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Decreasing train energy consumption through optimising travel times

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***Abstract*—A method has been elaborated for decreasing traction energy consumption by adequate setting of travel times in the train schedule. By means of a numeric experiment the effectiveness of increasing travel times of freight trains in low intensity traffic has been demonstrated. It has been proved that in that way considerable energy savings can be made at expense of some decrease of the average travel speed.**

***Keywords*—energy, consumption, traffic, speed, numerical experiment.**

I. Introduction

Usually in the train schedule travel times are set up close to the minimum possible. As a consequence the average train speeds are increased which improves transport services quality. However, in some cases – for example, when freight trains in low intensity traffic are operated – travel speeds are not a priority. Thus, possibilities exist for optimizing travel times so that higher energy efficiency can be reached [1]. This task can be accomplished using a simulation modeling method.

II. Problem statement

It is well known that the specific energy consumption for traction *E* (*kJ/kg*) under real operation conditions is a function of the travel time *T(s)*, as it is illustrated on Fig. 1 [1, 2]. The decreasing of *E* when *T* is raising (in the left part of the speed range) is due to the diminution of the energy consumption at lower speeds; its increasing at very low speeds – the right part of the curve – is related to the very low efficiency of the locomotive powering complex when operated with low load.

Usually, average operation speeds lay left to the minimum of the *E=f(T)* curve. Practically, it means that if in the train schedule such *T* values are set up, reserves exist for energy consumption decreasing through travel time rising. [6,7]. However, travel times should not exceed the T_{Emin} value, because it could lead back to energy consumption raising.

Thus, the challenge is to find such higher than the set up in the trains schedule *T* values which ensure lower energy consumption at reduced travel speeds.

In [2] software has been described suitable for solving optimization problems of this kind. It is based on a simulation model which enables reproducing trip on a given road sequence at various travel times. The corresponding energy consumptions are calculated and the optimal variant is selected. By means of this software in [2, 3, 4, 5] dependences of energy consumptions on travel time are examined under various operation conditions.

The method is illustrated below by an example where the dependence *E=f(T)* for a train with assigned parameters is examined and the optimal solutions field is defined.

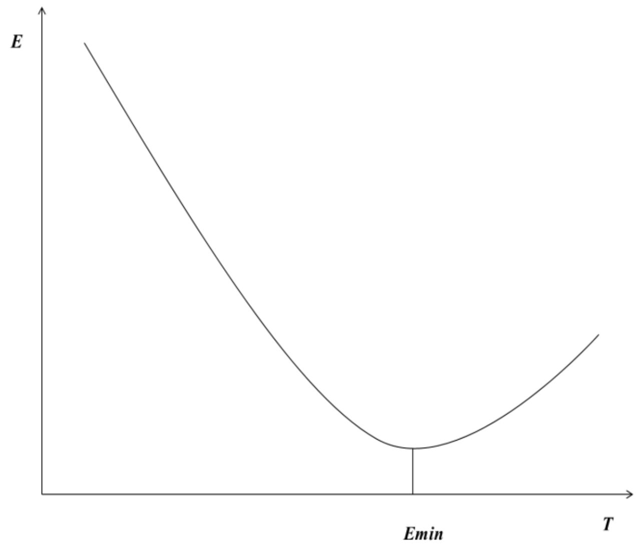

Fig. 1. *Dependence of specific energy consumption (E) from travel time (T) (E=f(T)).*

III. Input data for the numerical experiment

A prerequisite for carrying out the investigation ware the locomotive performance and efficiency curves which had to be input in the computer program SIMOL [2]. In this case a diesel locomotive from the series 07 of the Bulgarian State Railways (BDZ) has been considered whose characteristics *F=f(v)* and $G=f(n_k)$ are shown respectively on Fig.2 and Fig.3.

Travels have been examined on a straight horizontal 30 *km* long sequence with maximum speed limit 100 *km/h*. In order to eliminate the influence of control strategies on the energy efficiency it has been postulated that for all variants the control algorithm is optimal and consists of four phases: acceleration at maximal power, constant speed, coasting and braking (Fig.4).

