SPEED OF TRAINS IN TRACK JUNCTIONS

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Abstract

This work focuses on the speed of trains, primarily in railway stations. It also deals with the parameters which the speed depends on, for example the influence of the security device or the traction characteristics of the vehicles.

As part of the practical part, a direct measurement of speeds in suitable locations was carried out. Modelling of these situations in the OpenTrack program will be done in a next article, where a comparison of both methods will be carried out.

Keywords

Speed, acceleration, traction characteristics, track junctions

1 INTRODUCTION

Compared to the situation on the open line, where the speed of the train is mostly constant and is affected mainly by the track geometry parameters, the speed in railway stations depends on several factors.

Similarly to the track between stations, the influence of the centrifugal force when going through the curves is manifested , especially in the turnout diverging track (especially when the turnouts are mostly set up without cant); however, the influence of a safety device, for example the introduced ETCS L2 [1], [2], is also more pronounced.

In addition, there is currently an effort to introduce the highest possible speeds in the branch tracks. Therefore, a question arises whether trains are able to travel atthese speeds.

This thesis continues and develops the master's thesis of Ing. Horák [3].

Goals of the thesis

The goal of this work is to determine the speeds reached by trains in railway stations when passing through track junctions. This goal is achieved by carrying out measurements and evaluating train speed measurements in the railway station. The first method is direct measurement of the speed of trains in a given locality. A suitable site will be chosen from where the measurement will be carried out. This part will also include the selection of a suitable measurement method. In the second part, a simulation will be performed in the OpenTrack program. This part is not included in this article. Finally, a comparison of the speeds of old and new trains will be made. The goal is to verify whether the speeds in the branch tracks are usable, or, conversely, whether the railway infrastructure is not a limiting element.

Description of the present state

The current design of railway stations is carried out according to the ČSN 73 6310 [4] norm, where the basic parameters are given. More detailed principles are described in ČSN 73 6360-1 [5] and according to the internal regulations of Správa železnic, specifically regulation "S3 Železniční svršek, Díl IX Výhybky a výhybkové konstrukce" [6], which describes truck junctions, and also regulation „D1, Část první, Dopravní a návěstní předpis pro tratě nevybavené evropským vlakovým zabezpečovačem" [7], which deals with sign regulations. Thus, it introduces a speed signaling system that determines the speed in the tracks.

The main element that fundamentally affects the speed of trains in railway stations are turnouts and turnout structures.

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2 METHODOLOGY

Description of locations

The railway stations were chosen in such a way that there was a regular entry/departure of trains to/from the branch tracks. At the same time, they were chosen because the speed in their branch tracks is higher than the usual 50 km/h.

Another criterion was the operation of vehicles with different traction characteristics thus, it will be possible to compare the start-up techniques.

The first phase of the measurement focused only on passenger trains. The advantage of this solution is particularly the larger volume of data. In selected stations, passenger trains arrive and/or depart as often as on an hourly basis or even more often on busy working days. In addition, the organization of measurements is simpler since the largest volume of passenger traffic takes place during the morning and afternoon hours, i.e. with good accessibility. In contrast, freight traffic is heavy at night. For freight transport, it is also difficult to predict overtaking at a particular station. The choice of passenger trains was also supported by the fact that train sorting is available, i.e. the weight, which then enters the simulation.

The selected locations are the Šakvice and the Hrušovany u Brna railway stations. Both localities are situated on the Brno – Břeclav line, at Hrušovany u Brna and Šakvice stations regional railway to Židlochovice and Hustopeče u Brna turn out from this national-wide railway. Passenger trains are run from Brno to Židlochovice and Hustopeče u Brna every hour (on a half-hourly basis on peak working days) with mutual interleaving. In addition, the line is loaded with long-distance traffic, both passenger and freight. Express trains on the Brno – Břeclav – Olomouc line stop at Šakvice, Zaječí and Podivín stations, other long-distance trains pass through all stations between Brno and Břeclav. The scheme of the selected locations is shown in Fig. 1.

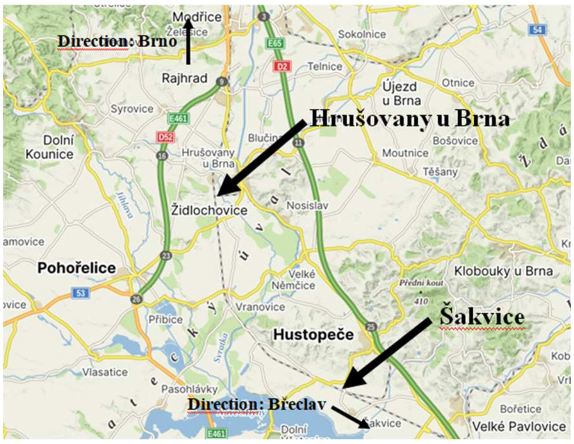

Fig. 1 Locations selected [8].

Šakvice

The first location is the Šakvice railway station. It is a branch railway station, located on the national railway line Brno – Břeclav and turn out from it the regional railway Šakvice – Hustopeče u Brna. The traffic scheme of the station is shown in Fig. 2.

