УДК 004.9

A. Lewandowski, K. Kędziora, I. Malujda, K. J. Waluś
Institute of Forensic Research in Cracow
Poznan University of Technology

METHODOLOGY OF MEASUREMENTS OF MOTION PARAMETERS OF PASSENGER VEHICLES

Ця стаття присвячена методології вимірювань рухомих параметрів пасажирського транспорту.
Ключові слова – методологія, пасажирський транспорт, прискорення

This paper is devoted to the methodology of measurements of motion parameters of passenger vehicles.
Keywords – methodology, passenger vehicle, acceleration

Introduction

Reconstruction of road accident includes reproduction of motion parameters of passenger vehicles, which take part in event. The most possible high fidelity of reproduction of vehicle’s motion justifies the performance of experimental tests of vehicle in unchanged conditions of state of road. It is possible to do so based on measuring instruments, which measure and register a course of tests. Finding the motion parameters of passenger vehicle can be achieved by measurement of:

- instantaneous distance,
- instantaneous velocity,
- instantaneous acceleration.

Example of device, which is using measurement of distance, is measuring system DATRON with photo-optical sensors. Differentiation of measured distance relative to time allows to determine velocity, and successive differentiation – acceleration. These operations are performed in advanced digital technique, which forms advanced information system.

Measurement of instantaneous velocity is used in “fifth wheel” device, in conventional solution electric generator, which is mounted on axis of fifth wheel, is used for measurement of velocity. On the basis of obtained velocity there is calculated displacement and acceleration.

Low precise devices with inertial mass were used once for measurement of acceleration. Nowadays common availability of microchip sensors of acceleration, which price is about more than ten dollars for a sensor, allows to their utilization for measuring tasks including measurements of accelerations of passenger vehicles. These sensors are distinguished by the following features: lightweight (sensor mass is only 2 grams), easy in use and cheap. Acceleration sensor is made in surface micromechanics technology MEMS (MicroElectroMechanical System). It consists of capacitor with comb capacitor plates placed in polysilicon, where ones are moveable and other ones are not. Moveable beam (which forms with immovable beams the comb structure) is deflected by force of inertia. Apart from electrical details of input signal processing, it should be added that microchip is consisted also of operational amplifier, which can be applied to form a sensitivity of indication of acceleration sensor.

Measuring systems, which use acceleration micro-sensors, for the sake of above mentioned features are the tools, which allow to investigate correlation between motion parameters of passenger vehicle and tracks, which occur on the road as a result of this motion. It concerns both rectilinear and curvilinear motion.

Measurements of accelerations in rectilinear motion

In case of measurements of parameters of vehicle, which is moving with rectilinear motion, the affecting acceleration causes the movement of body of a car, which is caused by its springing. Measuring sensors are usually connected with springing part of car body, this has a essential influence on current values of conducted measurements by impact of gravitational acceleration on sensors. Segregation of this factor demands additionally application of measurement of angle of rotation of car body. The need of measurement of angle of rotation of car body is explained by simplified model of braking presented in figure 1. There was assumed that acceleration vector of material particle characterizes the motion of car body. Coordinate system XV, ZV is connected with vehicle. During interaction of acceleration on car body, which is connected with change of motion, occurs rotation of local coordinate system, which is a function of springing features of car body relative to coordinate system connected with roadway X, Z.

Θ angle rotation of car body causes that measurement of acceleration's component in direction of sensor's axis XV shows a higher value aXV than parallel component to road (in direction of X axis). While component in perpendicular direction, measured along sensor's axis ZV, shows lower value. Obtaining the real motion parameters of vehicle in time function (along X axis) such as: acceleration, velocity and travelled distance, demands current measurement of angle of rotation of sensor Θ and taking this into account during calculating process, in accordance with relationship (1):

$$a_x = a_{xv} \cdot \cos\theta - a_{zv} \cdot \sin\theta \qquad (1)$$

Knowledge of function aX(t) allows to determine residual motion parameters of vehicle: velocity and distance, by integration.

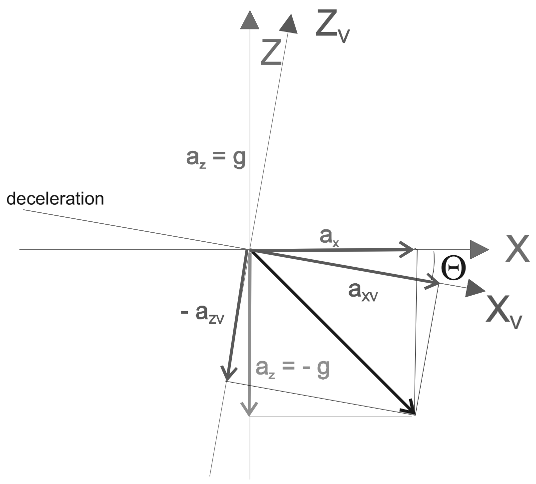

Fig. 1. Model of accelerations registered by biaxial sensor during vehicle braking

Characteristics of measuring system with MEMS sensors

Constructed measuring system in Institute of Forensic Investigations, which consists of two acceleration sensors and piezogyroscope (mounted individually on printed-circuit board), was mounted on cubic element made of duralumin. Such solution allowed to obtain a base for mutually perpendicular location of acceleration sensors. This situation is presented in figure 2.

