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RAILWAY VEHICLE DYNAMIC EFFECTS IN THE COURSE OF PASSING OVER TURNOUTS IN THE STRAIGTH DIRECTION

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1. Introduction

In the year 2000 started an operation in speed up to 160 km/h in some Czech railways sections of the 1st corridor. Whereas the corridor rails are mounted more accurately opposite to mounting rails of older technology in condition of running at a speed 160 km/h in corridor track dynamic effects by far they do not reach as high values as in condition of older design technology tracks. This fact is not concerned with turnouts – passing over a turnout tongue area and especially over a turnout frog area in straight direction is attended by increased dynamic forces in the wheel-rail interaction, which results in the increased wear of some turnout parts. This fact is concerned with unmovable frog turnouts placed in through tracks of corridor stations which are operated at a speed 160 km/h.

Methodology was created in order to detect and evaluate the dynamic effects of railway vehicles in the course of passing over turnouts. The principle of the methodology is explained in the following chapter.

2. Methodology of the railway vehicle dynamic effects detection in the course of passing over a turnout

There was chosen an acceleration measuring on wheelset axle boxes as an input quantity for detecting vehicle dynamic effects. Wheelset axle box has a close mechanical connection with the wheelset and it is also friendly to installation of measurements (sensors, cable connections). It is necessary to find such place which has unsuspended connection with the axle box. The sensors shall be placed as close as possible to wheelset axis in the longitudinal direction (see ***fig. 1*** where are the examples of sensors placing on axle boxes of several vehicles).

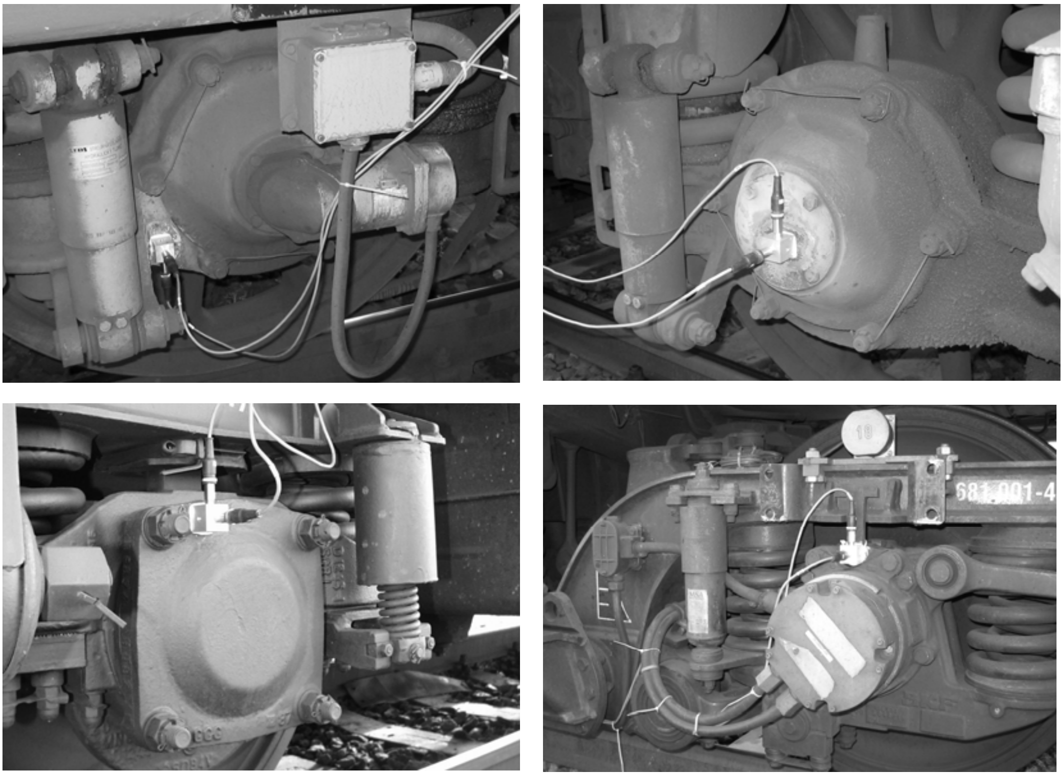


Fig. 1 *Techniques of sensor placing on axle boxes (locomotive class 263 – both top pictures, measuring car for stationary traction equipment – left bottom picture, unit class 680 – right bottom picture)*