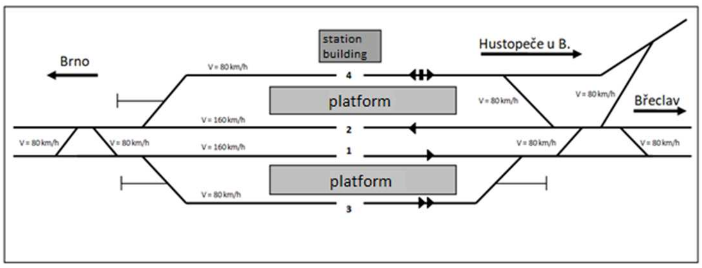

Fig. 2 Track diagram of the Šakvice railway station.

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Hrušovany u Brna

The second location is the railway station Hrušovany u Brna. It is a branch railway station located on the national railway line Brno – Břeclav and the regional railway Hrušovany u Brna – Židlochovice branches off from it. The traffic scheme of the station is shown in Fig. 3.

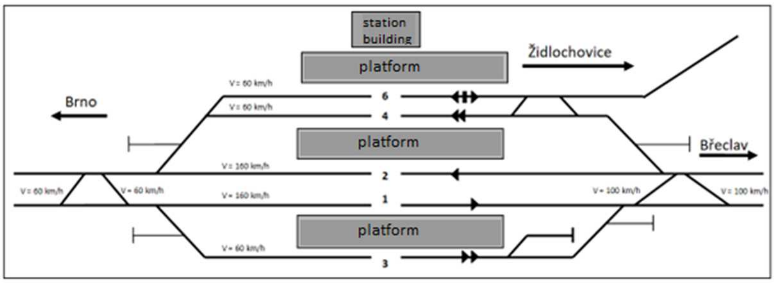

Fig. 3 Track diagram of the Hrušovany u Brna railway station.

Speed check

A Bushnell Speed Radar Gun, model 101911, serial number 001000250755-0000, was used to measure train speeds. According to the manufacturer, it is able to measure speed values in the interval 17–322 km/h at a maximum distance of 457 m. The temperature range is from 0 to 40 °C. The measurement error stated by the manufacturer is ±2 km/h.

The original assumption was the installation of stable Speed Meters of rail vehicles (hereinafter referred to as "radar") and photographic recording equipment. The measurement length was assumed to be a week, including non-working days. In order to find a suitable location, we visited the site and performed test measurements. The reason was, on the one hand, to find a suitable measurement site which would not be affected by shielding, e. g. by a noise barrier or masts of the traction line. Another reason was getting to know the traffic, i.e. which tracks the respective trains depart from, where they stop, whether at the end of the platform or in the middle (closest to the access to the platform). Having performed the trial measurements, we changed the method.

The advantage of measuring with a stable radar is the large volume of data obtained; moreover, over a longer period of time it allows to capture, for example, a change in non-working days or the operation of freight trains at night. In contrast, in this case only certain categories of trains were decisiveyet with certain specifics. A stable radar will record several values for each pass but these values cannot be assigned to an exact location. What is more, the number of values depends on several factors (roughness of the reflecting surface, unevenness of the surface, the angle at which the beam hits) and cannot be predicted. The result of this measurement would therefore be increasing or decreasing values at speeds which, however, would not be possible to assign to the given places and compile the dependence of the speed on the traveled path.

Taking these circumstances into account, we proceeded to change the method of data collection. In the end, the resulting method is measurement with a manual radar in predetermined places - the scheme of individual places is given for individual locations. The advantage of this approach is its simplicity and ease of use of the equipment, or easy adjustment of e.g. measured locations and essentially immediately. Another advantage is the quick response and monitoring of other parameters, such as the length of sets and the place of stopping, which would be very difficult or impossible to evaluate from a recording device.

One of the disadvantages of this approach is the limited amount of data. The measurement requires the presence of a person for the entire duration of the measurement which, due to unfavorable atmospheric conditions (especially in the winter months), limits the length of one measurement to two to four hours. The measurement must also be carried out in daylight, which does not provide the necessary amount of data, especially in the Šakvice location. Thus, the measurement had to be repeated. Other difficulties arise from the fact that the values are recorded manually and as a result, errors can arise due to the imperfection of human senses. The most difficult task is to correctly estimate the moment when the front of the train passes a given point, especially at more distant points. This is why a series of easily recognizable points (signal, beginning of the switch, heart of the switch) were chosen.

Other disadvantages of this approach include the limited range of speeds that the radar is able to measure (its lower limit is 17 km/h). The departures of freight trains in particular are very slow, and if the freight train only starts from the departure signal, it will not have reached the minimum speed by the first measured points and it is therefore not possible to compile the relevant departure curve. However, freight trains were not tracked in this work and thus, this limitation is not relevant for the purpose of this study.

