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Oleg Lyashuk, Prof., DSc., **Uliana Plekan,** PhD econ. sci.,**Oleg Tson,** Assoc. Prof., PhD tech. sci., **Bogdan Gevko,** PhD econ. sci.
Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine

Development Technologies of Cars Hybrid Power Plants

Innovations and trends in the field of power plants of hybrid cars were covered in the article. The essence of the car's power plant was analyzed. The special transmission of hybrid cars was described. The modes of operation of the power plant in a hybrid car were outlined. Modern technologies of power plants of cars were given.

The issue of increasing the efficiency of propulsion system of cars, increasing fuel efficiency and reducing toxic gas emissions in modern automotive industry was considered. It was emphasized that the practical use of combined power plants allows to significantly reduce the cost of transporting goods and passengers by vehicle, as well as to improve energy and environmental characteristics. The main modes of operation of the power plant in a hybrid car were listed by the authors, in particular: electric mode, hybrid mode, charge mode. Trends in the development of electric cars, which use electric propulsion systems instead of internal combustion engines, have been outlined. The trend of recent years in the development of electric cars included: an increase in the range of travel, fast charging and improvement of power electronic systems. The modern development of hybrid cars was analyzed in the article, in particular: Plug-in hybrid cars, use of a 48-volt network, an improvement of control modes in hybrid cars and energy recovery systems. Special attention was paid to changes in driving modes of hybrid cars.

In general, the technologies of power plants of cars are developing rapidly, are aimed at reducing fuel consumption. A combination of internal combustion and electric motors in hybrid cars makes it possible to achieve an optimal balance between fuel efficiency and environmental friendliness, and ensures convenience and performance when driving on the road.

hybrid, cars, propulsion system, transmission, engine, energy recovery, control modes

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Michael Podryhalo, Prof., DSc., **Olexand Polyanskyi,** Prof., DSc., **Yevgeniy Dubinin,** Prof., DSc., **Dmytro Klets**, Prof., DSc., **Vladyslava Baidala**, Assist., **Maksym Krasnokutskyi**, post graduate
Kharkiv National Automobile and Highway University, Kharkiv, Ukraine
e-mail: dubinin-rmn@ukr.net

Improving the Accuracy of Wheeled Vehicle Acceleration Estimation During Testing

The study considers the influence of installation errors during the installation of linear acceleration sensors on the accuracy of measurements during testing of wheeled vehicles, including the dynamic stability of the position. The possibility of automatic correction of these errors to improve measurement accuracy is considered. The work includes establishing the dependence of linear acceleration components on the angular deviations of the axes of the wheeled vehicle coordinate system and developing a method of automatic correction in real time to ensure high quality measurements and maintain the reliability of measurement systems.

wheeled machine, measurement error, deviation, acceleration, automation

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Formulation of the problem. The installation error of linear acceleration sensors can significantly affect the measurement accuracy. To increase the accuracy, it is necessary to correct the position of the sensors relative to the selected wheeled vehicle coordinate system. This is especially true for certification tests of wheeled vehicles, when the results of measurements determine the subsequent decision on the approval and operation of new or modernized wheeled vehicles.

Therefore, research aimed at improving the accuracy of estimating wheeled vehicle accelerations during testing is timely and relevant.

Analysis of recent research and publications. Paper [1] investigated the dynamics of parameter changes during the calibration of linear acceleration sensors to quickly check the sensitivity of the developed mobile registration and measurement complex before starting road tests.The author of [2] developed a methodology for determining the angle of longitudinal inclination of a vehicle and the slope of the road during dynamic tests. This technique significantly reduces the error when recording the parameters of wheeled vehicle movement, as well as tests on a road irregularities or uneven slope. The authors of [3] developed a mobile registration and measurement complex (MRMC) for dynamic testing of wheeled vehicles, which contributed to the development of software for analyzing signals received from the sensors.The mobile registration and measuring complex has been improved and received a more modern version [4, 5], which automatically takes into account measurement errors when using.

Setting objectives. The aim of the work is to clarify the dependencies of linear acceleration components on angular deviations of the axes of the wheeled vehicle coordinate system to improve the accuracy and reliability of measurements.

