odgovarajući zaključci.*
Ključne reči: *vozilo, sistem za upravljanje, sistem elastičnog oslanjanja, interakcija*

1. INTRODUCTION

There is an intensive interaction between the steering system and the suspension system of the motor vehicle. Thus, in practice, it is necessary for these two systems to have compatible geometrical, elastic-kinematic and dynamic parameters. Review and analysis of literature imply that a small number of older papers as [1] and [2] deal directly with interaction between the mentioned systems. Research carried out in those papers included independent front suspension systems (McPherson, double arm) combined with the rack-and-pinion steering system. Recent papers, like [3] and [4] present detailed dynamical models of the mentioned combination of the two systems.

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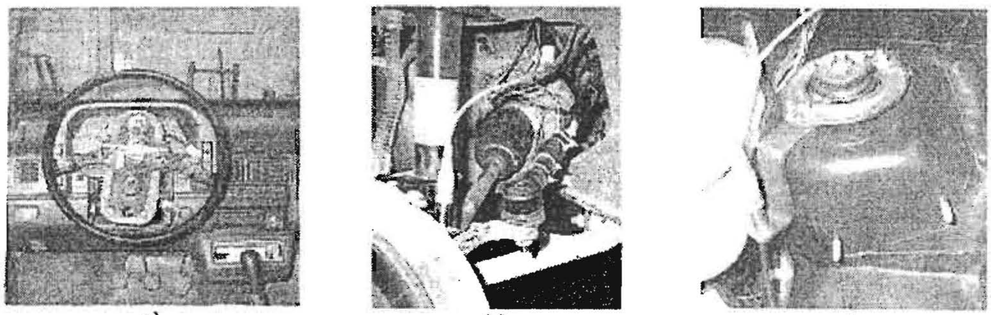
In order to closely investigate some aspects of the interaction between the steering system and the suspension system, extensive experimental research has been carried out [5]. This paper will present results of laboratory tests that include the turning of the steering wheel with vehicle standing and moving slowly on different pavements and introduction of an impulse into the steering and the suspension systems through the front left wheel (overcoming an obstacle in the shape of "step").

2. LABORATORY RESEARCH

Laboratory measurements were performed on the front McPherson suspension system and rack-and-pinion steering system of a passenger vehicle «Zastava Florida». According to the object of research, the following transducers were used, Fig. 1:

- dynamometric steering wheel with transducers for measuring the steering torque, M_v and steering wheel angle of rotation, β_v , Fig. 1a,
- strain gauge rosettes for measuring the left tie-rod's stress, σ_{sp}, Fig. 1b,
- inductive acceleration transducer for measuring the vertical acceleration at the centre of the front left wheel, $\ddot{z}_1$, Fig. 1b, and
- inductive acceleration transducer for measuring the vertical acceleration at the connection point between the front left damper and the car body, $\ddot{z}_A$, Fig. 1c.



a) b) c)

Fig.1 Transducers used in laboratory research

The research plan required performing of the laboratory test including the turning of the steering wheel with static vehicle and vehicle moving slowly on different pavements and introduction of the impulse into the steering and the suspension systems through the front left wheel (overcoming an obstacle in the shape of "step" function). The wheels were turned on laboratory floor and on concrete pavement.

Laboratory tests with vehicle's engine not running included the measurements on vehicle with front wheels on the ground or lifted above ground. The driver had to turn the steering wheel following the given "law": "neutral position - full left turn - full right turn – back to neutral position". The turning of the steering wheel had to be continuous and performed with constant speed.

Measurements carried out on a vehicle moving with small speed consisted of several tests: measurements with the use of previously mentioned test (with vehicle standing still), but with vehicle's engine running, and vehicle moving slowly ("parking regime") and measurements with vehicle's front left wheel overcoming an obstacle shaped as "step" function (80 [mm] in height and 50 [mm] in width), while the steering wheel is not controlled by the driver.

3. ANALYSIS OF THE RESULTS

Comparison of the experimental results obtained during the turning of the steering wheel following the given law is shown in Fig. 2. The steering wheel angle of rotation was used as independent variable (instead of time), due to insufficient repeatability of the steering wheel's angular velocity during different tests. Additionally, Fig. 2 shows direct couplings between individual measurands.