The sensors are always placed on a vehicle always only in one bogie, but regarding a measurement runs generally in both running directions without a vehicle turning. They are placed on axle boxes of both bogie's wheelset. Only one wheel of a wheelset contacts a turnout's tongue and frog with regard to turnout's deviation line in the course of passing over a turnout. Hence it is necessary to place the vertical acceleration sensors on axle boxes of all bogie's wheelset. There was experimentally verified that lateral acceleration sensors placed on axle boxes of the same wheelset measure identical values. Therefore the lateral acceleration sensors can be placed only on one axle box of each bogie's wheelset. Generally used scheme of accelerate sensors placing in vehicle is in ***fig. 2***.

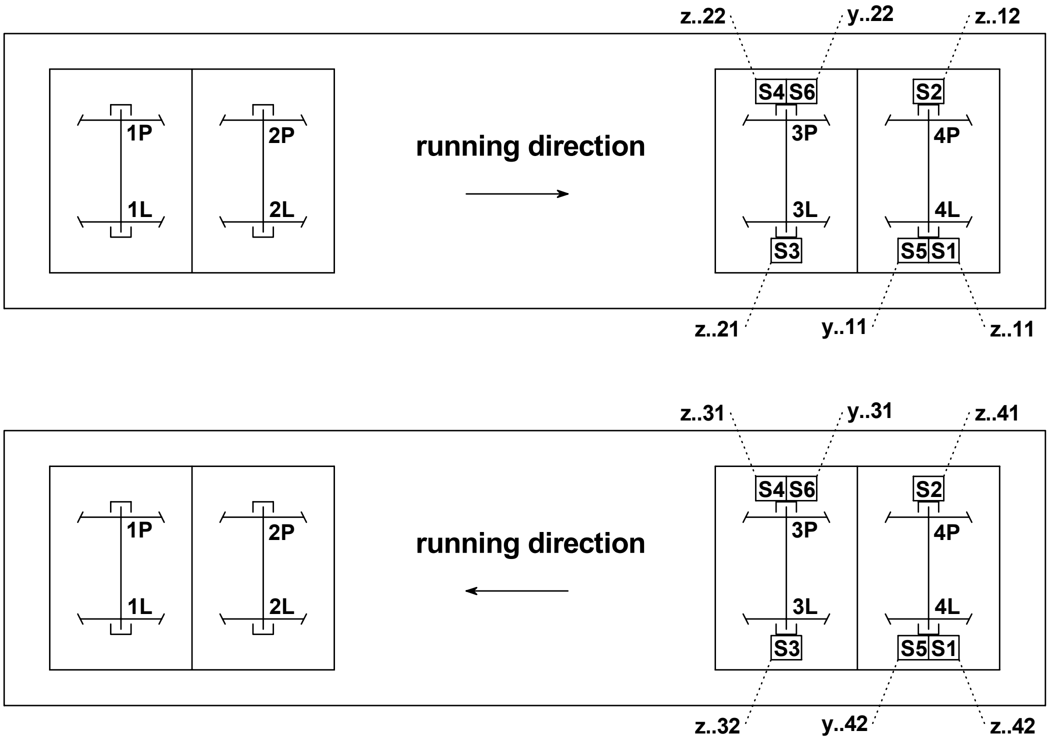


Fig. 2 *General scheme acceleration sensors placing in vehicle and measured quantities regarding the direction of vehicle passing over a turnout*

Sensors type B12/1000Hz are used for scanning the vertical acceleration (sensors No. 1÷4 in ***fig. 2***) and sensors type B12/200Hz for scanning the lateral acceleration (sensors No. 5 and 6 in ***fig. 2***). Acceleration of all sensors is recorded by sampling frequency 1200 Hz and with regard to a natural frequency of used sensors the records are filtered by low-past filter. Filter with frequency limit value 300 Hz is used for the vertical accelerations (sensors type B12/1000Hz) and filter with frequency limit value 85 Hz for lateral accelerations (sensors type B12/200Hz). An example of filtered records of vertical and lateral accelerations measured on axle boxes of the same wheelset in the course of passing over station throat is in ***fig. 3***. There are marked sections by shadowing in the charts when a wheelset passes over a turnouts tongue areas (light shadowing) and turnouts frog areas (dark shadowing). The shadowed sections of acceleration records (always of length 20 m) are also the input data for evaluating the vehicle dynamic effects in the course of passing over a turnout (see the following articles).

