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DETERMINATION OF THE CENTER OF GRAVITY OF MULTI-FUNCTIONAL FIRE-FIGHTING AND RESCUE MOTORCYCLES USED IN VIETNAM

Le Quang Bon

Purpose. To determine a reasonable place for installing the equipment unit for the fire-rescue motorcycle, which allows maintaining the stability of the motorcycle when driving at a speed of $v \leq 70$ km/h.

Methods. To calculate the motorcycle motion model Matlab was used.

Findings. The methods have been developed for determining the coordinates of the center of gravity of a multifunctional fire and rescue motorcycle equipped with an equipment unit. The effect of motorcycle speed on its stability when turning around was researched.

Application field of research. The results of the work can be used in recommendations for motorcycles exploitation in case of moving to the fire place.

Keywords: motorcycle, center of gravity, driving control.

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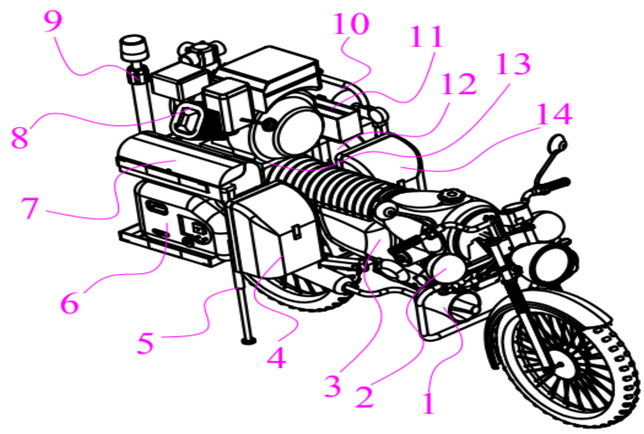
1. General layout of multi-functional fire-fighting and rescue vehicles

The multi-functional fire-fighting and rescue motorcycle (Fig. 1) is a scientific and technological product of the University of Fire Prevention and Fighting chaired by Lieutenant General Associate Professor Le Quang Bon. The vehicle is designed for fire-fighting and rescue at places where roads are narrow and alleys are difficult for large fire-fighting vehicles to access.

Figure 1. – Multi-function fire-fighting and rescue motorcycle products participating in the Vietnam International Defense Exhibition in 2022

The vehicle is designed on the basis of Japanese Honda CB150 Verza motorcycle with a single cylinder engine, SOHC, 150 cc air-cooled, electronic fuel injection system PGM-FI combined with 5-speed gearbox. This engine produces 13.04 horsepower at 8,500 rpm and maximum torque of 12.73 Nm at 6,000 rpm. The measured fuel consumption is 43.5 km/liter with the emission standard EURO 3. The vehicle is integrated with a fire-fighting system and equipment for rescue, patrolling, security, order and safety society (Fig. 2).



1 – priority whistle; *2* – priority flash; *3* – base motorcycle (Honda CB150 Verza); *4* – container for fire-fighting tools; *5* – electric kickstands keep the vehicle balanced during fire-fighting activities; *6* – generator; *7* – containers with fire-fighting hoses; *8* – Honda GX160 T2 engine fire pump; *9* – priority mast lights; *10* – fire extinguisher powder; *11* – portable intermediate water tank; *12* – roll water suction hose reel; *13* – rack frame; *14* – box containing multi-purpose demolition tools, drills, lights, gas masks

Figure 2. – General layout diagram of multi-functional fire-fighting and rescue vehicle

2. Method of determining the coordinates of the center of gravity of fire-fighting and rescue motorcycles

Determining the coordinates of the vehicle's center of gravity is very important because the center of gravity of the vehicle greatly affects the stability when moving [1–3]. The vehicle's center of gravity is characterized by the following three parameters:

– distance from the projection of the center of gravity on the road surface to the contact point of the front wheel, symbol l_1;

– distance from the projection of the center of gravity on the road surface to the contact point of the rear wheel, symbol l_2;

– height of center of gravity, i.e., the distance from the vehicle's center of gravity to the road surface, symbol h.

According to [4], [5] the coordinates of the center of gravity of a multi-purpose fire-fighting and rescue vehicle are determined through experimental methods as follows.

a) The method of determining the coordinates of the center of gravity of the fire engine in the longitudinal direction

To determine the center of gravity of the vehicle vertically we put the car on a horizontal plane with the front and rear wheels on the scale as shown in Figure 3. Let's denote the total weight of the vehicle with the symbol M ($M = mg$), and the weight acting on the front and rear wheels – M_f and M_r, respectively.

