Comparative of kinetic friction coefficient of material surfaces using manual method and video tracker application

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Abstract. A system consisting of a block with surface type of wood and jubin was slide down on the incline track. Experiments had been done to determine kinetic frictional coefficient ($\mu_k$) by manual method using stopwatch and technology by using video tracker application. The length of the track were varied by 5cm, 15cm, and 25 cm. To determine $\mu_k$ manually, stopwatch had been used to calculate the travel time on each track length. Then video tracker application had been used to observe the block while sliding from the top of the incline and then recorded it in video. The results of kinetic coefficients of the block surface that almost had similar value and hard to obtain by manual method, it can be simplified obtained by using video tracker application. Because the results were more rigorous and had smaller relative error. However, using video tracker application required a good camera resolution and good skills to operate it. So with the manual method would also be more effective and efficient but with long path length and the plane was sloping.

1. Introduction
There are forces acting on the object when it is in contact with a surface, component of the force that parallel to the surface is called the frictional forces, or simply friction. Friction is important in our daily life such as walking and writing. it is also needed to keep the wheel of a vehicle on the road etc [1]
If the object starts to move, the magnitude of the force working on the object is more than zero or more than the minimum static force, so that object has kinetic friction. Coefficient of kinetic friction, being the ratio of the magnitudes of two forces, kinetic frictional force and normal force [2].
From Newton’s 2nd law, the force in the x-direction can be described as:

$$\sum F_x = ma$$

$$mg \sin \theta - f_k = ma$$

$$mg \sin \theta - \mu_k mg \cos \theta = ma$$
\[ g(\sin \theta - \mu_k \cos \theta) = a \]  

(1)

If \( a = \frac{dv}{dt} \), speed equation will be

\[
\int dv = \int g(\sin \theta - \mu_k \cos \theta)dt \\
v = (\sin \theta - \mu_k \cos \theta)gt + v_0
\]

(2)

where

\[ a = (\sin \theta - \mu_k \cos \theta)g \]

(3)

Kinetic friction coefficient (\( \mu_k \)) will be obtained by

\[ \mu_k = \tan \theta - \frac{a}{g \cos \theta} \]

(4)

Physics learning with friction as the topic often had given the coefficient kinetic friction as a value. Teacher usually informed the value of \( \mu_k \) without further information to students about how the to find that value. This was because the experiment quite difficult as well as analyzing the coefficient of kinetic friction in the incline plane accurately. But experimental activities were expected to improve students comprehension for the concept of friction because students had done direct experience [3].

This research is done to analyze the concept of friction, mainly related to determine the value of kinetic frictional force on the incline. The data have been taken directly using a stopwatch with time as the variable. This research refers to experiment which has been conduct before titled Analisis Koefisien Gesek Statis dan Kinetis Berbagai Pasangan Permukaan Bahan pada Bidang Miring Menggunakan Video Tracker [4]. Analysis data process had been done using Video Tracker application, assuming that the method will give better results when compared to manual method using stopwatch.

Effectiveness in the experimental process along with the accurate and repeatable of the resulting data dependence on by several factors such as the material, surface, environment, and measuring equipment [5]. Thus, by comparing the experimental results using manual method and video tracker application, it is expected to get information related to which method provides kinetic friction coefficient data with better accuracy.

2. Experimental Method

The data were collected at the laboratory of Basic Science Center A (BSCA-ITB). The initial humidity is 61% and the temperature at 25.1°C, then the final humidity is 62% and the temperature at 25.6°C. The main system was a portable box with dimensions of 30 cm x 15 cm x 8 cm with a track length 28 cm and protractor. The object a square block with 3 cm x 3 cm, constant mass (43.8 gr), consist of two different material surfaces of wood and jubin. The video using Canon EOS 1300D DSLR Camera and Tracker Video Analysis and Modelling Tool (Ver 4.11.0) application.
The manual method for determining the kinetic friction coefficient had done by repeated measurements. The slopes of the plane were varied for each sliding object, i.e., wood and jubin. The length of the track field varied by 5cm, 15cm, and 25cm on each slope of the glide, with each repeated four times, until the length of each track field were reached.

Analyze data with other method had been using Tracker application to get the sliding speed data per unit of time. The process of fitting the data had done for each video experiments. Then gradient of v-t graphs were required to determine the kinetic friction coefficient according to the equation (4).

3. Result and Discussion
The determination of kinetic friction coefficients by direct observation yields relatively similar values for materials (blocks) made of wood and jubin. The largest coefficient of kinetic friction for wood is 0.395 and the smallest is 0.125 as seen in Table 1. While the jubin largest coefficient of kinetic friction is 0.269 and the smallest of 0.211 as released in Table 4.

<table>
<thead>
<tr>
<th>Angle</th>
<th>Distance (m)</th>
<th>Time (second)</th>
<th>Acceleration (m/s²)</th>
<th>μ_k</th>
<th>( \bar{μ}_k )</th>
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</table>

Standard Deviation
Error (%)

Table 1. Kinetic frictional coefficient for wood, angle 29° by directly observation

Table 2. Kinetic frictional coefficient for wood, angle 30° by directly observation
Experiment using manual method had been done with two variation of variables, changed in angle and glide track length. The acquisition of $\mu_k$ tend to be random for jubin with an increasingly glide track length, it was not indicating numbers pattern. For increasingly angle did not give much effect, the travel time tends to be similar at the same glide track length. Speed of the block will be increase as the length of track incline also increase, but with directly observation, human has reflect that causes we couldn’t get time for very fast speed, like 5cm length of the glide track. And for 25cm, it also difficult to get time moving of the block, because the speed also increase.
In fact, the area of the two surfaces of direct contact material were usually smaller than the total surface area [6]. As the object glide, there is the formation and disconnection of the bonds between the two surfaces with varied values, hence the coefficient of kinetic friction were not constant. But actually, coefficient kinetic friction was not simple as it seems, because the surfaces that appear to be highly polished can actually look quite rough when examined under a microscope. Even when two highly polished surfaces are in contact, they touch only at relatively few points [7].

Tracker application help to analyze fast moving objects, so it was possible to obtain the velocity of objects per unit of time with $v - t$ graph as in Figure 3, especially when using relatively short trajectories. The kinetic friction coefficient of the material can be accurately distinguished when using the Tracker application. But video analysis using Tracker requires a camera with high frame rate and skill to process the data.

The coefficient of kinetic friction for wood materials were obtained at 0.354 and error 0.226% then for jubin 0.234 and error 0.188% [8]. Here were shown graphs of $v - t$ from results of Tracker application analyze.

![Figure 3](image)

4. Conclusion

Based on the data can be concluded that using video tracker application in data processing, giving results in the level of accuracy is much higher than the manual method, especially for quite short of the track length, with a much shorter process. But, using manual methods were still quite good with longer track. Deficiencies in manual methods caused by the level of human reflexes in measuring time. While using video tracker required good frame per rate and higher cost.

5. References