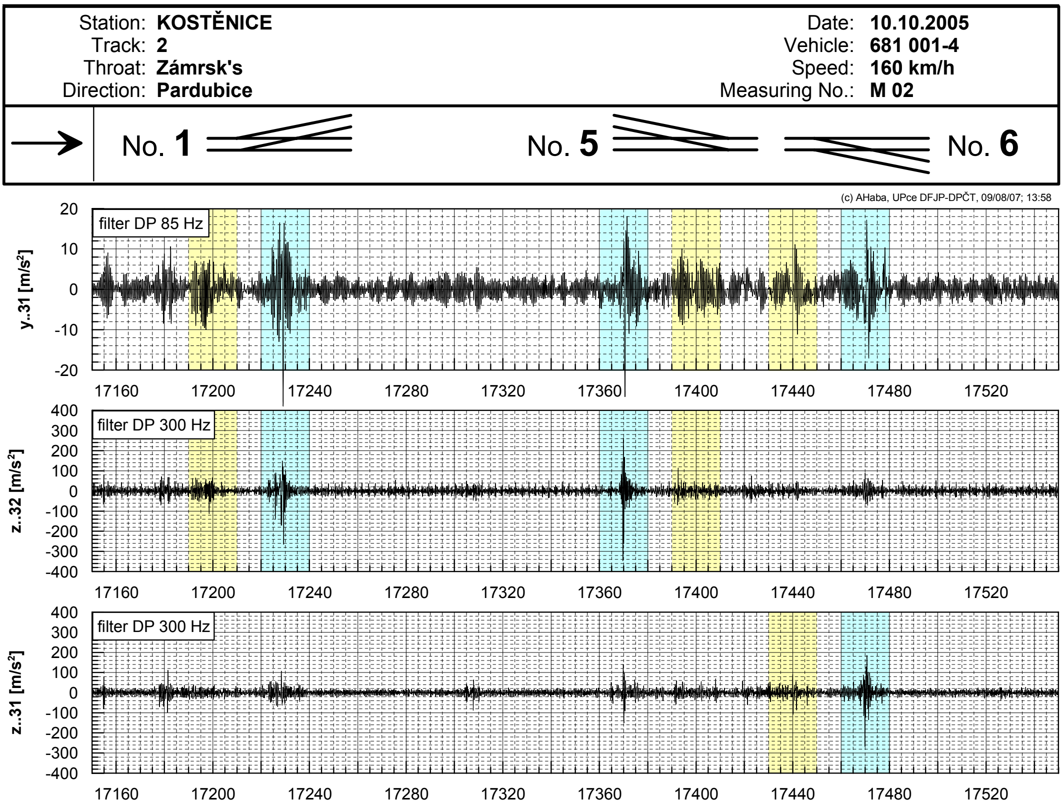


***Fig. 3** Filtered records of vertical and lateral acceleration measured on axle boxes of the same wheelset in the course of passing over a station throat*

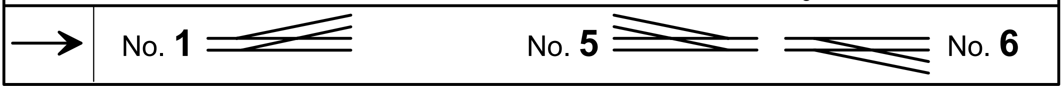
There are noted the increased values of acceleration measured on the axle boxes in the lateral and especially in the vertical direction in the course of passing over a turnout frog areas. Comparing of the both vertical acceleration records (quantities z..32 and z..31) and the scheme of turnouts position in the station's throat in headline of all graphs higher acceleration values are noted on axle box of that wheel which directly contacts a frog tongue in the course of passing over a turnout frog area. Hence the sections of acceleration record measured on axle box of the opposite wheel aren't shadowed and they aren't evaluated below.