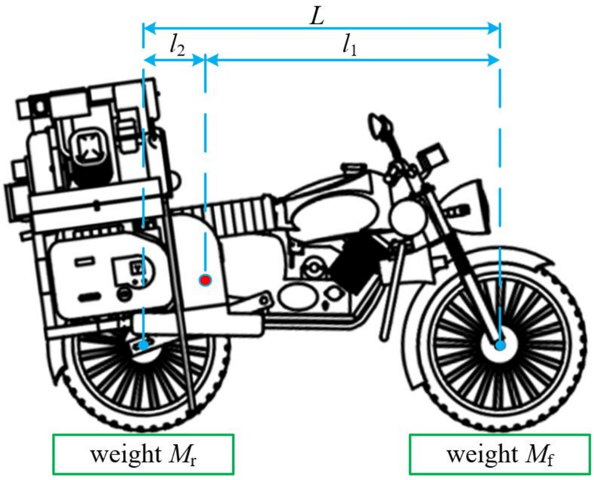


Figure 3. – Diagram of determining the horizontal longitudinal coordinates of the vehicle's center of gravity

The horizontal longitudinal coordinates of the vehicle's center of gravity are determined as follows:

$$l_1 = \frac{M_r}{M} L \quad \text{and} \quad l_2 = \frac{M_f}{M} L, \qquad (1)$$

where M – weight of vehicle, N;

M_f and M_r – vehicle weight distributed to the front and rear wheels, N;

L – wheelbase length of the vehicle, m.

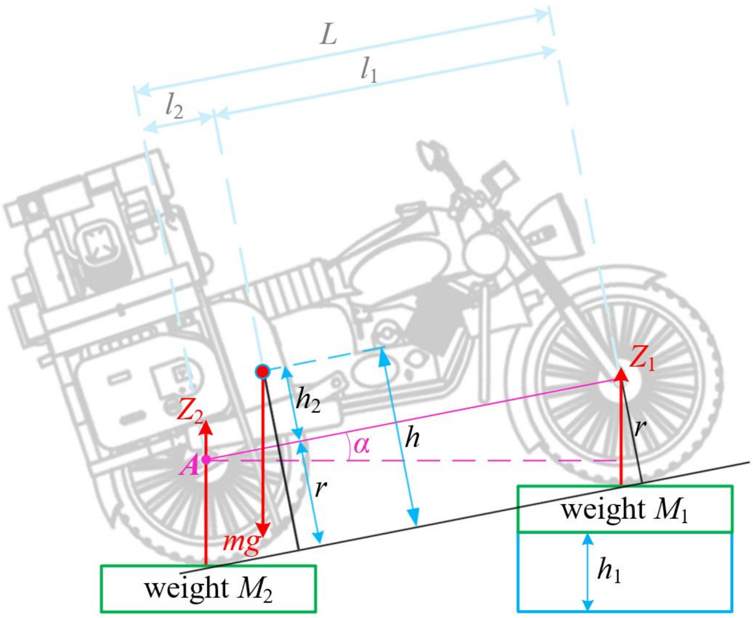
b) The method of determining the coordinates of the center of gravity of the fire engine according to the height

To determine the height of the center of gravity of the fire engine we raise the front axle to a height of h_1, the vehicle deviates from the road by an angle α (α = 9°). The measurement of the weight transferred to the rear wheel M_2 is done by using a balance arranged as shown in Figure 4. The weight of the vehicle transferred to the front wheel will be M_1:

$$M_1 = M - M_2. \qquad (2)$$

The calculations do not include the weight of the motorcycle driver, because his share is about 10 % of the weight of the motorcycle with equipment and tools for fire extinguishing.

Before raising the front wheel of the vehicle, the vehicle is standing on a horizontal plane.



Z_1 and Z_2 – the surface reactions at the points where the wheels touch the road, the wheels are on a horizontal surface

Figure 4. – Diagram to determine the coordinates of the vehicle's center of gravity by height

Setting up the equation for the equilibrium of moments relative to point A (the center of the rear wheel of the motorcycle) of gravity and the reaction force of the support acting on the front wheel, we get:

$$-mg \cdot l_2 \cos\alpha + mg \cdot h_2 \sin\alpha + Z_1 \cdot L \cos\alpha = 0, \qquad (3)$$

where m – mass of the motorcycle, kg;

g – free fall acceleration, m/s^2;

h_2 – distance from the center of gravity to the line connecting the centers of the wheels of the motorcycle, m;

Z_1 – the surface reaction at the point where the front wheel touch the road, N.