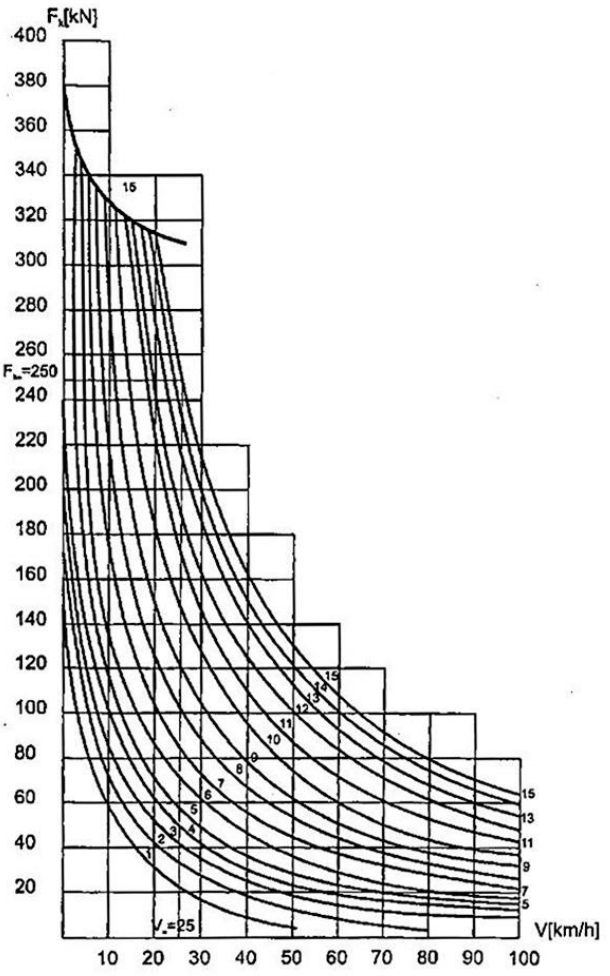

Fig. 2. Performance characteristics of the diesel locomotive series 07

It has to be pointed out that control atrstegies have a considerable impact on the energy efficiency. On the other hand, in each specific case an infinitely large number of control algorithms can be applied and simulation programs like SIDIS [1] or SIMOL [2] are analising a variety of them and selecting the optimal one, i.e. those which correspomds to minimum energy consumption.

Under this study only the tipping points coordinates on the phase trajectory have been optimised. However, more complicated control algorithms – for example "sawtooth" ones [1,2] – can be set up as well without changing the general approach.

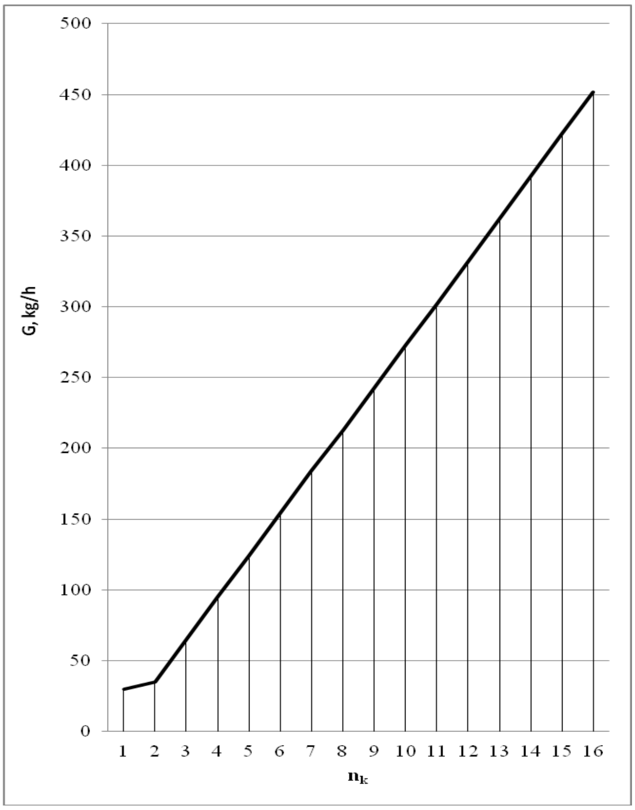

Fig. 3. Fuel consumption (G) at various controller positions (n_k) of the diesel locomotives series 07.

The experiment has been carried out with trains weighting 200 *t*, 400 *t*, 600 *t*, 800 *t* and 1000 *t* and travel times varying between 25 *min* and 60 *min*.

IV. Results

The energy consumption dependences on the travel time *T* for various train weights are displayed on Fig.4.