The evaluation of dynamic effects extension in the course of passing over a turnout is based upon the measured filtered acceleration records in particular sections represented tongue and frog areas of various turnouts as it was figured above. There are computed the following basic statistical characteristics of acceleration values in mentioned sections:

- mean value (Xm),
- standard deviation (s),
- minimum value (min),

- 0.15% quantil (0.15%),
- 2.5% quantil (2. 5%),
- 50% quantil (50%),
- 97.5% quantil (97.5%),
- 99.85% quantil (99.85%),
- maximum value (max).

Station:	**KOSTĚNICE**	Date:	**10.10.2005**
Track:	**2**	Vehicle:	**681 001-4**
Throat:	**Zámrsk's**	Speed:	**160 km/h**
Direction:	**Pardubice**	Measuring No.:	**M 02**



(c) AHaba, UPce DFJP-DPČT, 09/08/07; 13:58

Quantity	Section	Xm	s	min	0.15%	2.50%	50.00%	97.50%	99.85%	max
No. 1 (to the left) - TONGUE (up)	*17190 ÷ 17210*									
y..31 [m/s^2]	1t+	-0.02	3.44	-9.98	-9.64	-8.02	0.26	6.40	7.26	7.32
z..32 [m/s^2]	1t+	0.08	21.51	-113.40	-98.12	-42.91	-0.09	44.57	65.65	67.14
z..31 [m/s^2]	1t+	0.09	14.03	-33.95	-33.70	-26.97	0.75	27.13	37.96	39.49
No. 1 (to the left) - FROG (up)	*17220 ÷ 17240*									
y..31 [m/s^2]	1f+	-0.05	5.79	-28.95	-28.35	-11.07	-0.15	11.06	16.43	16.52
z..32 [m/s^2]	1f+	0.14	38.10	-264.77	-217.59	-108.23	1.30	78.62	127.19	149.89
z..31 [m/s^2]	1f+	0.19	22.66	-69.91	-64.43	-44.02	-0.60	47.55	106.62	107.38
No. 5 (from the left) - FROG (down)	*17360 ÷ 17380*									
y..31 [m/s^2]	5f-	-0.12	5.06	-26.63	-26.54	-8.66	-0.10	11.46	18.05	18.07
z..32 [m/s^2]	5f-	0.25	45.23	-347.69	-329.90	-74.95	1.60	79.05	210.88	263.16
z..31 [m/s^2]	5f-	0.12	24.95	-150.02	-145.73	-42.88	0.20	46.72	129.92	140.64
No. 5 (from the left) - TONGUE (down)	*17390 ÷ 17410*									
y..31 [m/s^2]	5t-	0.04	3.72	-8.78	-8.63	-7.03	-0.09	7.05	9.61	10.02
z..32 [m/s^2]	5t-	0.08	19.68	-69.92	-65.60	-40.07	-0.18	39.92	90.48	114.13
z..31 [m/s^2]	5t-	-0.03	18.01	-57.22	-51.65	-33.42	-1.09	36.29	61.48	68.56
No. 6 (to the right)- TONGUE (up)	*17430 ÷ 17450*									
y..31 [m/s^2]	6t+	-0.08	3.03	-11.15	-10.90	-5.12	-0.35	6.47	10.73	11.14
z..32 [m/s^2]	6t+	0.02	14.68	-47.46	-44.54	-28.50	-0.46	35.47	47.11	49.66
z..31 [m/s^2]	6t+	-0.06	20.67	-107.97	-101.81	-40.52	-0.28	37.82	90.44	91.40
No. 6 (to the right) - FROG (down)	*17460 ÷ 17480*									
y..31 [m/s^2]	6f+	0.09	4.46	-17.08	-16.86	-8.18	0.02	9.54	16.88	17.15
z..32 [m/s^2]	6f+	0.02	20.32	-72.05	-66.01	-39.45	-0.92	46.27	79.99	88.95
z..31 [m/s^2]	6f+	0.29	37.43	-267.22	-256.14	-75.56	1.32	73.69	148.95	185.47

Fig. 4 *Values of statistical characteristics computed from shadowed sections of acceleration filtered records measured on a vehicle axle boxes*

Then all evaluated sections are described by matrix where matrix row represents the measured quantity and matrix column represents the statistical characteristics (see ***fig. 4*** where are the values of statistical characteristics for sections of accelerate records in ***fig. 3***).

