Sborník vědeckých prací Vysoké školy báňské - Technické univerzity Ostrava
číslo 1, rok 2007, ročník LIII, řada strojní
článek č. 1546

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THE POSSIBILITIES OF NUMERIC ANALYSIS OF THE TRACTION VEHICLE MOTION RECORDING

MOŽNOSTI NUMERICKÉ ANALÝZY ZÁZNAMU JÍZDY KOLEJOVÝCH VOZIDEL

Abstrakt

Tento příspěvek se zabývá možností analýzy jízdy kolejových vozidel, zaznamenané pomocí registračního rychloměru na papírový proužek. Ukazuje možnosti digitalizace záznamu a využití zobrazení tohoto záznamu pro analýzu dynamiky pohybu vozidla.

Abstract

This contribution deals with the analysis of traction vehicle motion recorded by a speed tachograph on a paper strip, and also shows the possibilities of digitising the record and its use for dynamic analysis of the traction vehicle motion.

1 Introduction

Currently there are still more than half of the traction and special-purpose rail vehicles of all operators equipped with tachographs registering the data on a paper strip.

Such recording tachographs installed in those vehicles have either mechanical or electrical drive which records prescribed parameters mechanically on a sensitive layer of the paper strip.

The values are [1]:

- principal parameters (instantaneous speed for a given distance moved, time, driving and stopping times, operation of a vigilance button by the driver, illumination of the red signal on the on-board signal repeating device)
- additional parameters (e.g.: use of a horn, pressure in the air piping, driving direction etc.)

Recording of time and speed profile in relation to the distance moved are the most important values for analysing of the traction vehicle driving parameters and the dynamics:

$$V = f(l) \tag{1}$$

On the basis of these profiles, among others, the analysis of the traction vehicle dynamics in the form of the instantaneous vehicle acceleration can be performed. Knowing the vehicle position on the line, also other parameters can be determined (i.e. instantaneous drawing force or braking force).

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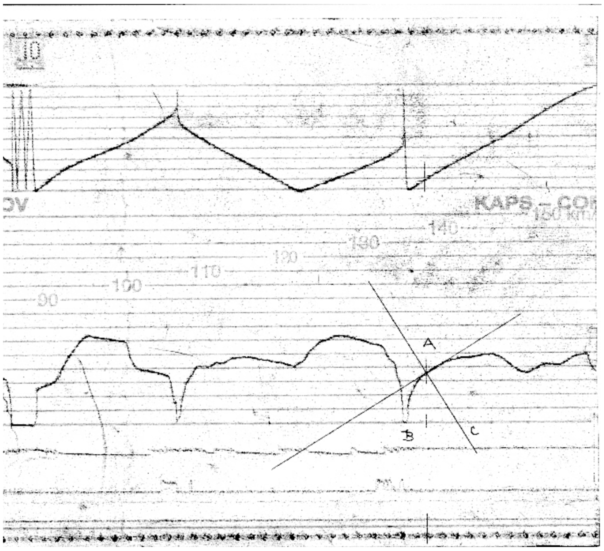

Fig. 1.: Sample of the record (the tachograph paper strip).

2 Possibilities for analysis

Possibilities for analysis come from the technical equipment design at the time of the final development of this recording device. The procedure for the basic analysis is described for example in [1] or [2]. These procedures are concerned with checking of the record readability, and deviations of the recorded values. For example [2] deals with the analysis of the traction vehicle motion dynamics in the form of determination of instantaneous value of acceleration for a given position in the record. The acceleration value can be set by the characteristics of a tangent and a normal line to the speed course according to relationship (*1*) at the point of analysis. The instantaneous acceleration value according to Fig. 2 comes out from relation [2]:

$$a = \overline{BC} \cdot \frac{n^2 \cdot m}{3.6^2 \cdot 10^3} \ \ [\text{m.s}^{-2}] \qquad (2)$$

where:

n the scale of speed

m the scale of distance

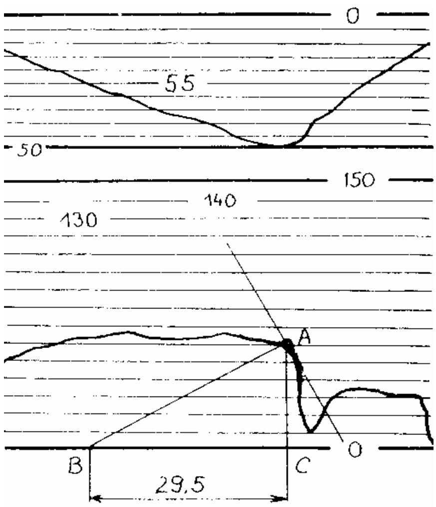

Fig. 2.: Sample of principle of the record analysis [2].

