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DEVICE FOR STUDYING COLLISIONS

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ABSTRACT

The collisions between two bodies occur in a very small interval of time during which, the two bodies exert relatively large forces on each other. The coefficient of restitution of two colliding bodies is defined as the ratio of the relative velocity after and before an impact, taken along the line of the impact.

The paper presents a proposed device for studying the coefficient of restitution in a collision between a model railway wagon and a buffer made of different materials (rubber, polystyrene, sponge). The wagon runs on the rails on an inclined plane with zero initial velocity and collides an energy-absorbing buffer in the end. Measuring the time of motion and the impact force variation, the acceleration and the impact velocities are calculated. The related coefficient of restitution is computed.

Keywords: collision, coefficient of restitution, rigid bodies

1. EXPERIMENTAL DEVICE

In order to study the collision between a model railway wagon and a buffer, an experimental device was designed with the following components, Figs 1 and 2:

- an inclined plane,
- two rails,
- a model wagon (with adjustable weights),
- 2 REED sensors mounted on the inclined plane,
- an electromagnetic sensor (under the wagon),
- a force sensor,
- a photo-gate sensor;
- a data acquisition device – logger Multilog Pro,
- a digital chronometer,
- a buffer (made of different materials: rubber, polystyrene, sponge).

The wagon was made of aluminium and lightweight materials. The wheels were designed with a toroidal shap (Fig. 3). The wood button fixed in the front of the wagon makes contact exactly on the buffer's center, so that the force sensor data could be more precise. In order to trigger the electromagnetic sensors from the inclined plane, a REED sensor is fixed under the wagon.

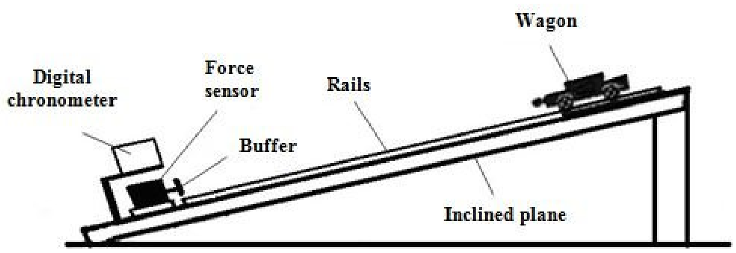

Fig. 1. Lateral view of experimental device

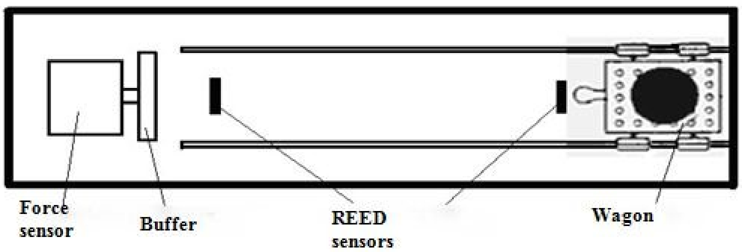

Fig. 2. Top view of experimental device

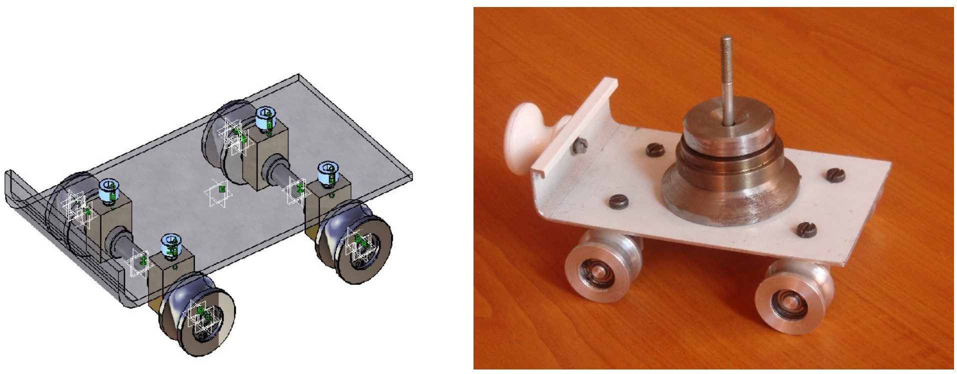

Fig. 3. The wagon design

The experimental device contains two Fourier sensors: for the force and the photo gate having the following characteristics [3]:

Force sensor measures forces on dual range ±10 N, ±50 N:

- accuracy: ±2 % over the entire range
- resolution (12-bit) for ±10 N: 0.005 N,
- resolution (12-bit) for ±50 N: 0.025 N,
- default sample rate: 10 samples per second.

