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MODELLING OF LOCOMOTIVE NORMAL LOAD

ABSTRACT

The paper deals with two topics. The one is strictly railways, that is theoretical theses for calculation of locomotive load at respective gradient. The second is an overview of computer program MS Access with the basic terms and definitions included in the program itself. It is intended to bring closer the language of information technology to the railways. The developed program for calculating the allowed mass of trains that can be hauled by certain locomotives enables fast calculation of any of the traction variants. A limitation related to mass has been included in the program.

KEY WORDS

timetable, calculation of train traction, performance characteristic, specific normal load

1. INTRODUCTION

Train timetable is the executive plan of train traffic organised for the transport of passengers and goods and for the railway purposes. Timetable co-ordinates the transportation requirements with available material-technical and personnel resources. The available material-technical resources as the basic elements for making a timetable include:

- condition of lines and railway station tracks,
- condition of safety-signalling, telecommunication devices and machinery and information system,
- condition of stable electric traction facilities,
- condition of passenger and freight wagon stock
- condition of traction vehicles.

For train scheduling the following parameters are also necessary: time necessary to run a certain section and the planned speed limitations.

These data may be obtained by good calculation of traction. Apart from obtaining the basic values to schedule the trains, thoughtful calculation of traction allows calculation of a whole series of values significant for the traction analysis from several aspects.

Modelling of the locomotive normal load is part of the whole calculation of the train traction. However, attention has to be paid to performance characteristic as essential element of these calculations.

If traction calculation is used from several aspects, it becomes complex and comprehensive, resulting in even more demanding performance. In order to solve this problem, computers need to be used and software developed based on extensive analyses in mathematical and logical sense, as well as good knowledge of adequate programming language.

2. DETERMINING OF SINGLE VALUES

In order to determine the train mass that a locomotive can haul at a steady speed, the tractive force needs to be defined. Here, train traction is considered in the least favourable case, which means at a relevant gradient. In such case the tractive force equals:

$$F = \frac{1}{100} \otimes [m_l \otimes (w_{hl} + i_m) + m_v \otimes (w_{hv} + i_m)]$$

where:

F [kN] – tractive force,
m_l [t] – locomotive mass,
W_{hl} [daN/t] – specific normal resistance for the locomotive,
i_m [‰] – relevant gradient,
m_v [t] – train mass,
w_{hv} [daN/t] – specific normal resistance for the train.

From this equation the mass of the train that can be hauled on the relevant gradient at a constant speed is calculated

$$m_v = \frac{100 \otimes F - m_l \otimes (w_{hl} + i_m)}{w_{hv} + i_m} \quad [\text{t}]$$

or

$$m_v = \frac{100 \otimes (F - W_{hl}) - m_l \otimes i_m}{w_{hv} + i_m} \quad [\text{t}]$$

W_{hl} [kN] – normal resistance for the locomotive.

Tractive force is determined from the performance characteristics for every locomotive separately. The performance characteristics most often consist of three curves:

- curve a – usually denotes the greatest tractive force a locomotive can realise regarding the adhesion force,

- curve b – denotes tractive force obtained from the maximum force of the traction vehicles at certain speeds,
- curve c – highest speed of the traction vehicle.

Normal resistance for the locomotives is usually presented in the form of a diagram as function of the driving speed. Normal resistance can usually be described as the function of square driving speed and must be determined for every locomotive, in order to perform the calculation by means of computer software.

The results of the resistance are obtained by measuring, and for computer calculations the specific normal resistance for the locomotives can be used. In order to calculate the resistance of the whole train, mainly the specific resistance is used. Specific normal resistance both for the locomotives and the train are usually calculated from the general expression:

$$w_h = a + b \otimes \left(\frac{V}{10}\right)^2 \quad [\text{daN/t}]$$

or

$$w_h = c + d \otimes V + e \otimes \left(\frac{V}{10}\right)^2 \quad [\text{daN/t}]$$

The coefficients a, b, c, d and e depend on the locomotive type, i.e. type and composition of the train. The travelling speed in these equations is measured in km/h.

A. Types of locomotives

The stock of the Hrvatske željeznice (Croatian Railways) includes:

1. electric locomotives,
   - alternate current – series 1141 and 1161,
   - direct current – series 1061, and
   - alternate Thyristor current - of series 1142,
2. diesel-electric locomotives – series 2061, 2062, 2063, 2041, 2042, 2043 and 2044,
3. diesel- hydraulic locomotives - series 2131, 2132, 2133 and 2141.

B. Functions of locomotive tractive force

Based on the performance characteristic of single locomotives in the following table there is an overview of examples of defined tractive forces functions according to the locomotive 1141 series. The functions of tractive forces are suitable for any calculation which includes the tractive force. Such a case occurs in the computer program that calculates locomotive load.