Achieving this goal involves solving the following tasks:

– to establish the dependence of linear acceleration components on the angular deviations of the axes of the wheeled vehicle coordinate system;

– estimate the error values that may occur when installing acceleration sensors on a wheeled vehicle based on the obtained equations;

– develop methods and strategies for automatic real-time correction to ensure high quality measurements and maintain the reliability of measurement systems.

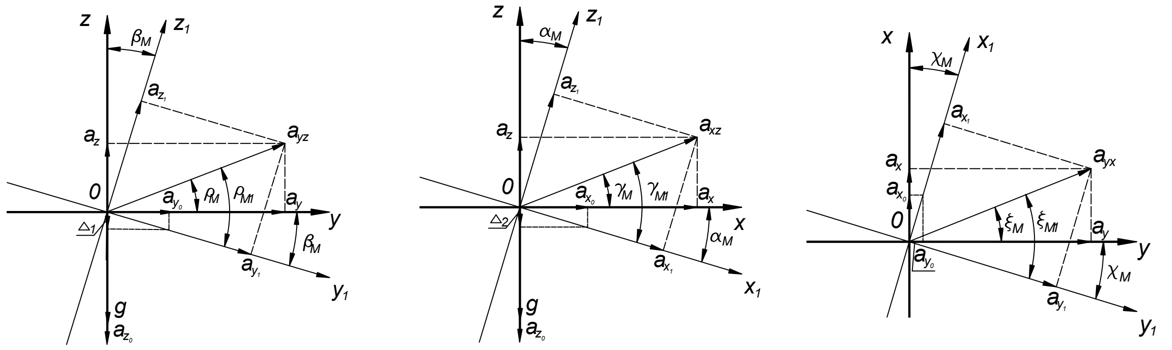
Presenting main material. During installation, the sensor axes are set according to the signal values: *OZ* axis – signal $a_z = g$; *OX* axis – signal $a_x = 0$; *OY* axis – signal $a_y = 0$ (a_x, a_y, a_z – the values of the linear acceleration components along the coordinate axes). However, the machine itself may be located on a support surface that is not horizontal. Therefore, it is necessary to introduce an automatic correction for the deviation of signals of linear acceleration sensors along the coordinate axes caused by the mismatch of their axes with the directions of the selected axes of the wheeled vehicle [6].

Consider the case of a mismatch between the location of the axes of a wheeled vehicle and acceleration sensors in the vertical transverse plane, which is a priority when assessing position stability. Let's assume that in the transverse plane, the coordinate system of the *YOZ* sensors is rotated relative to the Y_1OZ_1, coordinate system associated with the machine by an angle of $\beta_м$ (Fig. 1).

When the machine coordinate system is rotated clockwise relative to the sensor coordinate system, the angle $\beta_м$ is considered negative, and counterclockwise – positive. Determination of the angle $\beta_м$ is possible when moving from a standstill by generating test signals a_{z0} and a_{y0}.

In this case, the angle of rotation of the sensor coordinate system relative to the machine coordinate system is determined by the test signal value

$$\beta_м = \frac{\Delta_1}{a_{y0}} = arctg\left(\frac{a_{z0} - g}{a_{y0}}\right) \qquad (1)$$



a b c

a – in the transverse plane; b – in the longitudinal plane; c – in the horizontal plane

Figure 1 – Determining the relationships between coordinates

Source: developed by the author

Suppose that the coordinate system of the sensors is shifted relative to the coordinate system of the wheeled vehicle only in the transverse plane by an angle β_{M} ($a_{y0} = 0$, $\chi_{M} = 0$). In this case, there is no axis shift in other planes.

In this case

$$\begin{cases} a_{yz}^2 = a_{z1}^2 + a_{y1}^2 = a_z^2 + a_y^2; \\ \dfrac{a_z}{a_y} = tg\rho_{м}; \\ \dfrac{a_{z1}}{a_{y1}} = tg\rho_{м1}; \\ \rho_{м1} = \rho_{м} + \beta_{м}. \end{cases} \tag{2}$$

Equation (2) is reduced to the form

$$a_{y1}^2 \cdot \left(1 + \frac{a_{z1}^2}{a_{y1}^2}\right) = a_y^2 \cdot \left(1 + \frac{a_z^2}{a_y^2}\right). \tag{3}$$