Two important statistical characteristics analogous to evaluation of running behaviour according to UIC 518 method were chosen for evaluating of dynamic effects – 0.15% quantil and 99.85% quantil. Values of both mentioned statistical characteristics are next graphical processed with a view to evaluation of dynamic effects extension in the course of passing over a turnout. The evaluation is carried out especially by comparing of dynamic effects with respect to speed, running direction, next by comparing of particular turnouts with each other and also by comparing with running out of turnouts in the same conditions (see the next chapters).

One of the graphical both statistical characteristics processing is comparison of the particular turnouts with each other in the same conditions as it was figured above. There is a column chart in ***fig. 5*** where each column represents the turnout tongue or frog. Bottom column level comes up to 0.15% quantil value of acceleration and top column level comes up to 99.85% quantil value of acceleration. There are 5 sections which represent running out of turnouts in the same conditions like passing over turnouts on the right part of this graph. The speed was the common criterion here for the comparison, so all turnouts (sections out of turnouts included) were passed at the same speed. Generally the speed isn't sufficient for common criterion in the course of vehicle dynamic effects evaluation in case curved turnouts. It is necessary to take into account also another factors influencing dynamic effects like e.g. cant deficiency, turnout type (single sided, double sided) or curve radius.

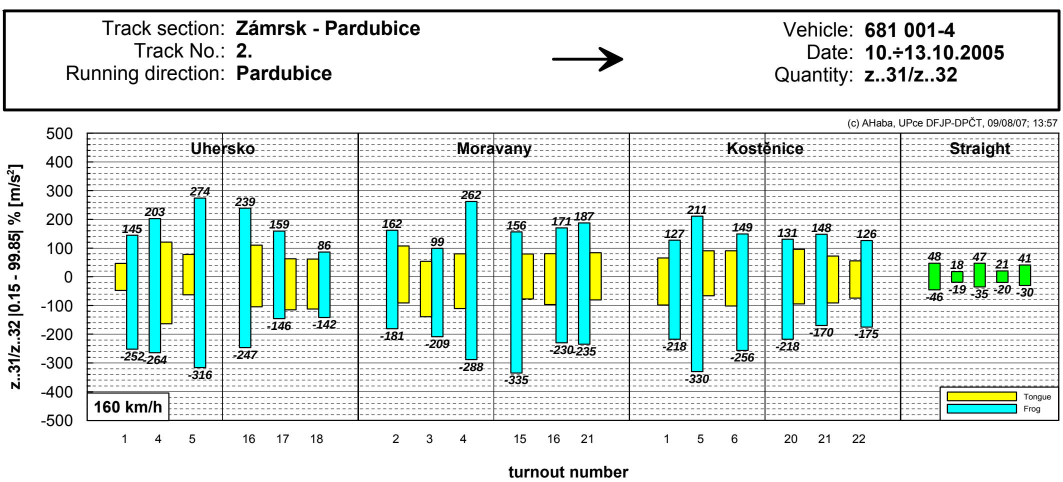


Fig. 5 *Vehicle dynamic effects comparison in the course of passing over all turnouts in that track section running out of turnouts including at a same speed*

There is a possibility to detect turnouts which show the increased dynamic effects in comparison with others in that type of graphical data processing. However it is impossible to decide about growth extension of vehicle dynamic effects due to growing speed of passing over a turnout.

The next type of the graphical processing of both chosen statistical characteristics is vehicle dynamic effects comparison of passing over the same turnout at a different speed and the different running direction – see ***fig. 6***. Graphical processing of both statistical characteristics is analogous to previous case.