The values which are necessary for this analysis are determined, however, directly in the given record by reading of ordinates of the given point (in the units of length), with an accuracy of a maximum of 0.5 mm.

For this type of analysis, a tangent to the speed course must be constructed in the given place in the record. Under given conditions the tangent is smoothed by estimation and its position depends on experience and precision of the analyser. For conditions in Fig. 1, a sensitivity analysis of change impact of tangent angle on change of instantaneous acceleration value was performed. Graphic presentation of this analysis is seen in Fig. 3.

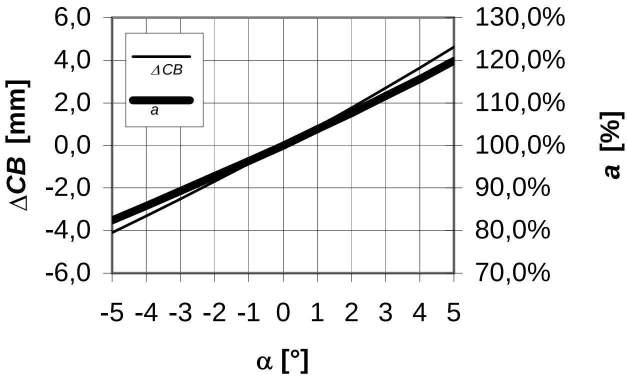

Fig. 3: Results of sensitivity analysis of graphic calculus.

3 Digitising of the record

One of the possibilities to increase the accuracy of solving this or another type of analyses of traction vehicles motions is digitising of this record by scanning. For this further step it is necessary, however, to ensure so that the output bitmapped file is not compressed or changed in any other way. Then, the file serves as a groundwork for further analyses where the course of speed $V = f(l)$ can be replaced by a set of points described in the system of coordinates of the scan grid. For further processing of the information in the record, a numerical method can be used, such as numerical derivation, interpolation etc.

Results from the analysis of testing on the digitised record in practice confirm that use of 600 dpi resolution will be suitable to achieve sufficient accuracy. This resolution is attainable with commonly used scanners. To check the resolution accuracy and subsequently to set the scale of the reproduction, a statistical evaluation of the point positions along the both *x*-axis and *y*-axis in relation to their defined position in the original was used (see Fig. 4).

The actual resolution along the *x*-axis was determined according to relationship:

$$r_x = \frac{\overline{X}_Z}{X_D} \cdot 25.4 \quad \text{[dpi]} \tag{3}$$

where:

$\overline{X}_Z$	[px]	mean distance of track marks in the scan
X_D	[mm]	defined distance of track marks in the record ($X_D = 2.5$ mm)

The calculated value of resolution in *x* direction is $r_x = 597.65$ px.inch^{-1}.

The relative error of resolution conforms to the value of $\Delta r_x = 3.9.10^{-3}$.

Accordingly, it is necessary to set a relative error of resolution for y-axis, which is $\Delta r_y = 2.8.10^{-3}$

Following the statistical evaluation of the defined parameters in the record, scales of their reproduction were set. The resulting scales are in Table 1. These values are used for further analysis.

Table 1: Scale of the reproduction.

Distance moved		
a_p		$m.px^{-1}$
a_m		$px.m^{-1}$
Speed		
b_{Vk}		$px/km.h^{-1}$
b_{Vp}		$km.h^{-1}/px$
Minute record		
b_{Tm}		$px.min^{-1}$
b_{Tp}		$min.px^{-1}$

4 Determination of the instantaneous acceleration value

An example of using the digitised presentation of the motion record is determination of instantaneous acceleration value in a given section of driving.