Where we get it from

$$a_{y1} = a_y \cdot \sqrt{\frac{1 + {a_z^2}/{a_y^2}}{1 + {a_{z1}^2}/{a_{y1}^2}}} = a_y \cdot \sqrt{\frac{1 + tg^2\rho_{м}}{1 + tg^2(\rho_{м} + \beta_{м})}} = a_y \cdot \frac{\cos(\rho_{м} + \beta_{м})}{\cos\rho_{м}} =$$
$$= a_y \cdot \cos\beta_{м}\left(1 - \frac{a_Z}{a_y} tg\beta_{м}\right) = a_y \cdot \delta_y , \tag{4}$$

where δ_y – the correction in the value of the sensor readings oriented along the *OY* axis

$$\delta_y = \cos\beta_{м}\left(1 - \frac{a_Z}{a_y} tg\beta_{м}\right). \tag{5}$$

After similar transformations, we get

$$a_{z1} \cdot = a_z \cos\beta_{м}\left(1 + \frac{a_Z}{a_y} tg\beta_{м}\right) = a_z \cdot \delta_z , \tag{6}$$

$$\delta_z \cdot = \cos\beta_{м}\left(1 + \frac{a_y}{a_z} tg\beta_{м}\right), \tag{7}$$

where δ_z – correction in the value of sensor readings oriented along the *OZ* axis.

For other coordinate axes, the correction for the installation error can be determined as follows: the angle of rotation of the sensor coordinate system relative to the wheeled vehicle coordinate system in the longitudinal plane is determined by the following relationship

$$a_{м} = \frac{\Delta_2}{a_{x0}} = arctg\left(\frac{a_{z0}-g}{a_{x0}}\right). \tag{8}$$

We assume that the coordinate system of the sensors is shifted relative to the coordinate system of the wheeled vehicle only in the longitudinal plane by an angle $\alpha_{м}$. At the same time, $\beta_{м} = 0$ and $\chi_{м} = 0$. In this case

$$\begin{cases} a_{yz}^2 = a_{z1}^2 + a_{y1}^2 = a_z^2 + a_y^2; \\ \frac{a_z}{a_y} = tg\rho_{м}; \\ \frac{a_{z1}}{a_{y1}} = tg\rho_{м1}; \\ \rho_{м1} = \rho_{м} + \beta_{м}. \end{cases} \quad \begin{matrix} (9) \\ \\ (10) \end{matrix}$$

Equation (9) is reduced to the form

$$a_{x1}^2 \cdot \left(1 + \frac{a_{z1}^2}{a_{x1}^2}\right) = a_x^2 \cdot \left(1 + \frac{a_z^2}{a_x^2}\right) \tag{11}$$

we get

$$a_{x1} = a_x \cdot \sqrt{\frac{1 + a_z^2 / a_x^2}{1 + a_{z1}^2 / a_{x1}^2}} = a_x \cdot \sqrt{\frac{1 + tg^2\gamma_{м}}{1 + tg^2(\gamma_{м} + \alpha_{м})}} = a_x \cdot \frac{\cos(\gamma_{м} + \alpha_{м})}{\cos\gamma_{м}} =$$

$$= a_x \cdot \cos\alpha_{м}\left(1 - \frac{a_Z}{a_x} tg\alpha_{м}\right) = a_x \cdot \delta_x, \tag{12}$$

where δ_x – refinement by the value of the sensor readings, which is oriented along the *OX* axis

$$\delta_x = \cos\alpha_{м}\left(1 - \frac{a_Z}{a_x} tg\alpha_{м}\right). \tag{13}$$

From equation (10) we obtain

$$a_{z1} \cdot = a_{x1} tg\gamma_{м} = a_{x1} tg(\gamma_{м} + \alpha_{м}) = a_{x1} \frac{\frac{a_Z}{a_x} + tg\alpha_{м}}{1 - \frac{a_Z}{a_x} tg\alpha_{м}}. \tag{14}$$

Substituting (12) into (14), we obtain

$$a_{z1} \cdot = a_z \cos\alpha_{м}\left(1 + \frac{a_x}{a_z} tg\alpha_{м}\right) = a_z \cdot \delta_z, \tag{15}$$

$$\delta_1 \cdot = \cos\alpha_{м}\left(1 - \frac{a_x}{a_z} tg\alpha_{м}\right). \tag{16}$$