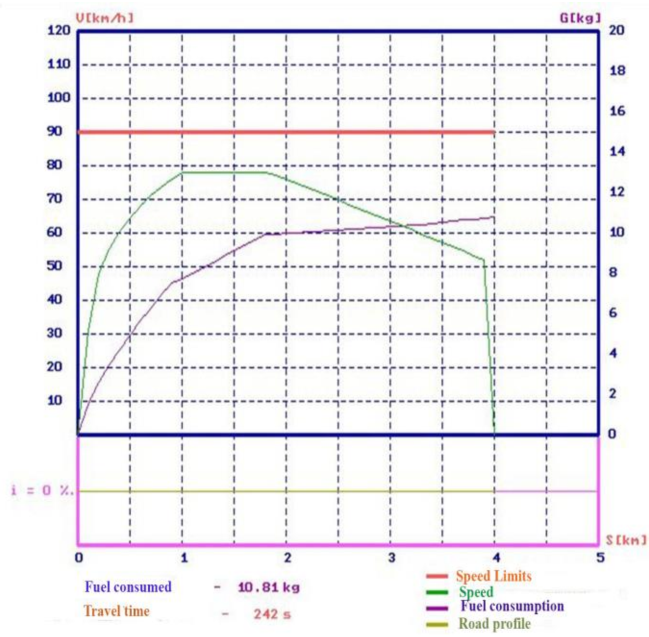

Fig. 4. Dependence of speed (v) on trsvel time (s) (Typical v=f(s) curve).

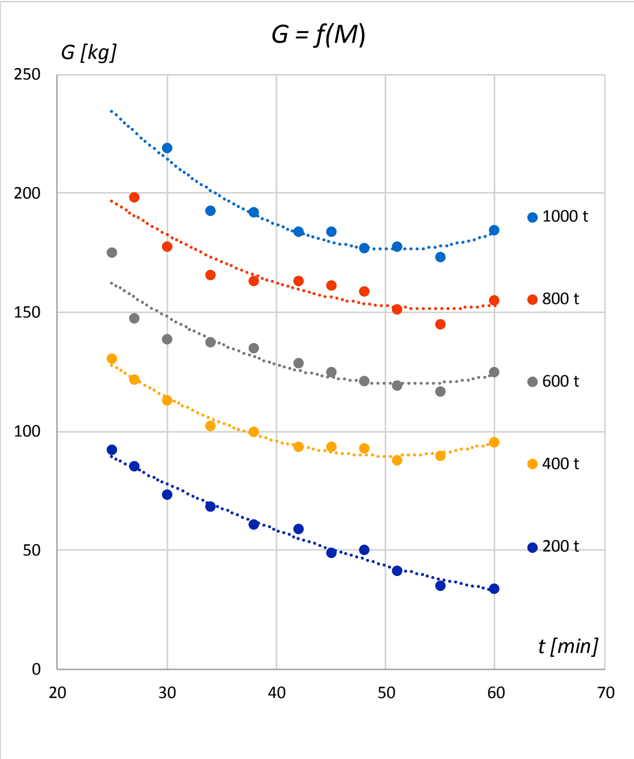

Fig. 5. Dependence of fuel consumption (G) on travel time (t) for various train weights *M*.

The obtained curves *E=f(T)* have minimums in the range of *T* = 48-53 *min*. There is one exception – for the train weighting 200 *t* whose minimum is probably placed out of the examined area.

The analysis shows that in this specific case increasing travel time can bring significant energy savings. For example, if for the operation of a train with weight 1000 *t* at *T*=30 *min* - corresponding to an average speed of v_{cp}=60*km/h* – 198 *kg* of diesel fuel would be necessary, the raise of the travel time up to 51 *min* (v_{cp}=35.3 *km/h*) would cut the fuel consumption to 178 *kg*, i.e. by 10%.

For a train with weight of 200 *t* increasing the travel time from *T*=30 *min* to *T*=51*min* would bring more significant reduction of fuel consumption: from 73.4 *kg* to 41.3 *kg* which means 56% saving.

If for a train weighting 600 *t* travel time will be augmented only by 10 min – from 30 min to 40 min the fuel consumption will decrease by 10% - from 138.8 *kg* to 125 *kg*.

V. Conclusions

- When composing train schedules energy consumption for traction has to be taken into account. In this way considerable energy savings can be obtained.
- In cases when high average travel speeds are not necessary – for example, in low intensity traffic of freight trains – optimal from energy consumption point of view travel times should be set up in the schedule.
- The simulation modeling method – particularly software like SIMOL – can be successfully used for optimizing travel times in train schedules so that higher energy efficiency can be reached.
- It is advisable to carry out additional experiments covering other types of locomotives and sequences with variable road profile. It could allow determining the areas where energy savings by increasing travel times could be obtained.

Acknowledgment

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