To describe the profile of speed, equidistant points for the speed profile were set and their coordinates were read (see Fig. 4). The instantaneous value of acceleration can be set from the starting relationships:

$$tg\alpha = \frac{\Delta Y}{\Delta X} = \frac{a_m}{b_{Vk}} \cdot \frac{dv}{dl} = \frac{a_m}{b_{Vk}} \cdot \frac{1}{v} \cdot \frac{dv}{dt} \tag{4}$$

Then for instantaneous value of acceleration:

$$a = \frac{b_{Vk}}{a_m} \cdot \frac{V}{3.6} \cdot tg\alpha \;\; [m.s^{-2}] \tag{5}$$

To determine the value of the tangent coefficient to the speed profile $tg\alpha$ a numeric procedure can be used. This is based on calculation of mid point derivation of function for i - th point of the speed representation out of the points which are immediately adjacent:

$$\dot{y} = tg\alpha = \frac{Y_{V(i+1)} - Y_{V(i-1)}}{X_{(i+1)} - X_{(i-1)}} \tag{6}$$

Taking into consideration the inaccuracies at manual determination of the points of the speed profile, the values which have been set according to relationship (*6*) are possible to be compared with calculation of tangent coefficient interlaid by points which are distant by a double distance from the point i according to the relationship as follows:

$$tg\alpha' = \frac{Y_{V(i+2)} - Y_{V(i-2)}}{X_{(i+2)} - X_{(i-2)}} \tag{7}$$

This procedure, however, does not enable the determination of the coefficient of tangent in end points which describe the speed. In this case it is possible to use the approach of one-sided derivation and to consider the resulting value in relation to the results of the calculation for surrounding points.

These procedures were used for analysing of an actual speed profile and are presented in Fig. 4. The resulting values of instantaneous acceleration are in Table 2 and graphically presented in Fig. 5.

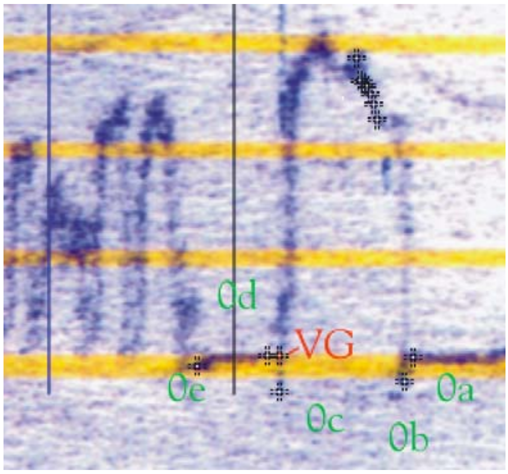

Fig. 4: Fragment of analysed record of the traction vehicle driving.

Table 2: Resulting values of instantaneous acceleration.

l	*V*	*a*	*a´*
[m]	[km.h^{-1}]	[m.s^{-2}]	[m.s^{-2}]
-136	25.6	-0.46	-
-119	25.4	-0.10	-0.35
-102	25.1	-0.23	-0.23
-85	24.3	-0.35	-0.35
-68	23.4	-0.45	-
-51	21.9	-	-

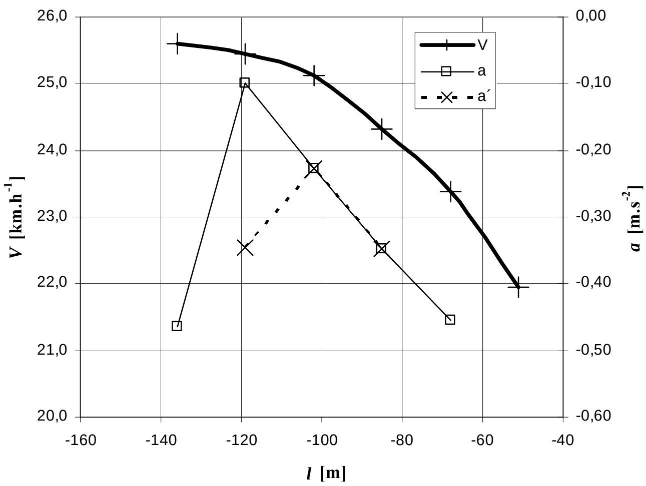

Fig. 5: Profile of acceleration instantaneous value
(*a* by equation 6; *a'* by equation 7)

5 Conclusion

The procedure described in this paper as well as further procedures of analysis enabled by digitising of the traction vehicle motion record were, with an acceptable result in practice, used for speed analysis in the case of collision of a rail vehicle with a road vehicle.

Within this application it was found that for definition of individual points of presentment it was necessary to use the principle of mid point interpolation of the point position in relation to width of pins used in the recording device.

It is necessary to include this procedure to determine the zone of tolerance of the resulting values.

This contribution originated in the scope of ESF RLZ programme 3a project at VŠB-TU Ostrava.

Reviewer: doc. Ing. Petr Škapa, CSc. Institute of Transport

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