In the horizontal plane, the angle of rotation of the sensor coordinate system relative to the wheeled vehicle coordinate system is determined by the following relationship

$$\chi_{м} = arctg\left(\frac{a_{y0}}{a_{x0}}\right). \tag{17}$$

Let's assume that the sensor coordinate system is offset from the wheeled vehicle coordinate system only in the horizontal plane by an angle $\chi_{\text{М}}$. In this case, there is no axis shift in other planes ($\alpha_{\text{М}} = 0$; $\beta_{\text{М}} = 0$). After performing transformations similar to the previous ones, the following expressions are obtained

$$a_{y1} \cdot = a_y \cdot \cos\chi_{\text{м}} \left(1 - \frac{a_x}{a_y} tg\chi_{\text{м}} \right) = a_y \cdot \delta_y\,, \qquad (18)$$

$$\delta_1 \cdot = \cos\chi_{\text{м}} \left(1 - \frac{a_x}{a_y} tg\chi_{\text{м}} \right), \qquad (19)$$

$$a_{X1} \cdot = a_X \cdot \cos\chi_{\text{м}} \left(1 - \frac{a_Y}{a_X} tg\chi_{\text{м}} \right) = a_X \cdot \delta_X\,, \qquad (20)$$

$$\delta_X \cdot = \cos\chi_{\text{м}} \left(1 + \frac{a_Y}{a_X} tg\chi_{\text{м}} \right). \qquad (21)$$

Let us consider the general case when $\alpha_{\text{М}} \neq 0$; $\beta_{\text{М}} \neq 0$; $\chi_{\text{М}} \neq 0$. In this case, the expression

$$a_X^2 + a_y^2 + a_z^2 = a_{X1}^2 + a_{y1}^2 + a_{z1}^2\,. \qquad (22)$$

From expression (22) we define

$$a_{x1} = a_x \cdot \sqrt{\frac{1 + \frac{a_y^2}{a_x^2} + \frac{a_z^2}{a_x^2}}{1 + \frac{a_{y1}^2}{a_{x1}^2} + \frac{a_{z1}^2}{a_{x1}^2}}} = a_x \cdot \sqrt{\frac{1 + \frac{1}{tg^2\xi_{\text{м}}} + tg^2\gamma_{\text{м}}}{1 + \frac{1}{tg^2\xi_{\text{м}1}} + tg^2\gamma_{\text{м}1}}}\,, \qquad (23)$$

$$a_{y1} = a_y \cdot \sqrt{\frac{1 + \frac{a_x^2}{a_y^2} + \frac{a_z^2}{a_y^2}}{1 + \frac{a_{x1}^2}{a_{y1}^2} + \frac{a_{z1}^2}{a_{y1}^2}}} = a_y \cdot \sqrt{\frac{1 + tg^2\xi_{\text{м}} + tg^2\rho_{\text{м}}}{1 + g^2\xi_{\text{м}1} + tg^2\rho_{\text{м}1}}}\,, \qquad (24)$$

$$a_{z1} = a_z \cdot \sqrt{\frac{1 + \frac{a_x^2}{a_z^2} + \frac{a_y^2}{a_z^2}}{1 + \frac{a_{x1}^2}{a_{z1}^2} + \frac{a_{y1}^2}{a_{z1}^2}}} = a_x \cdot \sqrt{\frac{1 + \frac{1}{tg^2\gamma_{\text{м}}} + \frac{1}{tg^2\rho_{\text{м}}}}{1 + \frac{1}{tg^2\gamma_{\text{м}1}} + \frac{1}{tg^2\rho_{\text{м}1}}}}\,. \qquad (25)$$