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Taking the above mentioned facts into account, the placement of stable meters was found to be the best solution either in the form of an induction loopor as sensors based on a piezo element to the given places, possibly supplemented by a photographic device. This solution enables accurate localization of the train, i.e. problems with determining the position disappear, and at the same time it enables deployment to several optimally distributed places. When measuring with a hand-held radar, the choice of points was influenced by the visibility from the station (which had to be located outside the traffic cross-section). Another limiting element was the distance from the station. Sensors in the rail would not be limited in this way. In addition, this method of measurement would allow for the collection of a large amount of data over a longer period of time, without the need for an operator to be present. Yet aAnother advantage is weight measurement which would make the simulation of freight train departures much more accurate. In the previous work, the weight was fixed, in spite of the fact that weight is considered a key factor when evaluating the behaviour of freight trains during the start-up.

The disadvantage of this solution is the time and financial complexity of the production of the necessary sensors. For this reason, it was not possible to use it for the purpose of this work.

Some of the points were measured at the front of the trains, some at the end of the trains. For the points that were measured at the end of the trains, it was necessary to adjust the station according to the length of the train.

Direct measurements took place on the following days:

Hrušovany u Brna: 20 Oct 2022, 20Dec 2022, 13June 2023, 03Oct 2023, 12 Oct 2023.

Šakvice: 20Oct 2022, 24Nov 2022, 3Oct 2023, 19Oct 2023, 31 Oct 2023.

Powered vehicles

Due to the fact that the vehicle fleet was changed while the measurements for this work were being conducted, the necessary amount of data for comparison was obtained.

The old vehicles were the 242, 362 series locomotives and the 842 series motor car. The new vehicles includedthe 530, 550 and 660 electric units.

For comparison, old and new vehicles were selected in each individual location in order to present the nature of traffic as much as possible.

Electric locomotives of the 242 series are four-axle single-phase for a 25 kV 50 Hz power supply system, reaching a maximum speed of 120 km/h. They are equipped with step-by-step power regulation. This is done by taps on the traction transformer and the locomotive has a total of 32 driving stages [8]. The locomotive is not equipped with an electrodynamic brake, it only uses a pneumatic brake during target braking. The traction characteristics are shown in Fig. 4a.

Vehicles with step-by-step regulation represent an old approach to power regulation in electrically powered vehicles. Thus, there is not just onecurve of the dependence of draw-hook tractive effort on speed; in fact, there are as many of them as the given vehicle‘s driving stages.

Vehicles with step-by-step power regulation are further divided into those used on a direct current system and those on an alternating current system. DC vehicles are older and they use rheostatic control (either with permanently non-load-bearing resistors, such as the 140 or 122 series, or with permanently loaded resistors, such as the 110 or 460 series).

AC vehicles with step-by-step regulation have DC traction motors and as a result of this, input AC current must be rectified and smoothed to DC. The powered vehicle therefore has an AC part and a DC part. The advantage of this is that the regulation already takes place in the AC part and it is thus not necessary to use lossy resistance regulation as in DC powered vehicles.

Electric locomotives for the 25 kV 50 Hz AC system, i.e. series 230, 240 and 242, use high-voltage shunt power regulation. Power regulation takes place in the traction transformer. The latter has a primary winding connected to the power supply from the traction line The secondary winding has a certain number of taps (typically 32), which are being switched in sequence. The current regulated in this way continues into the rectifier. It is made up of diodes connected to a bridge. The rectified current passes through the smoothing choke into the DC series traction motors.

Step-by-step power regulation suffers from several disadvantages. The structural arrangement of the oil-immersed shunt switch is very complicated, and when switching shunts, there are longitudinal impacts in the set and the wheels may slip and rail defects may occur (flats on the running surfaces of the wheels, local damage to the head of the rails, the so-called "wheel burns").

With developments in the field of semiconductor elementsin the 1980s, vehicles with continuous power regulation appearedwhich do not suffer from the aforementioned disadvantages of step-by-step regulation.

The locomotive of the 363/362 series is intended for operation on lines electrified with AC and DC power supply systems. It is designed as direct current and when driving under alternating voltage, a transformer and a rectifier are upstream in the traction circuits. Compared to vehicles with shunt power regulation, it uses separate excited DC traction motors. Power regulation takes place in the pulse converter. This solution enables the locomotive to be equipped with an electrodynamic brake, i.e. the traction motors behave like separate excited

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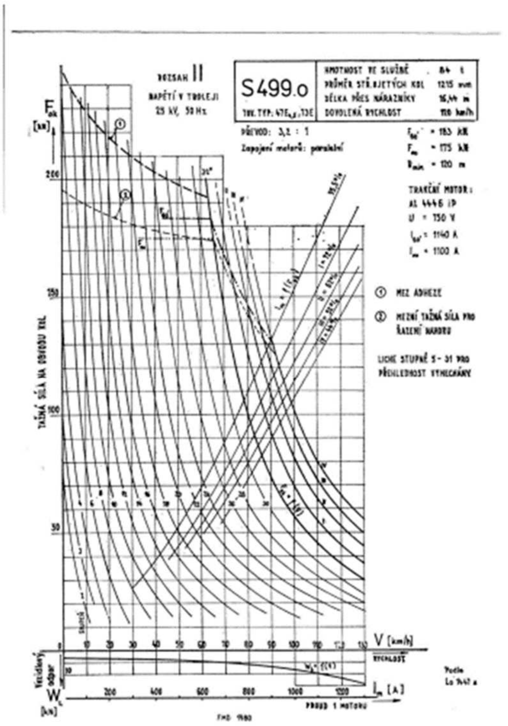
alternators during braking and the obtained current is either wasted in the resistors or can be returned into the network.