From (3) inferred:

$$h_2 = \frac{(-Z_1 L + mgl_2)\cos\alpha}{mg\sin\alpha}. \tag{4}$$

On the other hand, we have:

$$h - h_2 = r, \tag{5}$$

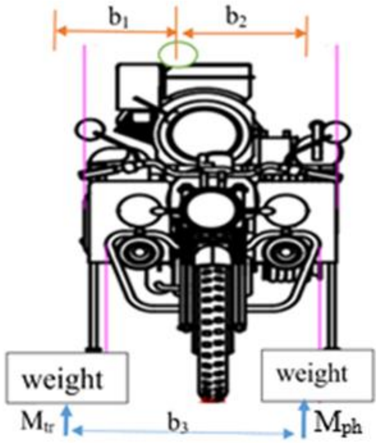
where r is the radius of the motorcycle wheel.

So we have:

$$h = h_2 + r = r + \frac{(-Z_1 L + mgl_2)\cos\alpha}{mg\sin\alpha}. \tag{6}$$

c) The method of determining the lateral horizontal coordinates of the center of gravity of the fire engine

To determine the lateral horizontal coordinates of the vehicle's center gravity we also weigh the vehicle as shown in Figure 5.



b_1 and b_2 – distance from the center of gravity of the vehicle to the left and right stand;
b_3 – distance of 2 supports; M_{tr} and M_{ph} – vehicle weight distributed to the left and right

Figure 5. – Diagram of determining the lateral horizontal of the vehicle's center of gravity

The lateral horizontal coordinates of the vehicle's center of gravity are determined by the following formula:

$$b_1 = \frac{M_{tr}}{M} b_3 \quad \text{and} \quad b_2 = \frac{M_{ph}}{M} b_3. \tag{7}$$

where b_1 and b_2 – distance from the center of gravity of the vehicle to the left and right stand, m;
b_3 – distance of 2 supports, m;
M_{tr} and M_{ph} – vehicle weight distributed to the left and right, N.

3. Research results on the influence of the coordinates of the center of gravity on the angle of inclination of the fire-fighting and rescue motorcycle

The equation of motion of the center of mass of the motorcycle [2; 5–7] was done with the Matlab software considering (1), (6) and (7).

General form of equations:

$$m\ddot{X} = R_X^e; \quad m\ddot{Y} = R_Y^e; \quad m\ddot{Z} = R_Z^e.$$

where $R_{X,Y,Z}^e$ – the projections of the forces on the corresponding axes.

Initial conditions:

$$X_0 = 0; \quad Y_0 = 0; \quad Y_0 = 0 \quad \text{if} \quad t_0 = 0.$$

The start tilt angle is determined experimentally and depends on the speed of motion of the motorcycle.

In order to evaluate the stability of a fire-fighting motorcycle in motion we choose the output function as the vehicle's inclination angle as an indicator of stability when turning around and turning into a corner. The changed parameters are the coordinates (X_m, Y_m, Z_m) of the center of gravity of the fire-fighting equipment block installed on the vehicle and the speed of the motorcycle (changing from 8 to 14 km/h). The results of the survey are shown on the graph in Figure 6.

