OPTIMIZATION RATIONAL PARAMETERS OF THE DRIVING SIMULATOR

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Abstract: *This study aims to achieve accurate simulation alignment with real-life road conditions for optimal training effectiveness. By investigating the tilt and displacement of the vehicle during manoeuvres, experiments establish a basis for configuring simulation parameters. The goal is to attain correlation with empirical observations and adjust the simulator's rational parameters accordingly. The study's specific aim is to determine these parameters and locate the optimal installation coordinates for the electric motor within the simulator structure.*

Key words*: simulator, adaptation, manoeuvres, rational parameters, electric motor, crankshaft and motion reducer.*

Introduction

Optimising rational parameters in driving simulators is a critical pursuit that is essential for enhancing their efficacy in various applications, including driver training, research, and development. In order to improve the adaptation of the simulated scenarios displayed on the simulator monitor to the real road conditions, it is essential to elicit an appropriate response from the simulator [1,2,7,8]. For example, whilst performing manoeuvres on various routes, like ascending an overpass, the lorry adjusts its orientation with an angle α (Figure 1). Experimental studies have determined the values of tilt and displacement of the car on different paths [3,4,5]. In order to reproduce such phenomena, the rational parameters of the simulation have to be adapted to those derived from experimental data.

The aim of this study is to determine the rational parameters of the simulator and the installation coordinates of the electric motor.

The main components of the simulator are shown in Figure 2. As shown, the electric motor (5) is connected to the worm gearbox (6). The crankshaft (1) is securely fixed to the shaft of the worm gear reducer by means of a key. The upper surfaces of the crankshaft (2) act as a connecting rod and are supported by means of ball bearings and a screw assembly. The upper part of the P-shaped upper surface accommodates a spherical bearing hinge (3), which is connected to the upper part by bolted ears and secured by a bolt. This hinge is in turn connected to the central platform (4) by a finger. This finger is mounted by a bolt. When activated, the simulator transmits motion from the engine to the motion reducer, causing the crankshaft (1) to rotate at a maximum speed of 1800 rpm. The P-shaped upper surface, which acts as a connecting rod, induces a complex movement in the crankshaft, which results in vertical oscillations or reciprocating movements in the central platform (4). The electronic frequency of the reducer of the electric motor is modulated in order to vary the frequency of the torque and the stop occurs when the upper part (2) of the crankshaft reaches its zenith (at 1800 revolutions).

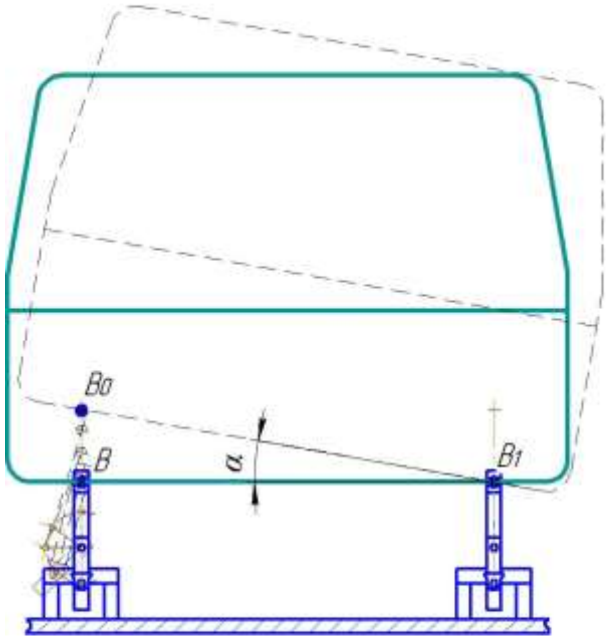

Fig. 1. The pitch (rolling) of the simulator cabin due to the movement of the motion components.