a) b)



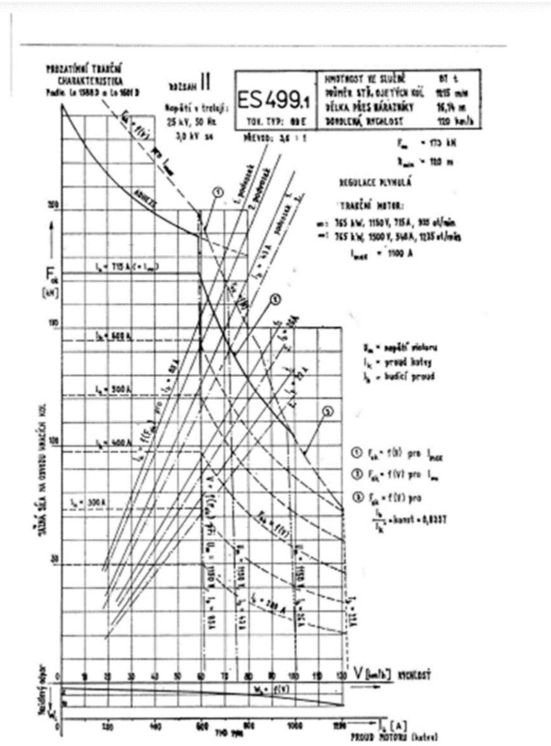


Fig. 4: a) (left) Traction characteristics of the 240 and 242 series locomotives. On the vertical axis, the force on the circumference of the wheels is plotted, on the horizontal axis the speed is plotted. The curves of the particular driving stages are clearly visible (only every second one is plotted), the characteristic is limited on the right side by the maximal speed and on the top by the adhesion limit [9], [10].
b) (right) Traction characteristics of the 363 and 362 series locomotives. They are equipped with continuous regulation. The limit is the cover of the traction characteristic, which applies at 100% proportional traction. At a lower proportional traction, it forms its equidistant. Only some are shown, in the graph they are shown in 100 A steps; however theoretically there is an infinite number of them [9], [10].

The electric locomotives of the 363/362 series are four-axle two-systems, for 3 kV and 25 kV 50 Hz power supply systems (measurement was carried out only on a single-phase power supply system). They are equipped with continuous pulse power regulation with thyristor electrical equipment [11]. They are equipped with an electrodynamic brake without the possibility of recuperation. Thus, at higher speeds, EDB is primarily used (with decreasing speed, its effect decreases); pneumatic brake is only used at speeds below approx. 40 km/h. This allows a smoother braking curve to be achieved. The traction characteristics of the locomotive 363 are shown in Fig. 4b. (Note: The locomotives 363 and 362 differ in the gear ratio in the axle gearboxes and therefore also in the maximum speed, which for the 363 series is 120 km/h, for the 362 series 140 km/h. In the measured locations, only the 362 series locomotives were used).

The motor cars of the 842 series are four-axle, with only two axles being driven. Power transmission is hydrodynamic, the maximum speed is 100 km/h.

The new generation of vehicles is represented by electric units of the 530 and 550 series for regional transport and the 660 and 660.1 for long-distance transport.

Electric units 530 and 550 are single phase for the 25 kV 50 Hz system. They are equipped with continuous pulse power regulation with asynchronous traction electric motors; half of the wheels in the unit are always driven. The 530 series units are four-car, the 550 series two-car units. They reach a maximum speed of 160 km/h and are equipped with an electrodynamic brake.

Electric units 660 and 660.1 are two-system for 3 kV and 25 kV 50 Hz voltage systems (measurements were performed only on a single-phase power supply system). They are equipped with continuous pulse power regulation with asynchronous traction electric motors; half of the wheels in the unit are always driven. The units of the 660 series are three-car, the units of the 660.1 series are five-car. They reach a maximum speed of 160 km/h and are equipped with an electrodynamic brake.

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3 RESULTS

The following results are always divided according to the individual locations. A comparison of the old and new sets is presented for each location, always at start-up and braking.

In the location of Hrušovany u Brna we measured old vehicles three times (20 Oct 2022, 20 Dec 2022, 13 June 2023) and new vehicles two times (03 Oct 2023, 12 Oct 2023).

In the location of Šakvice we measured old vehicles two times (20 Oct 2022, 24 Nov 2022) and new vehicles three times (3 Oct 2023, 19 Oct 2023, 31 Oct 2023).