For locomotives of series: 1141, 1142, 1161, 1061
- tractive force [kN] A – denotes constant regime,
- tractive force [kn] B – denotes one-hour regime.

For locomotives of series: 2062, 2063, 2044, 2043 the tractive force is calculated with:
- electrical heating turned off,
- electrical heating turned on.

For locomotives of series: 2141 tractive force is calculated for:
- passenger transfer,
- cargo transfer.

For locomotives of series: 2131, 2132, 2133 tractive force is calculated for:
- first degree of transfer,
- second degree of transfer.

C. Normal resistance function

Normal resistances for locomotives are also defined as functions based on the respective diagrams, and in Table 2 there is an example of normal resistance for the locomotive number 1141.

Table 1: Example of tractive force of the locomotive number 1141

Speed range [km/h]	Tractive force F [kN] A	Speed range [km/h]	Tractive force F [kN] B
Locomotive 1141 (up to 120 km/h)			
0 ... 37	F = 176	0 ... 21	F = 189
38 ... 82	F = 221*(8 + 0,1*V) / (8 + 0,18*V)	22 ... 86	F = 221*(8 + 0,1*V) / (8 + 0,18*V)
83 ... 94	F = -1,675*V + 294,65	87 ... 91	F = -1,46*V + 280,86
95 ... 120	F = 481105/V^2 - 84,4*V + 2597	92 ... 120	F = 481105/V^2 - 84,4*V + 2597
Locomotive 1141 (up to 140 km/h)			
0 ... 94	F = 148	0 ... 76	F = 159
95 ... 121	F = -1,18*V + 259,4	77 ... 96	F = 221*(8 + 0,1*V) / (8 + 0,18*V)
122 ... 140	F = 931826/V^2 - 35,22*V - 2408,7	97 ... 119	F = -1,35*V + 283,5
		120 ... 140	F = 931826/V^2 - 35,22*V - 2408,7

Table 2: Example of normal resistance for the locomotive number 1141

Types of locomotives	Normal resistances for locomotives W_{hl} [kN]
1141	$1,64 + 0,0328*(V/10)^2$

D. Specific normal resistance for single types and compositions of trains

Specific normal resistance for a train depends on the type and composition of the train and it is calculated according to the following calculations:

- mixed cargo trains:

$$W_{hv} = 1{,}5 + 0{,}0625 \otimes \left(\frac{V}{10}\right)^2$$

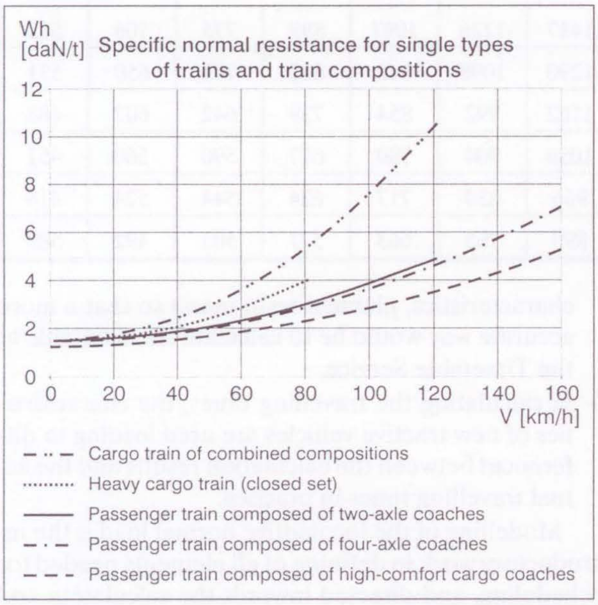

Figure 1 - Graphical presentation of the specific resistance for trains

Table 3: Overview of actions within the program

Steps	Number of the locomotive	Program action
1st step:	all locomotives	Selection of locomotive number
2nd step:	a) for el. locomotive:	Selection of operation regime
	b) for locomotive no: 2062, 2063, 2043, 2044	Selection of el.heating condition
	c) for locomotive no.: 2141	Selection of transmission type
	d) for locomotive no.: 2131, 2132, 2133	Selection of transmission rate
2nd a step:	for locomotive no.: 1141, 1142	Selection of highest travelling speed
3rd step:	all locomotives	Selection of traffic type
4th step:	all locomotives	Selection of traffic subgroup
5th step:	all locomotives	Performing calculation
6th step:	all locomotives	Printing calculation
7th step:	all locomotives	quitting the program