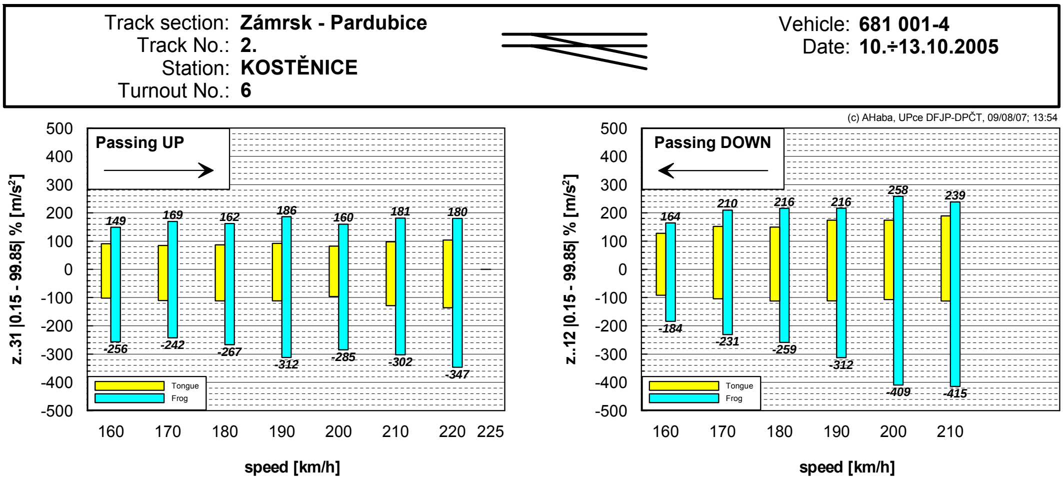


Fig. 6 *Dynamic vehicle effects in the course of different passing speed over a turnout*

Although it is impossible to compare vehicle dynamic effects in the course of passing over several turnouts between each other in that type of graphical data processing, but there is a possibility to monitor the dynamic effects growth due to growing speed of passing over a turnout, but only separately for the turnout.

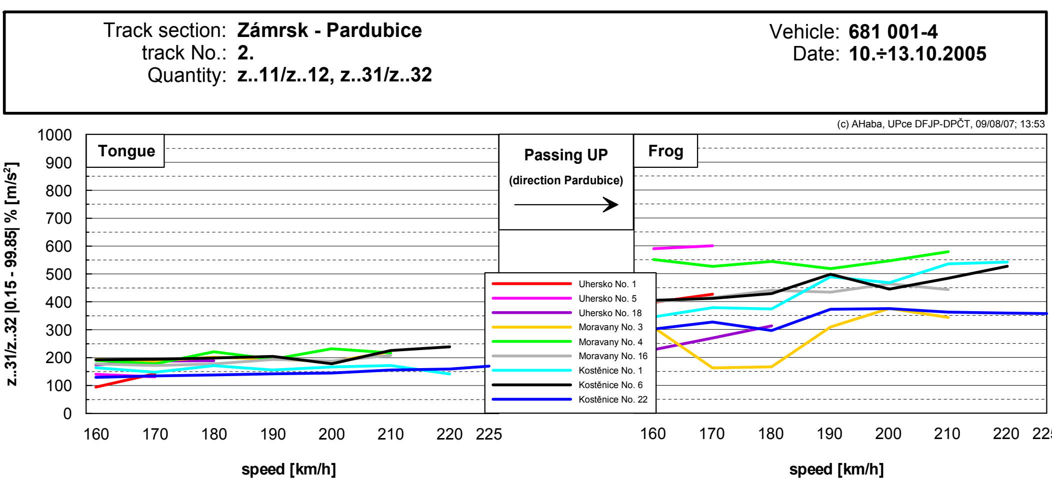


Fig. 7 *Vehicle dynamic effects in the course of the different passing speed over all turnouts*

The last used type of both chosen statistical characteristic processing is the comparison of dynamic effects growth in the course of passing over particular turnouts, but in condition of all turnout display. Each turnout is represented by a line which is set by points whose value is the division of 99.85% quantil and 0.15% quantil of acceleration.