The data in the following tables were calculatedas the arithmetic mean of all measurements, missing incomplete records and obvious errors.

Hrušovany, direction Hustopeče u Brna, deceleration

Tab. 1 Hrušovany, direction Hustopeče u Brna, old rolling stock.

Train	Point	5	4	3	2	1	0
242 and 4 coaches	Stationing [km]	*0.000*	*0.178*	*0.202*	*0.241*	*0.280*	*0.319*
	Speed [km/h]	*43.5*	*32.0*	*29.5*	*26.3*	*23.5*	*9.0*

Tab. 2 Hrušovany, direction Hustopeče u Brna, new rolling stock.

Train	Point	5	4	3	2	1	0
530	Stationing [km]	*0.000*	*0.162*	*0.186*	*0.225*	*0.264*	*0.303*
	Speed [km/h]	*66.5*	*52.5*	*49.3*	*42.0*	*35.3*	*29,0*

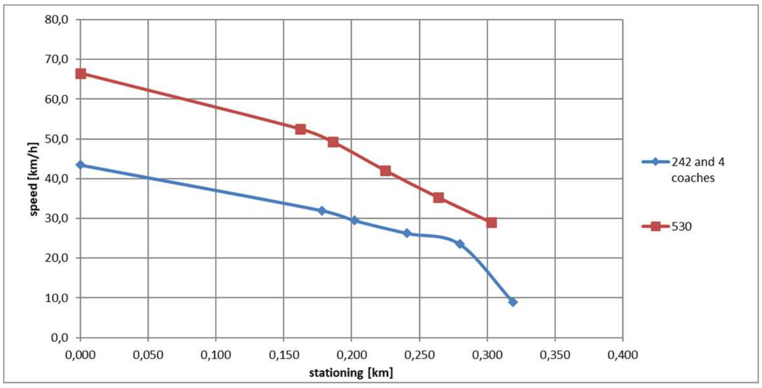

Fig. 5 Comparison between train 242 with 4 coaches and train 530, Hrušovany, direction Hustopeče u Brna.

Hrušovany, direction Židlochovice, deceleration

Tab. 3 Hrušovany, direction Židlochovice, old rolling stock.

Train	Point	5	4	3	2	1
363 and 3 coaches	Stationing [km]	*0.000*	*0.149*	*0.173*	*0.212*	*0.251*
	Speed [km/h]	*58.5*	*49.0*	*49.0*	*45.5*	*39.5*

Tab. 4 Hrušovany, direction Židlochovice, new rolling stock.

Train	Point	5	4	3	2	1
530	Stationing [km]	*0.000*	*0.162*	*0.186*	*0.225*	*0.264*
	Speed [km/h]	*56.3*	*50.4*	*49.7*	*45.0*	*35.6*

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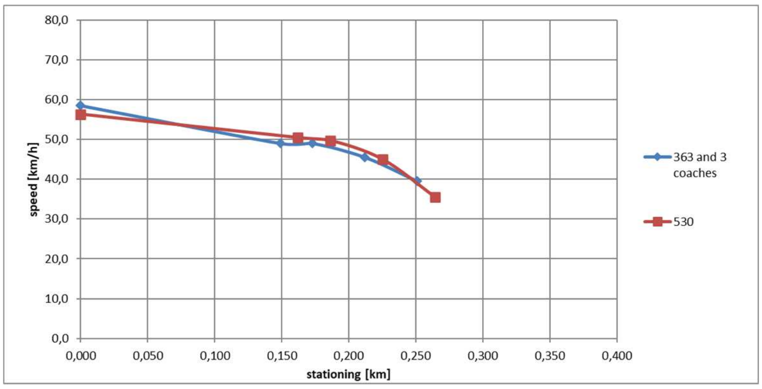

Fig. 6 Comparison between train 363 with 3 coaches and train 530, Hrušovany, direction Židlochovice.

Hrušovany, direction Brno, acceleration

Tab. 5 Hrušovany, direction Brno (main line), old rolling stock.

Train	Point	0	1	2	3	4	5
242 and 4 coaches	Stationing [km]	*0.025*	*0.061*	*0.100*	*0.139*	*0.163*	*0.341*
	Speed [km/h]	*18.0*	*26.3*	*36.9*	*42.9*	*50.8*	*62.7*

Tab. 6 Hrušovany, direction Brno (main line), new rolling stock.

