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Comment on "Application of gravitational method by determination of rail vehicles constant resistance", by Tepić and Kostelac, Transactions of FAMENA 32 (2), 2008, pp. 31-40

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This comment refers to a procedure of vehicle resistance measurement based on free motion of a toy down a straight inclined track. It is shown that the procedure is seriously in error, that many incorrect statements have been made and that the conclusions drawn from the experiments are invalid.
Keywords: railway vehicles, scaled model, resistance, sliding bearings, gravitational method

1. Introduction

The article [1] describes a procedure for vehicle resistance measurement based on free motion of a toy down a straight inclined track.
The toy was allowed to move freely at four different inclination angles of the track. According to the statements from the article, the toy accelerated until it reached nearly constant velocity. The velocity of the toy was estimated by counting digital camera image frames which had been recorded during the passage of fixed-length track segments.
This comment shows that the procedure is seriously in error, that many incorrect statements have been made and that the conclusions drawn from the experiments are invalid.

2. Invalid references to railway vehicles

The mention of "rail vehicles" in the title of [1] is misleading for the reader.
The method was not applied to a railway vehicle, but to a toy whose geometrical shape visually resembles a railway vehicle. A toy cannot be treated as a scaled mechanical model of a vehicle without providing evidence of similarity between the relevant physical phenomena.
There are several other parts in the text which have expressed invalid connections between the toy and railway vehicles.

3. Doubtful statements on the reliability of the method and on measurement accuracy

The statements presented in the conclusion of [1]
"Based on experimental and theoretical work, a reliable method for the determination of constant motion resistance in rail vehicles was given", and
"The method of gravitational motion on slope is simple and reliable in the determination of constant resistance as it is based only on accurate measurements of motion velocity",
are doubtful because evidence of reliability were not presented. Furthermore, the velocity was not measured, but image frames have been counted and the velocity was calculated subsequently. Afterwards, the highest calculated velocity was equated with the equilibrium velocity. Such a procedure of combined counting and calculation introduces various kinds of errors.
There has been no attempt to assess the accuracy neither of the obtained velocity data nor of the final results of the experiment summarized in the resistance formula (17) of [1].
If frames have been counted, one would expect the data denoted as "No. of frames" in Table 2 of [1]

to be a whole number, giving a temporal resolution of 1/25th of a second under the assumption of a known frame rate of 25 fps [1]. By contrast, the 56 measurements of Table 2 of [1] are reported with two decimal places. These results artificially increase the temporal resolution of the measurement to a nonsensical 1/2500th of a second.
One can only guess how such data could have been obtained and what the measurement error distribution is like. Therefore, any statement on measurement accuracy is highly doubtful.

4. Fictional accuracy and irreproducible results
A resistance formula (17) of [1] is given in the conclusion of [1] and it is stated that this expression approximates the measurement results with “high accuracy” of 99.98%. In another place in the text it is noted that 99.98% is the “certainty” of approximation. The usage of such terminology can be misleading for the reader, whereas to call the remaining 0.02% the “maximum error” is notably wrong.
There is a physical reason why the maximum error in the resistance values given by (17) of [1] amounts to at least 5%. As can be easily proven, the gravity component acting along the track in the first inclination case (EXP. 1) is about 0.22 N. However, (17) of [1] gives an initial resistance of 0.2333 N which would inhibit free motion of the vehicle.