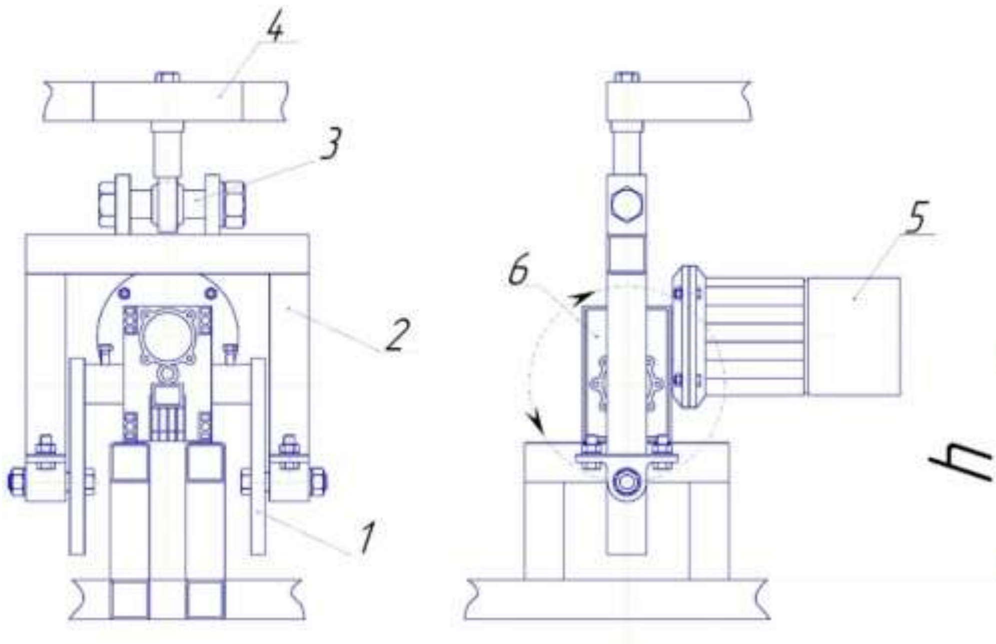

Fig. 2. Main components of the simulator: 1-crankshaft; 2-simulator upper part (connecting rod); 3-simulator hinge bushing; 4-central platform; 5-electric motor; 6-worm gear reducer; h-height of installing the electric motor on the frame.

Using the calculation diagram shown in Figure 3, the dimensions of the crankshaft, the length of the simulator's upper part (connecting rod) and the installation coordinates of the electric motor are determined, thus determining the basic kinematic and geometric parameters of the simulator mechanism. One of the main objectives is to identify rational simulator movement parameters. When the simulator cabin is moving at its maximum inclination (Figure 3), it is necessary to take into account the angle of cabin inclination (α = 10-120) and to minimise the load on points A and B of the simulator movement in order to select the appropriate parameters for the simulator. These are indispensable factors to be taken into account.

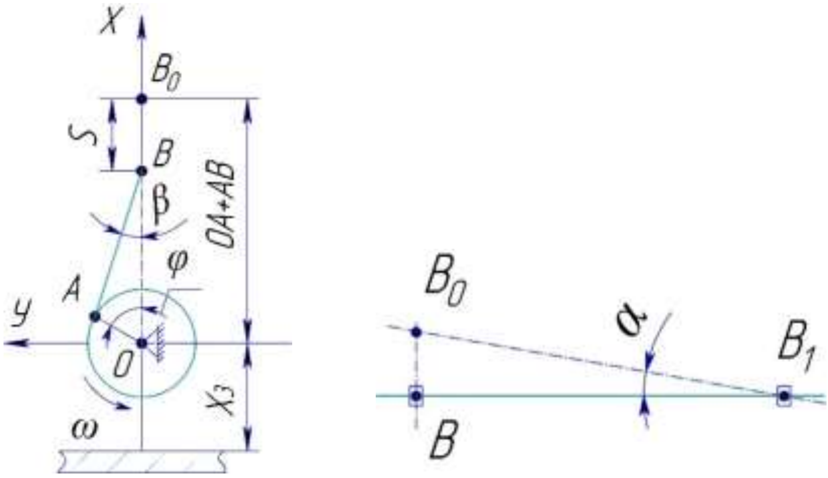

Fig.3. Computational diagram for determining the rational parameters of the simulator motion.