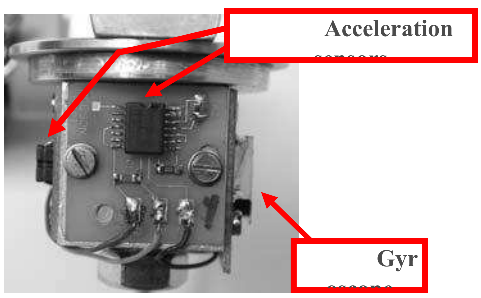

Fig. 2. Measuring system fastening – side view

For gauge head mounting in research vehicle there was applied vacuum cup holder, which was provided with system of mutually perpendicular bolts. These bolts allow to locate measuring system properly in coordinate system of vehicle. Applied mounting bolts possess base planes, which provide perpendicularity of axis. Applied solution with usage of bolt connections and application of proper base planes, is versatile and provides a possibility of proper (and reliable) orientation of measuring element, what is presented in figure 3. (Moreover rubber element of vacuum cup holder, in some way, suppresses a part of vibrations of car body.)

Fig. 3. Exemplary orientation of measuring element relative to fastening plane

Block diagram of device is presented in figure 4.

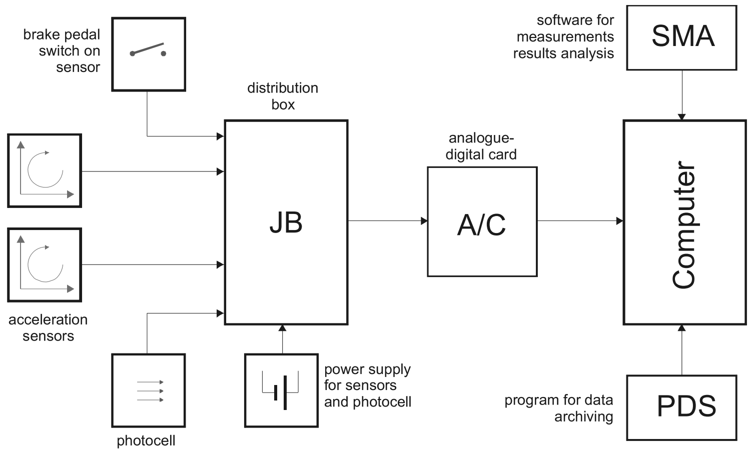

Fig. 4. Block diagram of measuring system with acceleration sensors and piezogyroscope

Biaxial acceleration sensors with piezogyroscope generate analogue measurement signal and delivers it to distribution box (JB), which is also supplied by signals from photocell. Photocell's task is binary registration of presence of reflective strips on vehicle's path, which are spaced in known distance, and on the basis of that there is calculated instantaneous velocity of this vehicle. Photocell performs as verifier of indications of acceleration sensors. Additionally when one knows a position of strips on vehicle's path then one can conduct a verification of indications of sensors on the basis of travelled distance by vehicle. Registration of moment of brake actuation allows to analyse durations of transient processes (escalation of braking forces) in hydraulic system. Analogue signals, converted by analogue-digital card (A/C) on digital form, are registered in portable computer by PDS program.

PDS and SMA programs

PDS program for data archiving, which are obtained during measurements, allows to:

- calibration of acceleration sensors and piezogyroscope,
- give a name of file, which possesses measurement data,

− record data in form of voltage values and text,
− check operation of photocell and circuit-breaker on brake pedal.

Calibration is conducted before series of measurements. G (denotes gravitational acceleration, which is equal 9,81 m/s2) and –g values are master. Calibration of piezogyroscope comes down to zero adjustment of sensor during standstill.

Software window of PDS program is presented in figure 5.