There is some analogy with statistical characteristics named “Variation span” and it is the value of the total height of the columns from the two previous graphical processing. The lines representing particular turnouts shall be colour-diversified (see ***fig. 7***).

There is a possibility to detect turnouts which show the intense growth of the dynamic effects in comparison with others.

The mentioned above method of railway vehicle dynamic effects detecting in the course of passing over a turnouts were use in years 2004-2006 in terms of two high-volume research projects. It was the project “Vehicle-track interaction in condition of increased speed” that concerned to vertical vehicle dynamic effects detecting in the course of passing over straight turnouts at high speed and the project “Check on state of curved turnouts in terms of verification track section in the term may-june 2006”, which was concerned to lateral vehicle dynamic effects detecting in the course of passing over curved turnouts at increased speed. Principle aims and detected results of both projects are introduced in the next chapter.

3. Executed measurements and their results

In the year 2004 were carried out high-speed tests of unit class 680 in 1st corridor track section of AC traction supply system between stations Břeclav and Hrušovany u Brna. The maximum reached speed was 230 km/h. There were also executed measurement of acceleration on axle boxes of unit 680 head car 681 001-4 in order to vertical vehicle dynamic effects detection in the course of passing over the chosen turnouts at the increased speed in the terms of this tests.

There is a displayed size of vehicle dynamic effects in the course of passing over turnouts in stations Podivín, Zaječí and Šakvice at a speed 160, 200 and 220 kmph in ***fig. 8***.

It is clearly visible in fig. 8, that the particular turnouts show its dynamic effects of the different size at the speed 160 km/h. Increased dynamic effects are shown especially at Šakvice’s turnouts and next also some turnouts of station Podivín. Contrariwise relatively low dynamic effects are shown at turnouts No. 2 and 3 of station Zaječí even at the speed 200 km/h.