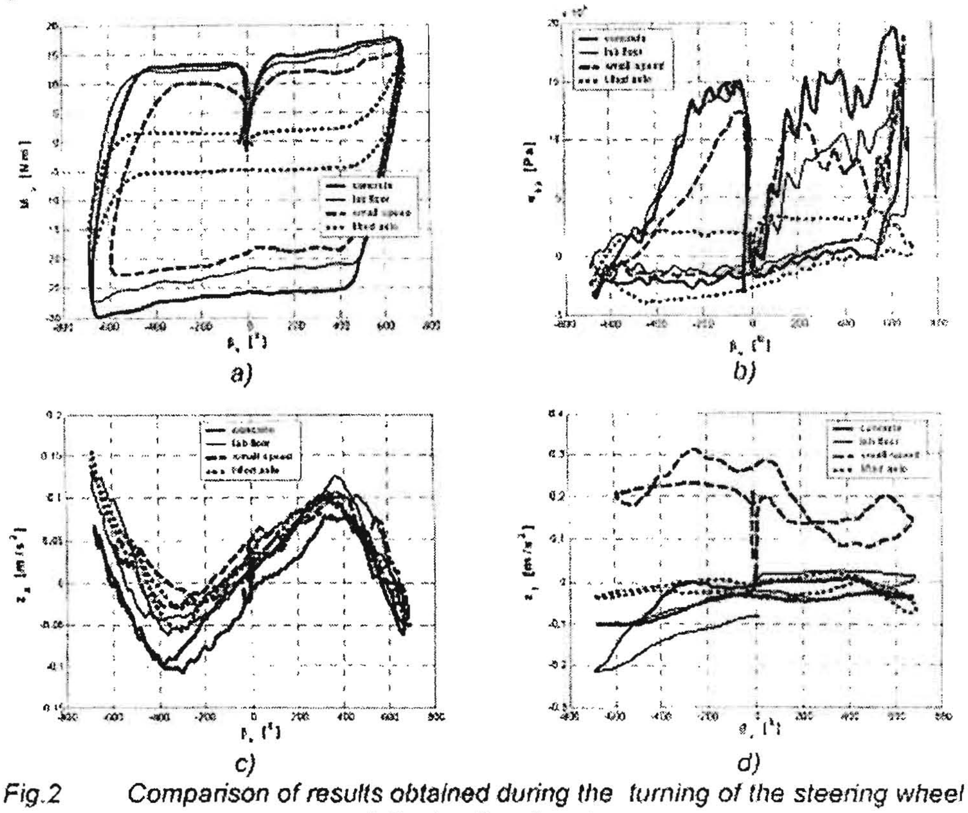


Fig.2 Comparison of results obtained during the turning of the steering wheel following the given law

The direct coupling between the steering wheel torque and the steering wheel angle of rotation, Fig 2a, shows that the curve may be approximated correctly enough with a series of straight lines. In other words, the steering wheel torque and angle of rotation have a high linear correlation coefficient in parts of the test. Main normal stress at the tie-rod's cross section, Fig. 2b, does not have obvious analytical dependence on the steering wheel angle of rotation. The coupling between the steering wheel angle of rotation and the vertical acceleration at the connection point between the front left damper and the car body is shown in Fig. 2c. Graphical representation implies that there is corresponding analytical dependence and that the parts of the curve may be approximated with, for instance, sinus function. Direct coupling between the steering wheel angle of rotation and the vertical acceleration at the centre of the front left wheel. Fig. 2d, shows a highly linear dependence.

Comparison of the result acquired during overcoming the "step" shaped obstacle in front of the front left wheel is presented in Fig. 3. Diagrams show time functions of measurands for vehicle driving forth and back over the obstacle. Displays are not synchronised in time (the results are presented in their original form), so they only point to the different reactions of the vehicle when it drives forth or back over the obstacle.