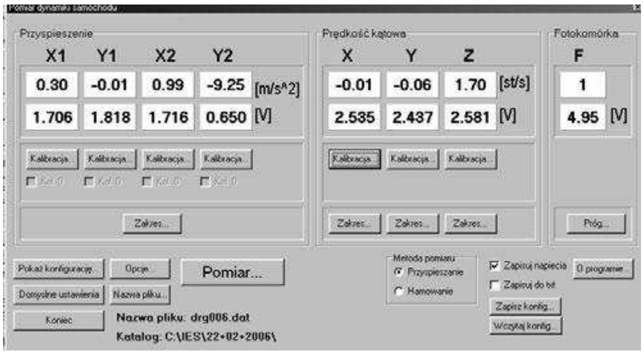

Fig. 5 Software window for data archiving PDS

For results analysis there was elaborated an SMA program, which allows to present, in synthetic and analytical form, results of measurements of motion parameters of researched vehicle, and in particular allows to do:

− observation of registered courses of accelerations in local coordinate system of vehicle and in global coordinate system of road,
− calculation of velocity course and travelled distance by integration of acceleration,
− observation of angular velocity and angle of rotation of car body,
− determination of instantaneous velocity on the basis of data from photocell.

Moreover program allows for signal filtration with usage of moving average and Butterworth's filter, and also allows to calculate mean and integral of analysed course in given time interval.

Example of analysis of registered course of deceleration of vehicle's braking is presented in figure 6.

Verification researches pointed out that error of measured distance during acceleration and deceleration tests of vehicles and motorcycles does not exceed 2%.

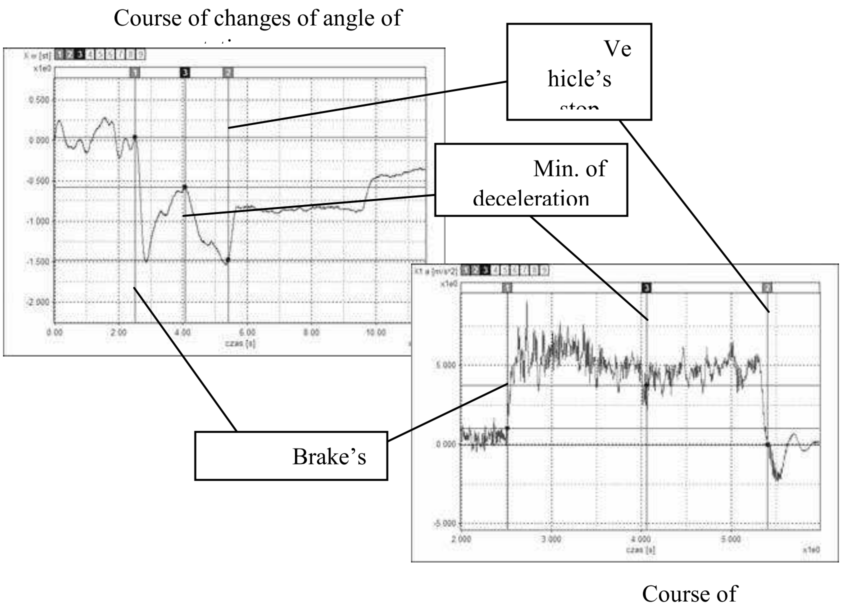

Fig. 6. Example of recorded courses of acceleration and rotation angle of motorcar body

Measurements of accelerations in curvilinear motion

Search of correlation between dynamics of vehicle's motion, which moves with curvilinear motion, and tracks, which are left on pavement by vehicle, demands determination of values of acceleration in three mutually perpendicular directions. For this aim it is not possible to apply measuring set in presented above specification, for the sake of to small number of acceleration and angular velocity sensors. In order to perform a measurement of accelerations in curvilinear motion, it is necessary to conduct a modification of measuring system and software. Set of sensors for measurements in spatial system should be equipped with additional acceleration and angular velocity (piezogyroscope) sensors.

Likewise in case of measurements in biaxial system, determination of values of accelerations registered by set of sensors in local coordinate system (connected with vehicle) is not sufficient to determine value of acceleration of moving vehicle. In order to determine these values it is necessary to perform a transformation of values of accelerations, which are measured in local coordinate system connected with vehicle (figure 7), to global coordinate system connected with roadway. In practise it consists in correction of measured values of accelerations by difference, which results from rotation of system. In contrast to two-dimensional measurements, where rotation between two coordinate systems is not difficult to do, this transformation consists of several stages and is more complex.

In many publications concerning simulation of passenger vehicle's or aircraft's movement there are presented mathematical relationships, which allow to perform transformations between both three-dimensional systems based on Euler's matrixes, Bryant's angles (called air or aircraft) and others [3, 4, 5]. Their precious advantage is simplicity of calculations. Essential disadvantage is fact that sequence of rotations performing has a huge influence on values of accelerations in new coordinate system. During performing the calculations for numerical simulations the sequence of particular rotations can be assumed in advance, while in case of data transformation, obtained during experimental researches, this sequence can be random only. Moreover, as it results from literature [1, 2, 3], the disadvantages of mentioned algorithms are: occurrence of singular points for specified values of angles and increase of uncertainty of calculations together with increase of values of angles of inclination.