Train	Point	0	1	2	3	4	5
530	Stationing [km]	*0.025*	*0.061*	*0.100*	*0.139*	*0.163*	*0.325*
	Speed [km/h]	*18.8*	*33.4*	*43.3*	*51.5*	*57.0*	*69.7*

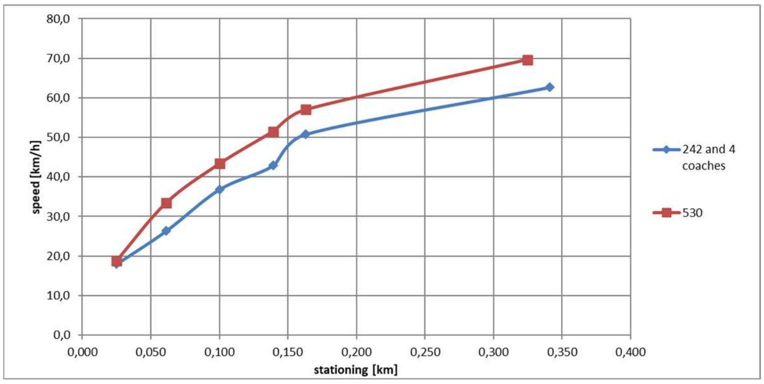

Fig. 7 Comparison between train 242 with 4 coaches and train 530, Hrušovany, direction Brno (main line).

Tab. 7 Hrušovany, direction Brno (near line), old rolling stock.

Train	Point	0	1	2	3	4	5
363 and 3 coaches	Stationing [km]	*0.025*	*0.061*	*0.100*	*0.139*	*0.163*	*0.313*
	Speed [km/h]	*19.0*	*30.0*	*42.0*	*47.0*	*52.0*	*55.0*

Tab. 8 Hrušovany, direction Brno (near line), new rolling stock.

Train	Point	0	1	2	3	4	5
530	Stationing [km]	*0.025*	*0.061*	*0.100*	*0.139*	*0.163*	*0.325*
	Speed [km/h]	*20.8*	*30.8*	*40.2*	*47.0*	*50.8*	*55.0*

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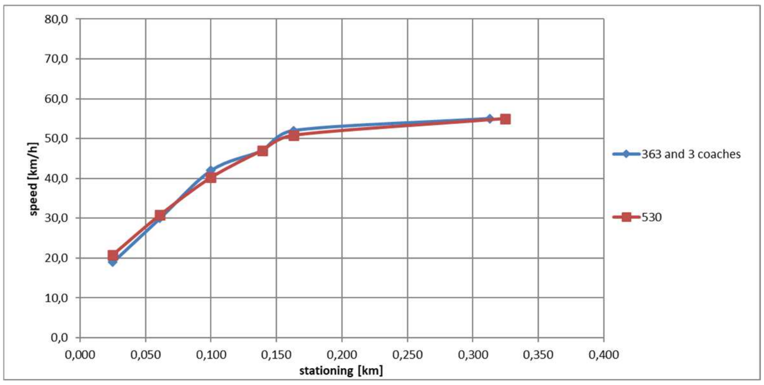

Fig. 8 Comparison between train 363 with 3 coaches and train 530, Hrušovany, direction Brno (near line).

Šakvice, direction Hustopeče u Brna, acceleration

Tab. 9 Šakvice, direction Hustopeče u Brna (near line), old rolling stock.

Train	Point	0	1	2	3	4	5
242 and 4 coaches	Stationing [km]	*0.000*	*0.095*	*0.153*	*0.184*	*0.345*	*0.463*
	Speed [km/h]	*0.0*	*30.0*	*40.0*	*39.9*	*50.2*	*57.0*

Tab. 10 Šakvice, direction Hustopeče u Brna (near line), new rolling stock.

Train	Point	0	1	2	3	4	5
530	Stationing [km]	*0.000*	*0.095*	*0.153*	*0.184*	*0.330*	*0.448*
	Speed [km/h]	*0.0*	*38.6*	*49.3*	*47.9*	*64.9*	*73.7*

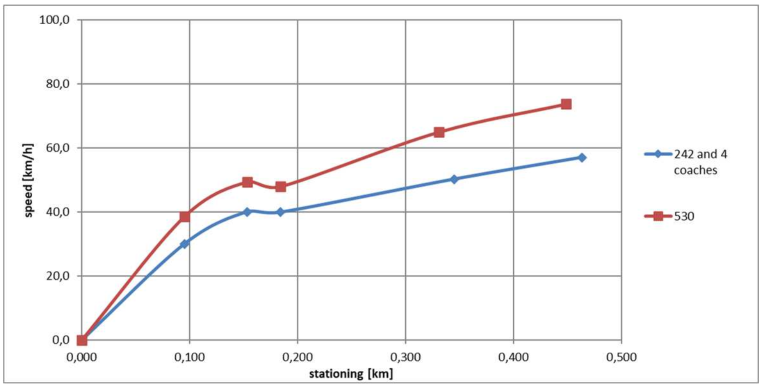

Fig. 9 Comparison between train 242 with 4 coaches and train 530, Šakvice, direction Hustopeče u Brna (near line).

Šakvice, direction Břeclav, acceleration

Tab. 11 Šakvice, direction Břeclav (main line), old rolling stock.

Train	Point	0	1	2	3	4	5
842	Stationing [km]	*0.000*	*0.095*	*0.153*	*0.184*	*0.248*	*0.366*
	Speed [km/h]	*0.0*	*38.0*	*49.0*	*52.0*	*58.0*	*70.0*

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Tab. 12 Šakvice, direction Břeclav (main line), new rolling stock.