The following information can be derived from the above calculation diagram:

$$OB = OA\cos\varphi + AB\cos\beta = OA + OB. \quad (1)$$

According to the Law of Sines:

$$\frac{OA}{\sin\beta} = \frac{AB}{\sin\varphi} \quad (2)$$

$$\sin\beta = \frac{OA}{AB}\sin\varphi$$

from this point,

$$\cos\beta = \sqrt{1-(\frac{OA}{AB})^2\sin^2\varphi} \quad (3)$$

The chassis displacement along the S-axis during the complete cycle of crankshaft movement is calculated as follows:

$$S = OA(1-\cos\varphi) + AB(1-\sqrt{1-(\frac{OA}{AB})^2\sin^2\varphi} \quad (4)$$

In the course of the chassis displacement along the S distance in the motion of the mechanism, the inclination (roll), denoted as α, of the body with respect to the BB_0B_1

plane is observed. This is in accordance with the Law of Sines, and it is expressed as follows [2]:

$$\frac{BB_0}{\sin\alpha} = \frac{B_0B_1}{\sin(90-\frac{\alpha}{2})} = \frac{B_0B_1}{\sqrt{\frac{1+\cos\alpha}{2}}}, \tag{5}$$

$$\frac{\sqrt{\frac{1+\cos\alpha}{2}}}{\sin\alpha} = \frac{B_0B_1}{B_0B_1}. \tag{6}$$

From the Law of Cosines:

$$BB_0^2 = B_0B_1^2 + BB_1^2 - 2B_0B_1 \cdot BB_1\cos\alpha\ . \tag{7}$$

from this point,

$$\cos\alpha = \frac{BB_0^2 + BB_1^2 - B_0B_1^2}{2B_0B_1 \cdot BB_1\cos\alpha} \tag{8}$$

Subsequently, the velocity magnitudes at points A and B are calculated:

$$v_A = \sqrt{v_{xA}^2 + v_{yA}^2}\ ,\ v_B = \sqrt{v_{yA}^2 + v_{yB}^2} \tag{9}$$

$$v_{xA} = -OA\omega\sin\varphi\ ,\ v_{yA} = -OA\omega\cos\varphi \tag{10}$$

Here, ω represents the angular velocity of the worm gear reducer.

The velocities at points A and B are calculated as follows:

$$a_A = \sqrt{v_{xA}^2 + v_{yA}^2}\ ,\ a_B = \sqrt{v_{yA}^2 + v_{yB}^2} \tag{11}$$

$$a_{xA} = -OA\omega^2\cos\varphi\ ,\ a_{yA} = -OA\omega^2\sin\varphi \tag{12}$$

On the basis of the above, it is essential to determine the installation coordinates and acceptable lengths for the simulator to simulate the tilt of the body as closely as possible to the actual circumstances and to reduce the applied load. To facilitate this process, experimental methods were utilised [3]. The following independent factors were considered as characteristics:

– X_1: Length of the crankshaft used in the simulator, measured in millimetres (mm).

– X_2: Length of the upper section of the simulator's connecting rod, measured in millimetres.

– X_3: Height for the installation of the electric motor onto the frame, measured in millimetres.

Table 1 displays the levels of the factors and the extent of their variations.

Table 1.

Values of Factor Levels and Ranges of Change for the Factors

Indicator	*Factor X_1*		*Factor X_2*		*Factor X_3*	
	Actual Value, mm	Encoded Value	Actual Value, mm	Encoded Value	Actual Value, mm	Encoded Value
Variation Range	15	–	30	–	20	–
Upper Level	150	+1	380	+1	320	+1
Baseline Level	135	0	350	0	300	0
Lower Level	120	-1	320	-1	280	-1

Drawing upon the acquired experimental outcomes, the rational parameters of the simulator mechanism have been discerned and empirically validated. The findings indicate that the most suitable parameters for the designed simulator encompass a crankshaft length between 120 and 125 millimeters, an upper part (connecting rod) length ranging from 350 to 365 millimeters, and an optimal height for the installation of the electric motor on the frame within the span of 300 to 315 millimeters.

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