*The photo gate sensor m*easures the time necessary for an object to pass between its arms and it has the following characteristics:

- range: 0 to 5 V,
- detector rise time: 180 ns,
- detector fall time: 180 ns,
- infrared source: Peak at 800 nm,
- parallax error: for an object passing within 1 cm of the detector, with a velocity less than 10 m/s, the difference between the true and effective length is less than 1 mm
- signal output: MiniDin.

The two aluminium rails of 1 meter length are mounted along the inclined plane at a distance of 80 mm between them.

The two electromagnetic REED sensors are installed on the inclined plane at a distance of 0.787 m between them, taking into account that the bottom sensor makes contact with the wagon sensor exactly on the collision moment.

The upper REED sensor starts automatically the digital chronometer when the wagon starts from the rest and the bottom REED sensor stops the chronometer, obtaining an accurate time reading. The force sensor was mounted on a wooden support, so that the force sensor reaches an optimum impact position for obtaining a central impact of the bodies.

The two sensors are connected to a data logger –Fourier System Multilog Pro. The recorded data are displayed on the computer as graphs and tables, using Multilab soft.

2. PROCEDURE

The railway wagon runs on the inclined rails with zero initial velocity. If the friction is negligible, the wagon will go down with a constant acceleration and finally will collide the energy-absorbing buffer placed on the bottom of the plane (Fig. 4).

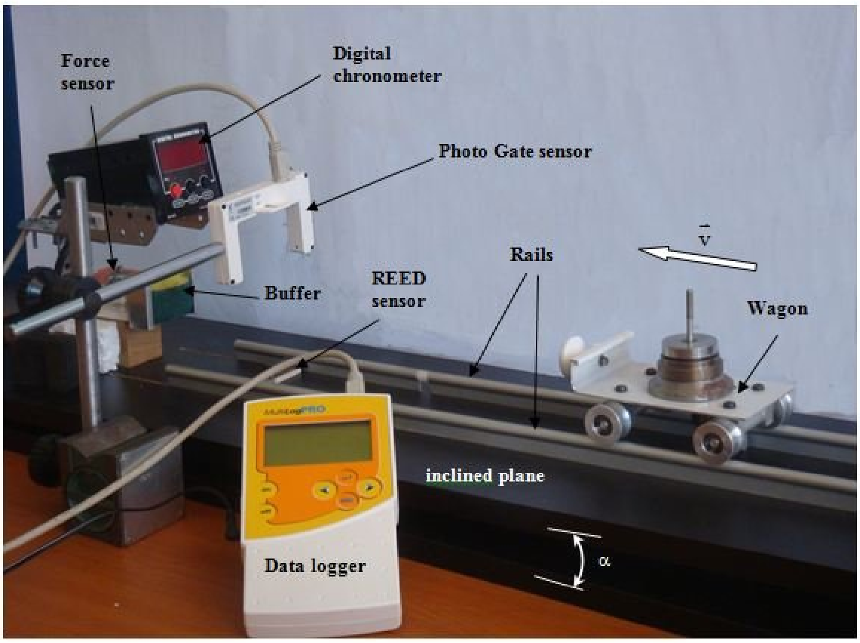

Fig. 4. Experimental device

As the wagon moves along the rails, the electromagnetic sensor installed under the wagon passes over the first REED sensor mounted on the inclined plane and triggers the digital timer. At the other end of the rails, a second REED sensor is mounted, which is designed to close an electric circuit, which makes possible to stop the digital timer.

The second REED sensor is mounted so that, when the wagon collides the buffer, it closes automatically the circuit and stops the digital timer. This set up is used to measure the travel time of the wagon between the two REED sensors. This time is used to determine the wagon acceleration before the impact. That acceleration is given by the equation of motion:

$$x = x_0 + v_0 t + \frac{at^2}{2} \tag{1}$$

where

$x_0 = 0$,

$v_0 = 0$

and

$$x = \frac{at^2}{2}, \rightarrow \; a = \frac{2x}{t^2}$$

The wagon velocity before impact is given by:

$$v_1 = v_0 + at, \tag{2}$$

where $v_0 = 0 \rightarrow v_1 = at$.