Train	Point	0	1	2	3	4	5
550	**Stationing [km]**	*0.000*	*0.095*	*0.153*	*0.184*	*0.276*	*0.394*
	Speed [km/h]	*0.0*	*42.1*	*55.4*	*59.6*	*72.0*	*77.7*

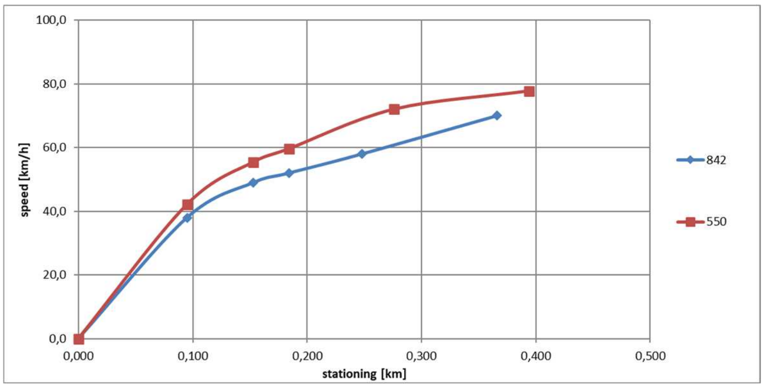

Fig. 10 Comparison between train 842 and train 550, Šakvice, direction Břeclav (main line).

Šakvice, direction Brno, deceleration

Tab. 13 Šakvice, direction Brno (near line), old rolling stock.

Train	Point	0	1	2	3	4	5
242 and 4 coaches	**Stationing [km]**	*0.000*	*0.118*	*0.279*	*0.310*	*0.368*	*0.463*
	Speed [km/h]	*69.0*	*63.0*	*54.4*	*46.3*	*37.5*	*0.0*

Tab. 14 Šakvice, direction Brno (near line), new rolling stock.

Train	Point	0	1	2	3	4	5
530	**Stationing [km]**	*0.000*	*0.118*	*0.264*	*0.295*	*0.353*	*0.448*
	Speed [km/h]	*71.1*	*58.9*	*49.6*	*49.1*	*44.1*	*0.0*

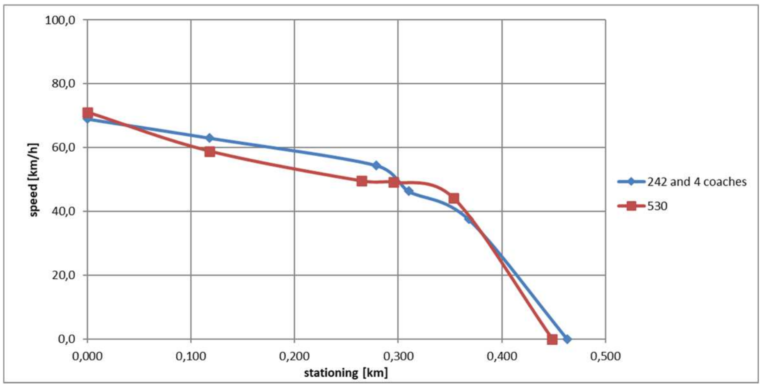

Fig. 11 Comparison between train 242 with 4 coaches and train 530, Šakvice, direction Brno (near line).

Tab. 15 Šakvice, direction Brno (terminated), old rolling stock.

Train	Point	0	1	2	3	4	5
842	**Stationing [km]**	*0.000*	*0.118*	*0.182*	*0.213*	*0.271*	*0.366*
	Speed [km/h]	*-*	*74.0*	*70.0*	*58.0*	*50.0*	*0.0*

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Tab. 16 Šakvice, direction Brno (terminated), new rolling stock.

Train	Point	0	1	2	3	4	5
550	**Stationing [km]**	*0.000*	*0.118*	*0.210*	*0.241*	*0.299*	*0.394*
	Speed [km/h]	*68.6*	*57.2*	*47.0*	*45.4*	*40.0*	*0.0*

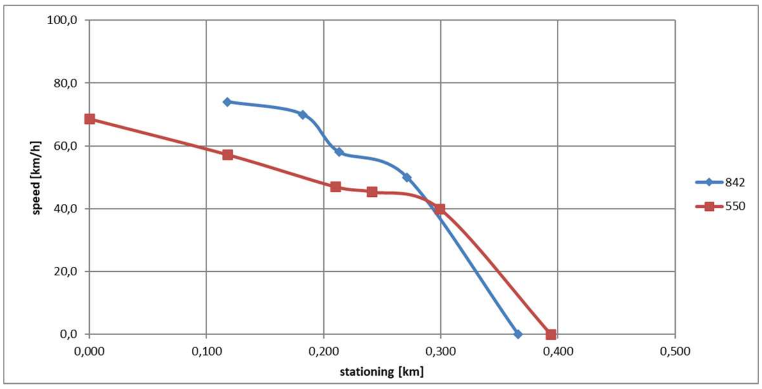

Fig. 12 Comparison between train 842 and train 550, Šakvice, direction Brno (terminated).