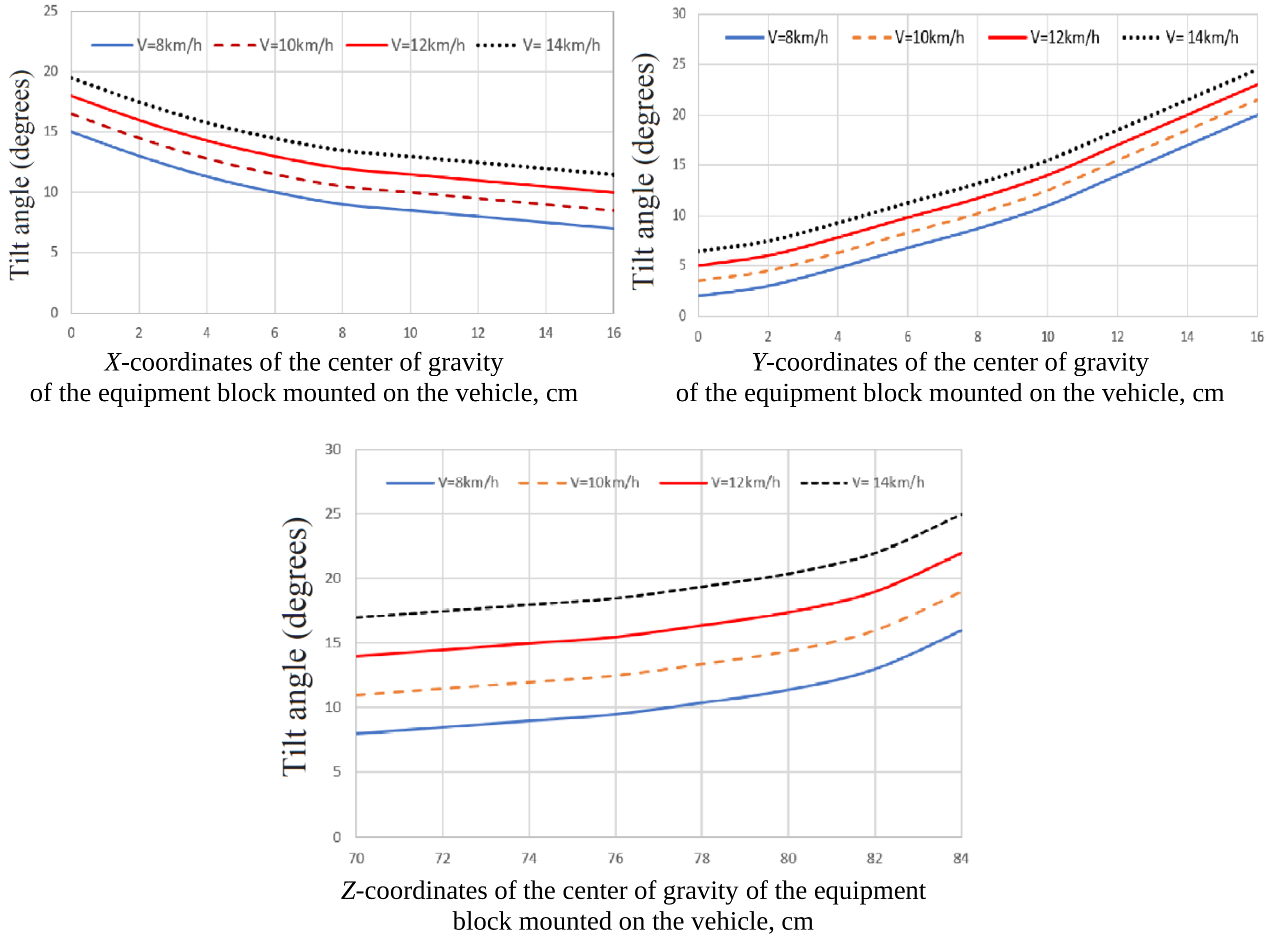


Figure 6. – The influence of the coordinates of the center of gravity of the equipment mounted on the vehicle on the tilt angle of the vehicle

According to the publications [5–7] the moving of the motorcycle will be stable if the tilt angle does not be more than 25–30°.

4. Conclusion

Firefighting and rescue motorcycles are designed on the basis of Honda CB150 Verza motorcycles when installing a block of fire-fighting and rescue equipment. Applying the planar dynamics model for two-wheeled vehicles, the system of differential equations of motion is established. Surveying the system of equations performed on Matlab gives the following results.

– The influence of the coordinates of the center of mass of the device mounted on the fire engine is significant on the vehicle's tilt angle (angle φ) in the dynamic model.

– The influence of the coordinates of the center of gravity on the tilt angle of the vehicle is different whereby the *Y*-coordinate of the center of gravity of the vehicle has the greatest influence, the *Z*-coordinate of the center of gravity has the smallest influence. The obtained survey results show that when designing and installing fire-fighting equipment on vehicles, the coordinates in the center of the Y axis must be reduced to increase the stability of the vehicle when turning around and turning into narrow alleys.

– When turning around, the greater the speed of moving, the greater the angle of inclination of the vehicle, so when turning around and turning into a corner it is necessary to determine a reasonable speed (max 14 km/h) to ensure the safety of the vehicle's approaching the fire as quickly as possible.

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Determination of the center of gravity of multi-functional fire-fighting and rescue motorcycles used in Vietnam

Определение центра тяжести многофункциональных пожарно-спасательных мотоциклов, используемых во Вьетнаме

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ОПРЕДЕЛЕНИЕ ЦЕНТРА ТЯЖЕСТИ МНОГОФУНКЦИОНАЛЬНЫХ ПОЖАРНО-СПАСАТЕЛЬНЫХ МОТОЦИКЛОВ, ИСПОЛЬЗУЕМЫХ ВО ВЬЕТНАМЕ

Ле Куанг Бон

Цель. Определить для пожарно-спасательного мотоцикла обоснованное место установки блока оборудования, позволяющее сохранять устойчивость мотоцикла при движении со скоростью $v \leq 70$ км/ч.

Методы. Для расчета модели движения мотоцикла использовался Matlab.

Результаты. Разработана методика определения координат центра тяжести многофункционального пожарно-спасательного мотоцикла, оснащенного блоком оборудования. Исследовано влияние скорости мотоцикла на его устойчивость при развороте.

Область применения исследований. Результаты работы могут использоваться в рекомендациях по эксплуатации мотоциклов при выезде к месту пожара.

Ключевые слова: мотоцикл, центр тяжести, управляемость.

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