This velocity was also measured using the photo-gate sensor and was compared to the previous result. The obtained values were in good agreement.

The force sensor is fixed on the buffer as it measures the force variation during collision. The change in wagon momentum is given by:

$$mv_2 - mv_1 = \int F \cdot dt \tag{3}$$

where

F is the force acting on the buffer, m is the wagon mass and

v_1 and v_2 are the velocities of the wagon before and after collision.

The momentum variation is found by calculating the time integral of the force measured by the force sensor.

The wagon velocity after collision is calculated with the following equation:

$$v_2 = v_1 - \frac{\int F dt}{m} \tag{4}$$

Finally, the coefficient of restitution is calculated as the ratio between wagon velocity after and before collision:

$$k = \frac{v_2}{v_1} \tag{5}$$

The value of the coefficient k is always between 0 and 1 and depends on the materials of the two colliding bodies.

As an example, the measured force for the collision wagon - sponge buffer is shown in graph of Figure 5 [4]. For a time of motion $t=3.58$ s, a momentum variation of 0.31 N·s is measured and a restitution coefficient of 0.208 is calculated.

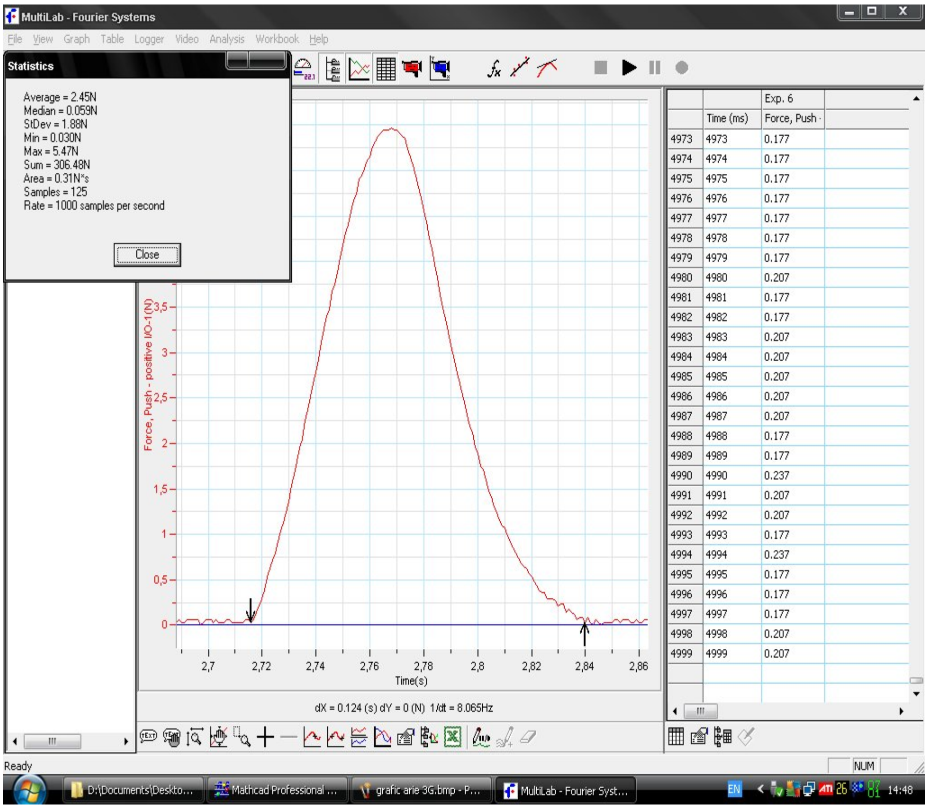

Fig. 5. Force versus time graph for a sponge buffer ($t=3.58$ s)

3. CONCLUSION

An experimental device was designed in order to study the collision coefficient for different pairs of materials. A model railway wagon collides with a buffer and the impulse variation is measured with a force sensor. Using momentum theorem for collision, the velocity after impact and the restitution coefficient are calculated.

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