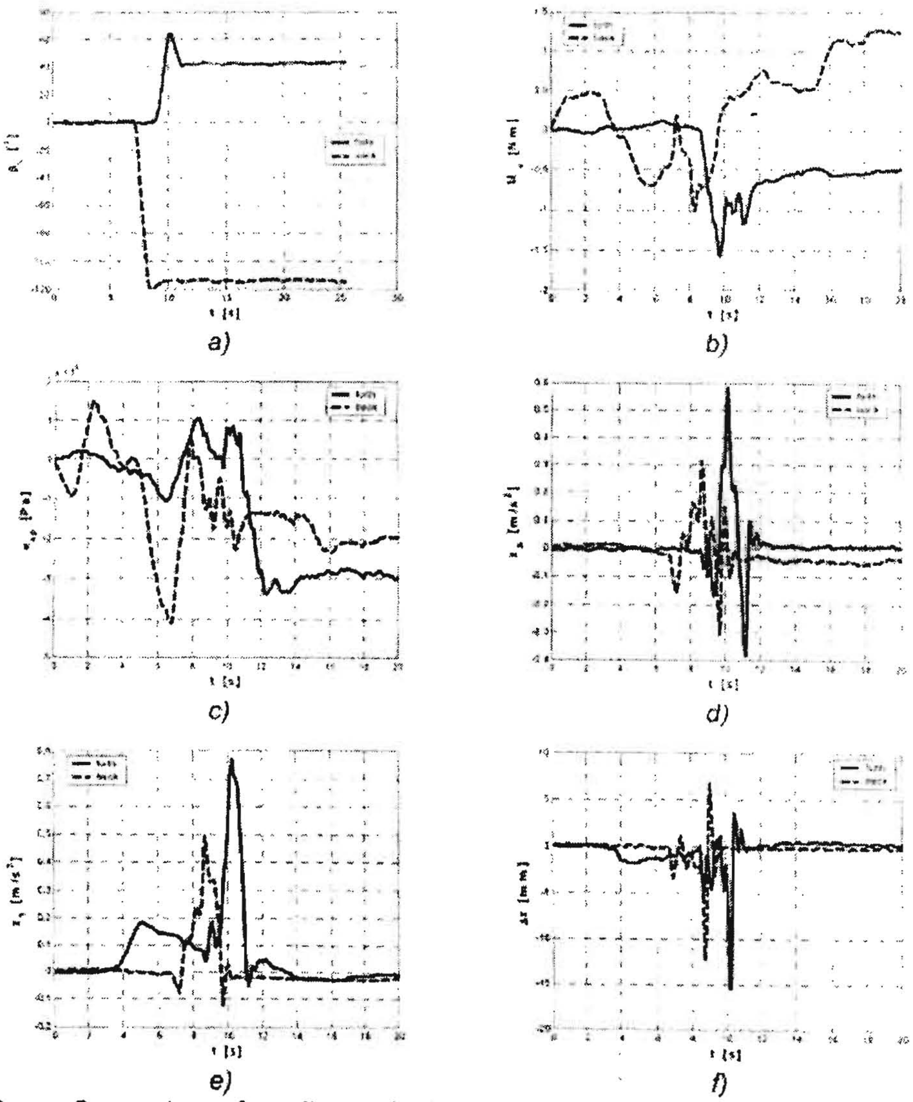


Fig.3 Comparison of results acquired from vehicle's front left wheel driving forth and back over the "step" shaped obstacle

Diagrams in Fig. 3 show that, during the overcoming of the "step" obstacle, the reaction in suspension and steering systems elements occurs and it depends on longitudinal direction of front left wheel's motion. Impulse vertical load transfers from the pavement, through the wheel hub, back to the elements of the steering and suspension systems, all the way to the steering wheel.

The steering wheel exhibits the change in torque, Fig. 3a, and in angle of rotation, Fig 3b, not introduced by the driver. The occurrence of the steering wheel turning as a reaction to front left wheel overcoming an obstacle, shows that the front left wheel has also turned without the influence of the driver. In practice, this phenomenon is called "bump steer effect" (turning of the wheel due to the passing over the road bump) and it manifests as a vehicle tendency to "pull" to one side of the road, when the front suspension compresses, thus demanding the correction from the driver. This effect is present in all combinations of the steering and the suspension systems and represents one aspect of their interaction.

Fig. 3a shows that the steering wheel turns left for around 45 [°], when the front left wheel travels forth over the obstacle and it corresponds to turning of the wheel by 2[°] to the left (for a given obstacle). Larger turn of the steering wheel is noticed when the wheel passes backwards over the obstacle – the steering wheel then turns 120 [°] to the right, while the wheel turns right for 6 [°]. Rotation of the wheel around the vertical axis is transferred back to the steering wheel.

Torque is present on the steering wheel as a consequence of the existence of the inertial moments on the steering wheel, Fig. 3b. Torque values are ten times smaller than the values of torque introduced by the driver during turning on the same pavement (laboratory floor) in static conditions (maximal load of the steering wheel).

Variation of normal stress in tie-rod's cross section, Fig. 3c, follows the variation of the steering wheel torque. Obtained values of normal stress are several times smaller than those achieved during the test of turning the steering wheel of the static vehicle on the same pavement, because stabilisation moment at the tire-road contact is smaller.

Vertical acceleration at the connection point between the damper and the car body, Fig. 3d, changes almost identically when wheel passes forth and back over the obstacle, with noticeable difference in maximal values (most likely coming from the vehicle speed during the passing over the obstacle). The same conclusion applies to vertical acceleration at the centre of the front left wheel, Fig. 3e.

The diagram of the relative suspension stroke, Fig. 3f, may provide means to reconstruct the physical nature of the process of vehicle wheel overcoming a road obstacle. At first, a spring and a damper of the suspension system compress due to a contact with an obstacle. Then, maximal values of compression occur (the wheel has climbed on the obstacle). Further, the wheel gets off the obstacle and the spring and the damper stretch out to achieve the initial position. The induced vibration of the curb weight excites additional stretching of the spring and the damper before the initial position is reached. Maximal spring and damper deflection is 12÷16 [mm].

4. CONCLUSIONS

Analysis of the experimental results obtained during vehicle laboratory tests in static regimes, with the steering wheel turned by the given law, has shown high values of linear correlation (in parts of the test) between the steering wheel angle of rotation and vertical acceleration at the centre of the front wheel. This means that there is geometrical and kinematical interaction between the steering and the suspension system. Vertical acceleration at the connection point between the damper and the car body also shows obvious (even analytical) dependence on the steering wheel angle of rotation, which is the consequence of kinematical processes at the steering and suspension systems.

The results obtained during experiment of front left wheel overcoming the road obstacle ("step" shaped excitation function) point to the fact that impact vertical load (equivalent acceleration at the centre of the front left wheel) is transferred from the road, back to the elements of the suspension and steering systems and, finally, to the steering wheel. During passing over the unit vertical road obstacle, spontaneous turning of the wheel around its vertical axis and deflection of springs and dampers of the suspension system occur. In practice, this phenomenon manifests as a vehicle tendency to "pull" to one side when front suspension system deflects and it is one version of interaction of the suspension system with the steering system.

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