Tab. 17 Šakvice, direction Brno (speed train), new rolling stock.

Train	Point	0	1	2	3	4	5
660.1	**Stationing [km]**	*0.000*	*0.118*	*0.289*	*0.320*	*0.378*	*0.473*
	Speed [km/h]	*84.0*	*71.7*	*54.3*	*51.7*	*47.0*	*0.0*

Tab. 18 Šakvice, direction Brno (speed train), old rolling stock.

Train	Point	0	1	2	3	4	5
362 and 8 coaches	**Stationing [km]**	*0.000*	*0.118*	*0.372*	*0.403*	*0.461*	*0.556*
	Speed [km/h]	*92.5*	*82.0*	*52.0*	*47.5*	*38.0*	*0.0*

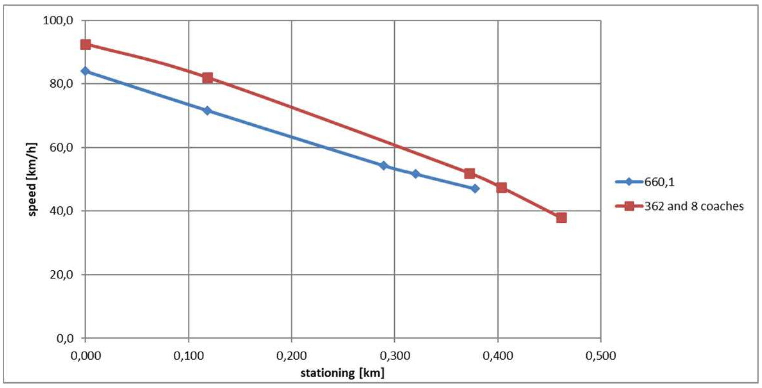

Fig. 13 Comparison between train 660.1 and train 362 with 8 coaches, Šakvice, direction Brno (speed train).

4 DISCUSSION

During the summer schedule change, there was a complete change of the rolling stock on the examined trains. Another goal of the research work was to compare the braking and starting curves of the old and new sets. Apart from the change of sets, there was no other change in the conditions so it was possible to mark the measurement outputs as comparable.

From the comparison in Hrušovany u Brna, it can be seen that while the sets of passenger trains led by locomotive 362 Fig. 6 and Tab. 3, for braking and Fig. 8, Tab. 7,

Tab. 8 for starting, there is no significant difference compared to the new units; for sets driven by locomotives 242, there is a difference of over 10 km/h Fig. 5, Tab. 1, Tab. 2 for braking and Fig. 7, Tab. 5, Tab. 6 for starting.

There can be two reasons for this phenomenon. These differences appear more prominently during braking, so a possible explanation could be the absence of EDB in locomotive 242, i.e. that train drivers reduce the speed more slowly by driving through the ramp and use the pneumatic brake until the final braking, while in vehicles with EDB, train drivers use just the electrodynamic brake at higher speeds (higher than 40 km/h).

The second reason may be that the sets with locomotive 362 were monitored in the Hrušovany locality where the speed in the diverging track of the turnout is 60 km/h, while in the Šakvice locality it is 80 km/h. This means that the differences in the starting and braking curves are manifested when starting/braking from higher speeds, i.e. that the limiting element in the Hrušovany locality is the track infrastructure, not the traction characteristics of the vehiclesbut.

Conversely, in the locality of Šakvice, it is possible to observe faster departures of trains led by new electric units, compared to the old sets with locomotives 242 Fig. 9, Tab. 9, Tab. 10 and motor cars 842 Fig. 10, Tab. 11,

Tab. 12. On the other hand, some inconsistencies appeared in braking, e.g. when old vehicles have a curve comparable to new vehicles Fig. 11, Tab. 13, Tab. 14 or old vehicles are closer to the more theoretical braking curve (quadratic curve) than the new Fig. 12, Tab. 15, Tab. 16 and Fig. 13, Tab. 17, Tab. 18 The cause of this phenomenon is not clear, it may be due to the individual driving styles of train drivers.

5 CONCLUSION

The assumptions were as follows: new vehicles are more powerful and thus, so they will achieve steeper starting and braking curves. These will also be reached when driving through the diverging track of the turnout (the relative difference will be the same, the absolute difference will be lower). All types of trains will have better traction properties (the train will start with the highest possible acceleration).

The following conclusions emerge from the measured results: New vehicles with better traction characteristics generally achieve higher accelerations and the acceleration and braking curves are more similar to the theoretical ones. However, these advantages are only achieved when starting/braking at a higher speed, i.e. when using switches with a lower speed in the diverging track, the limiting element is the infrastructure, acceleration is then the same for old and new sets. Better traction properties are more evident in stop trains whereas long-distance trains usually do not have the fastest possible acceleration. Differences compared to old vehicles are negligible, or old vehicles achieve even better values. Last but not least, the human factor plays a significant role.

Further development of the thesis will be an increase in the number of measurements andpossibly a more thorough statistical analysis and modelling in the Opentrack program. Optional extension of measurement to freight trains is also possible

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