- heavy cargo trains:

$$W_{hv} = 1{,}5 + 0{,}0238 \otimes \left(\frac{V}{10}\right)^2$$

- passenger trains composed of two-axle coaches:

$$W_{hv} = 1{,}5 + 0{,}040 \otimes \left(\frac{V}{10}\right)^2$$

- passenger trains composed of four-axle coaches:

$$W_{hv} = 1{,}5 + 0{,}0222 \otimes \left(\frac{V}{10}\right)^2$$

- passenger trains composed of high-comfort four-axle coaches:

$$W_{hv} = 1{,}5 + 0{,}0159 \otimes \left(\frac{V}{10}\right)^2$$

3. THE CONCEPT OF MS ACCESS PROGRAM

The calculation of locomotive load for different types and compositions of trains is solved by calculating complex values. As the best solution, a computer program for calculating these has been developed. This program carries out the following steps:

Description of the program actions:

- operation regime – it can be constant or one-hour,
- electrical heating – it can be turned on or off,
- transfer type – it can be passenger and cargo,
- transfer rate – it can be first and second,
- highest travelling speed – it can be for the locomotive 1141 (120 or 140 km/h) and for the locomotive 1142 (120 or 160 km/h)
- type of traffic – it can be passenger and cargo
- type of traffic subgroup – it can be in passenger (trains of two-axle coaches, four-axle trains and

Printing format of the locomotive load calculation results

Locomotive 1142 V_{max}= 160 km/h

Constant regime

Passenger train – four-axle coaches

Table 4: Example of load calculation for the locomotive of the 1142 series

	Train mass (t)												
Gradient / Km	40	50	60	70	80	90	100	110	120	130	140	150	160
0	3000	3000	3000	3000	3000	3000	3000	2789	2249	1833	1508	1250	1044
1	3000	3000	3000	3000	3000	3000	2743	2236	1840	1527	1276	1083	906
2	3000	3000	3000	3000	3000	2747	2249	1861	1553	1305	1103	956	798
3	3000	3000	3000	2904	2733	2298	1902	1591	1341	1137	969	855	712
4	2776	2680	2570	2451	2326	1972	1645	1386	1177	1005	862	774	641
5	2359	2288	2207	2117	2022	1724	1447	1226	1047	899	775	706	582
6	2049	1994	1931	1861	1786	1530	1290	1098	942	812	703	650	531
7	1808	1765	1715	1658	1598	1373	1162	992	854	739	642	602	488
8	1616	1581	1540	1494	1444	1245	1056	904	780	677	590	560	451
9	1460	1431	1397	1358	1316	1137	966	830	717	624	544	524	418
10	1330	1305	1276	1244	1208	1045	890	765	663	577	505	492	389

high-comfort four-axle trains) and in cargo traffic (trains of combined composition and heavy trains).

Calculation is carried out for relevant gradients ranging from 0 to 30 ‰, and for speeds from critical to the maximum a locomotive can reach.

Printing format is adapted to the form of the table that can be applied in adequate regulations (Instruction 52).

4. CONCLUSION

Timetable is the operation process which encompasses all the elements needed to carry out the transportation such as material and technical resources and guidelines in passenger and cargo transport. In order to achieve the best possible scheduling of a timetable, the elements that are included in the timetable need to be of the highest quality as well. The elements required for the timetable include also calculations of the normal resistance of a locomotive.

The current organisation of the Hrvatske željeznice has been organised in such a way that within the Department for Traction of Trains and Train Vehicles, the train travelling times are calculated on the basis of the characteristics of tractive vehicles. Such a condition leads to certain errors in timetable due to the following reasons:

- the calculation of travelling times requires elements that are not related to the vehicle traction (track characteristics, planned train mass) so that a more accurate way would be to calculate the timetable at the Timetable Service,
- in calculating the travelling times, the characteristics of new tractive vehicles are used leading to differences between the calculation results and the actual travelling times in practice.

Modelling of the locomotive normal load is the introductory work in defining of all elements needed for scheduling, and directed towards the calculation and quality of performance characteristics that can be calculated by various methods. It has to be noted that the construction year of the tractive vehicle and the replacement of the traction vehicle components are the elements which can influence accurate performance characteristic of the tractive vehicle.

The development of the railway traffic in Europe has started many new relations as well, ways of dealing with problems and ways, the basic activity - of performing transport. One of the relations that will undergo changes is also the way and type of providing elements of the train traction for the development of timetables.

SAŽETAK

MODELIRANJE OPTEREĆENJA LOKOMOTIVA U RAVNINI

Cjelokupni rad obrađuje dvije tematike. Prva je stroga željeznička i to teoretske postavke za proračunavanja optere-

ćenja lokomotiva na mjerodavnom usponu. Druga je pregled informatičkog programa MS Access-a s osnovnim pojmovima i definicijama u samom programu. Namijenjena je približavanju informatičkog jezika željeznici. Izrađeni program za izračunavanje dopuštene mase vlakova koju pojedine lokomotive mogu vući omogućava brzi proračun bilo koje varijante vuče. Unutar programa napravljeno je i jedno ograničenje vezano za masu.

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