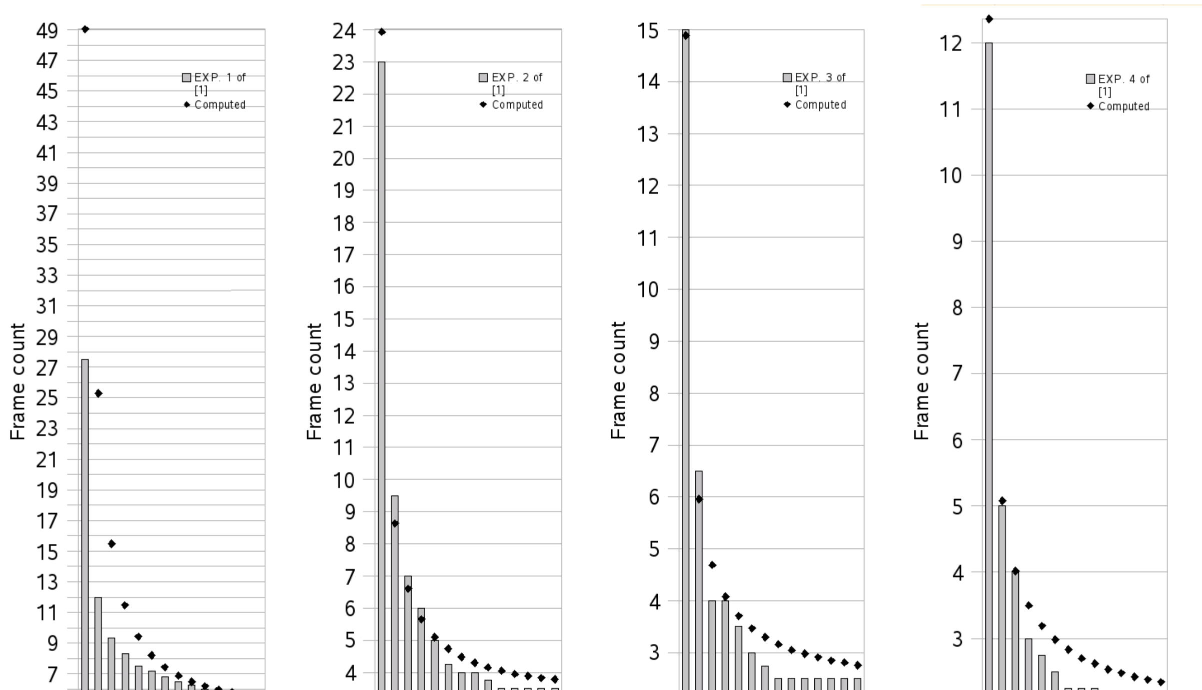

Figure 1: Comparison of frame counts stated by Table 2 of [1] and the computed frame counts.

Figure 1 reveals excessive non-smoothness in the measured data from Table 2 of [1] which casts a lot of doubt on the process used to obtain these values. As has been suspected before, reporting data with two decimal places obviously creates a false impression of accuracy and temporal resolution of the measurement method.
A numerical solution of the equation (3) of [1] including expression (17) of [1] reveals many more problems with the experiments. In Figure 1 the computed image frame counts are reported for each 5-cm-long track segment and compared to the experimental results stated in Table 2 of [1]. Due to the aforementioned error in the initial resistance, an initial velocity of 0.02 m/s was given to the toy in the case of EXP. 1. The experimental results describe significantly faster motions than the computed results (Figure 1). This means that Table 2 of [1] is in contradiction with other statements

of [1]. The contradiction in any case implies that the results of [1] are not reproducible and thus [1] is not relevant in a scientific sense.

5. Repeated invalid references to railway vehicles

The last paragraph of the conclusion of [1] makes another invalid connection between the experiments and railway vehicles. This conclusion is further elaborated in the fifth section which says:

"...the function "..." has a minimum resistance value of 0.1924 N at the velocity 0.1283 m/s. The multiplication by 3.6 gives the value in km/h. Finally the multiplication by a model scale ratio of 87 yields the value of 40.18 km/h for real rail vehicles. It is obvious that there is a similarity between the experimental minimal values "...." and the minimum constant resistance for real rail vehicles with sliding bearings where the minimum occurs between 40 and 50 km/h".

By applying this invalid reasoning to the whole velocity range from 0 to 0.625 m/s, one could come to the conclusion that the toy models the total resistance of a railway vehicle in the range from 0 to 196 km/h without providing evidence of similarity between any of the physical phenomena influencing total resistance. The perception that the toy adequately models the resistance of railway vehicles with sliding bearings is entirely invalid. It shall not be further argued that discussing hydrodynamic similarity between a lubricated railway bearing and a toy is absurd.

A recent paper [2] by the same authors as [1] also contains many invalid references to railway vehicles. Introducing formula (17) of [1], [2] states that [1] has "extended" the approach of Davis and Strahl by assuming for (17) of [1] a fourth degree polynomial, whereas Davis and Strahl assumed quadratic polynomials. The Davis and Strahl expressions are used in railway engineering to describe the total resistance of trains. From Figure 6 of [1] or from Figure 6 of [2] it is immediately clear that in the interval from 0.2 m/s to 0.625 m/s (which corresponds to the interval from 63 km/h to 196 km/h according to the reasoning of [1]), (17) of [1] is almost perfectly linear. A comparable resistance characteristic has never been observed in connection with railway vehicles. The idea that the Davis or Strahl expressions could be "extended" in any way by making trivial experiments with toys has never been heard of before.

6. Conclusion

The preceding comments also apply to [3] and [4] since [1] is predominantly a translation of these texts. Paper [1] is scientifically not relevant for reasons explained above.

References

[1] Tepić J., Kostelac M., Application of gravitational method by determination of rail vehicles constant resistance, Transactions of FAMENA 32 (2), 2008, pp. 31-40.

[2] Tepić J., Kostelac M., An analysis of the influence of railway vehicle mass and velocity on curve resistance values, Transactions of FAMENA 34 (1), 2010, pp. 51-58.

[3] Tepić J., Analiza stalnih otpora šinskih vozila određenih metodom gravitacionog kretanja, Mašinstvo 57 (6), 2008, pp. 1-6.

[4] Tepić J., Određivanje stalnog otpora teretnog voza, Železnice 61 (5-6), 2005, pp. 140-152.