Given the ratio of

$$tg\xi_{\text{м}} = \frac{a_x}{a_y}\,, \qquad (26)$$

$$tg\xi_{\text{м}1} = \frac{a_{x1}}{a_{y1}}\,, \qquad (27)$$

$$\xi_{\text{м}1} = \xi_{\text{м}} + \varphi_{\text{м}} \qquad (28)$$

we get

$$a_{x1} = a_x \cdot \sqrt{\frac{1 + \frac{a_y^2}{a_x^2} + \frac{a_z^2}{a_x^2}}{1 + \left(\frac{\frac{a_y}{a_x} ctg\chi_{\text{м}} - 1}{\frac{a_y}{a_x} + ctg\chi_{\text{м}}} \right)^2 + \left(\frac{\frac{a_z}{a_x} + tg\alpha_{\text{м}}}{1 - \frac{a_z}{a_x} tg\alpha_{\text{м}}} \right)^2}} = a_x \cdot \delta_x\,, \qquad (29)$$

$$a_{y1} = a_y \cdot \sqrt{\frac{1 + \frac{a_x^2}{a_y^2} + \frac{a_z^2}{a_y^2}}{1 + \left(\frac{\frac{a_x}{a_y} + tg\chi_м}{1 - \frac{a_x}{a_y} tg\chi_м}\right)^2 + \left(\frac{\frac{a_z}{a_y} + tg\beta_м}{1 - \frac{a_z}{a_y} tg\beta_м}\right)^2}} = a_y \cdot \delta_y, \tag{30}$$

$$a_{z1} = a_z \cdot \sqrt{\frac{1 + \frac{a_x^2}{a_z^2} + \frac{a_y^2}{az}}{1 + \left(\frac{\frac{a_x}{a_y} ctg\alpha_м - 1}{\frac{a_x}{a_y} + ctg\alpha_м}\right)^2 + \left(\frac{\frac{a_y}{a_z} ctg\beta_м - 1}{\frac{a_y}{a_z} + ctg\beta_м}\right)^2}} = a_z \cdot \delta_z \tag{31}$$

Therefore, these established dependencies open up the possibility of implementing automatic correction of errors in the installation of acceleration sensors, including those related to the vertical transverse plane when assessing the stability of the position of wheeled vehicles.

Conclusions.

1. The obtained refined dependencies of linear acceleration components on angular deviations of the axes of the wheeled vehicle coordinate system are a significant step in the further development of measurement and control systems. These dependencies open up the possibility of automatic correction of inaccuracies in the installation of acceleration sensors, which is crucial for achieving high measurement accuracy.

2. Using the equations obtained, a qualitative and quantitative assessment of the potential errors that can occur during the installation of acceleration sensors on a wheeled vehicle can be made. This assessment is critical to ensuring the reliability and accuracy of measurements in real-world applications. In addition, based on these dependencies, methods and strategies can be developed for the automatic real-time correction, which will maintain high quality measurements even when sensor installation changes are possible

3. The results obtained have a high potential for further improvement of measurement and control systems in the field of wheeled vehicles. This will improve the quality and reliability of measurements and open up the possibility of automatic correction of systematic errors in real time.

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М.А. Подригало, проф., д-р техн. наук, **О.С. Полянський,** проф., д-р техн. наук, **Є.О. Дубінін,** проф., д-р техн. наук, **Д.М. Клец,** проф., д-р техн. наук, **В.Ю. Байдала,** асист., **М.В. Краснокутський**, аспір.
Харківський національний автомобільно-дорожній університет, м.Харків, Україна

Підвищення точності оцінювання прискорень колісних машин при випробуваннях

У дослідженні розглянуто вплив монтажної похибки під час установки датчиків лінійних прискорень на точність вимірювань при проведенні випробувань колісних машин, в тому числі – на динамічну стійкість положення. Розглянуто можливість автоматичного коригування цих похибок для поліпшення точності вимірювань. Робота включає встановлення залежності компонент лінійних прискорень від кутових відхилень осей системи координат колісної машини та розробку методу автоматичного коригування в реальному часі для забезпечення високої якості вимірювань і підтримання надійності вимірювальних систем.

Використовуючи отримані в роботі рівняння, можна провести якісну та кількісну оцінку потенційних похибок, що можуть виникнути під час монтажу датчиків прискорень на колісній машині. З урахуванням цих залежностей можна розробити методи та стратегії виправлення похибок у реальному часі при можливих змінах установки датчиків.

Отримані результати мають важливе значення для поліпшення систем вимірювань та контролю динамічних параметрів колісних машин, забезпечуючи надійність та автоматичне виправлення системних похибок.

колісна машина, похибка вимірювання, відхилення, прискорення, автоматизація

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