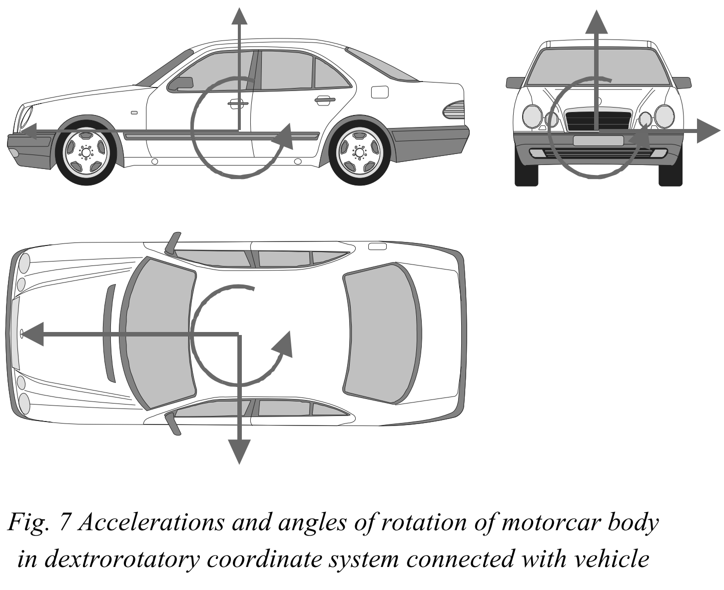

Fig. 7 Accelerations and angles of rotation of motorcar body in dextrorotatory coordinate system connected with vehicle

In order to perform a rotation of coordinate systems in experimental applications, it is necessary to use algorithms, where sequence of conducting the particular rotations does not play part. Such possibility provides the application of quaternion method [5]. In this method the sequence of rotations of local coordinate system relative to particular axis of global coordinate system must be assumed only for determination of initial position of transformed system, this procedure in case of calibration of system before measurements of accelerations can be omitted. Successive orientations of local coordinate system, which result from performed rotations, are determinate with taking into account successive mean values of angular velocities for particular rotations, which are measured in specified time intervals.

Software, which will be elaborated and next will be applied for measurement data analysis obtained during measurements of accelerations of vehicles in spatial system, will use presented above procedure based on quaternion algebra.

1. Z. Dziopa, „Mechanika lotu”, Wydawnictwo Politechniki Świętokrzyskiej, Kielce 2007. 2. J. Gajda, „Zastosowanie kwaternionów w algorytmach wyznaczania orientacji przestrzennej obiektów ruchomych, Mechanika teoretyczna i stosowana”, Tom 28, Zeszyt 1-2, Warszawa 1990, pp. 583 – 592. 3. G. Hoffmann, „Application of Quaternions, translation of original report: Anleitung zum praktischen Gebrauch von Quaternionen”, Technische Universität Braunschweig, 2005. 4. Z. Lozia, „Analiza ruchu samochodu dwuosiowego na tle modelowania jego dynamiki”, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 1998. 5. R. Róziecki, „Bifurkacyjna analiza dynamiki lotu samolotu supermanewrowego z wektorowaniem ciągu”, Wrocław 2007, rozprawa doktorska.

УДК 004.942

К.К. Колесник
Національний університет “Львівська політехніка”,
кафедра систем автоматизованого проектування

АВТОМАТИЗОВАНА ТЕХНОЛОГІЯ РОЗРАХУНКУ МІКРОСЕНСОРІВ ПЄ’ЗОРЕЗИСТИВНОГО ТИПУ

Розроблено технологію та підсистему для проведення автоматизованого розрахунку та створення проектної документації мікросенсорів п’єзорезистивного типу за допомогою API функцій САПР (CAD/CAM/CAE). За допомогою підсистеми одержано залежності між фізичними величинами, які вимірюються завдяки мікросенсорів, та вихідною напругою з мостової схеми п’єзорезисторів мікропередавачів.
Ключові слова – мікросенсор, п’єзорезистор, документація, САПР

The technology and subsystem for execution of automated calculation and creation of the technical documentation of the piezoresistive microsensors with the help CAD/CAM/CAE is presented. The associations between physical values and voltage out from a bridge circuit of piezoresistive microtransmitters are obtained.
Keywords – microsensor, piezoresistor, docmentation , CAD

Вступ

Продукування мікроелектромеханічних систем – MEMS (MicroElectroMechanical Systems) дає змогу вирішити проблеми, що пов’язані з матеріалоємністю створюваних конструкцій та їх енергоспоживанням. Особливістю мікросистем є можливість суміщати в собі електричну та механічну