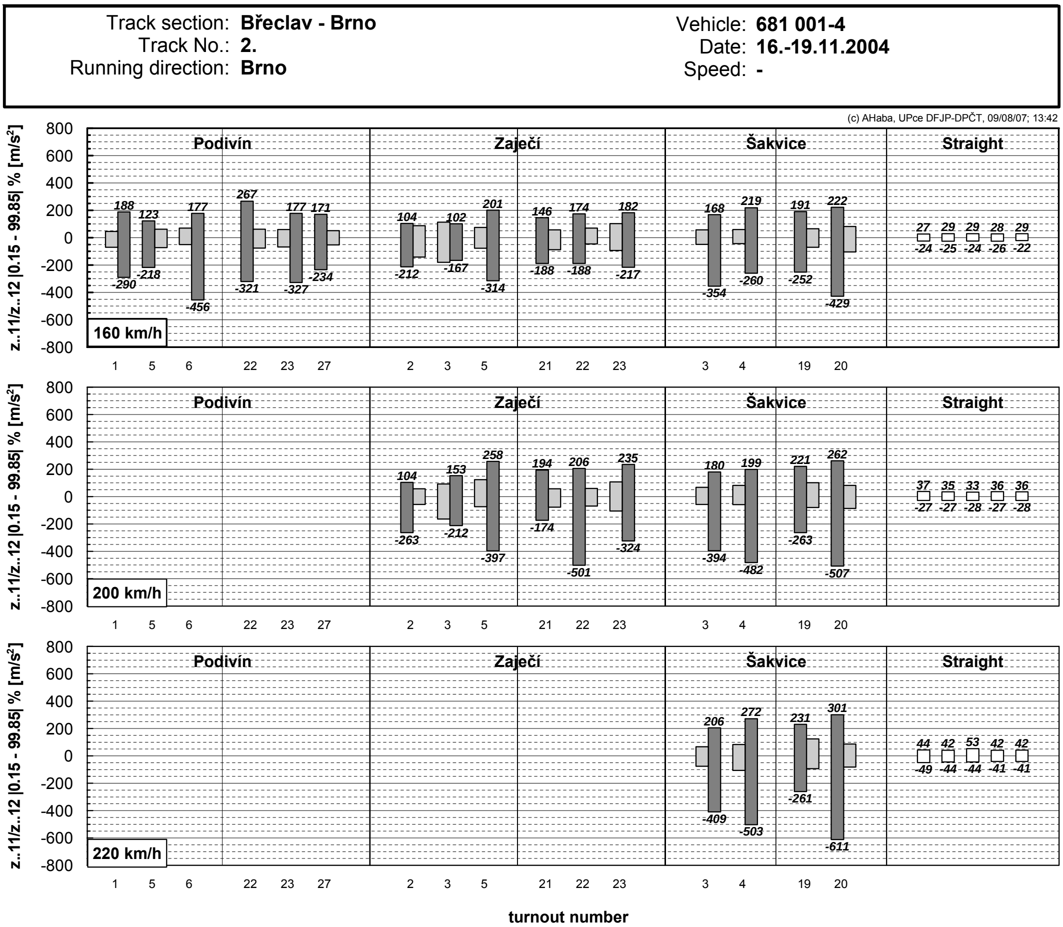


Fig. 8 *Vertical dynamic effects of vehicle 681 001-4 in the course of passing over turnouts of 2nd track line at track section Břeclav – Hrušovany u Brna*

There was detected a reason of increased vehicle dynamic effects after mentioned above evaluation of vehicle dynamic effects of some turnouts. For that purpose KŽV, s.r.o. corporation measured lateral profiles of chosen turnouts frog area rails. There was chosen turnout No. 6 of station Podivín and turnout No. 2 of station Zaječí for the comparison. There are displayed measured frog area rail profiles of both mentioned turnouts in ***fig. 9*** and ***10***. There are displayed the profiles as a unproportional spatial model in the top part of both figures, there are displayed the profiles through each other in the bottom part.

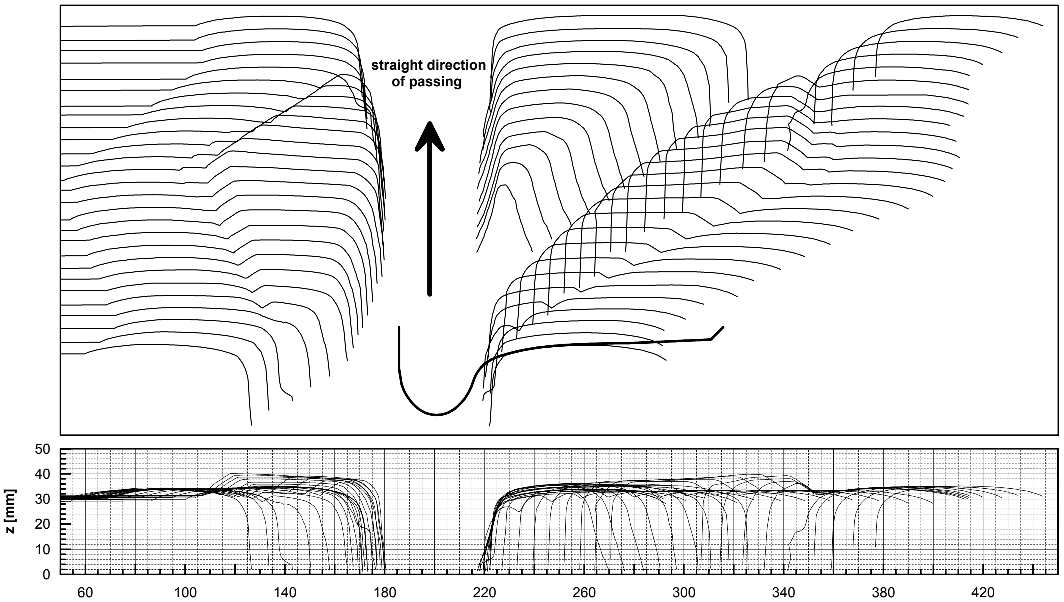


Fig. 9 Frog area lateral profiles of Podivín's turnout No. 6

There is possible to take cognizance of clear wing rail elevation in ***fig. 9***, which is typical for frog type "Insert". It stands to reason, that the mentioned elevation was the reason of increased vehicle dynamic effects in the course of passing over frog area of that turnout.

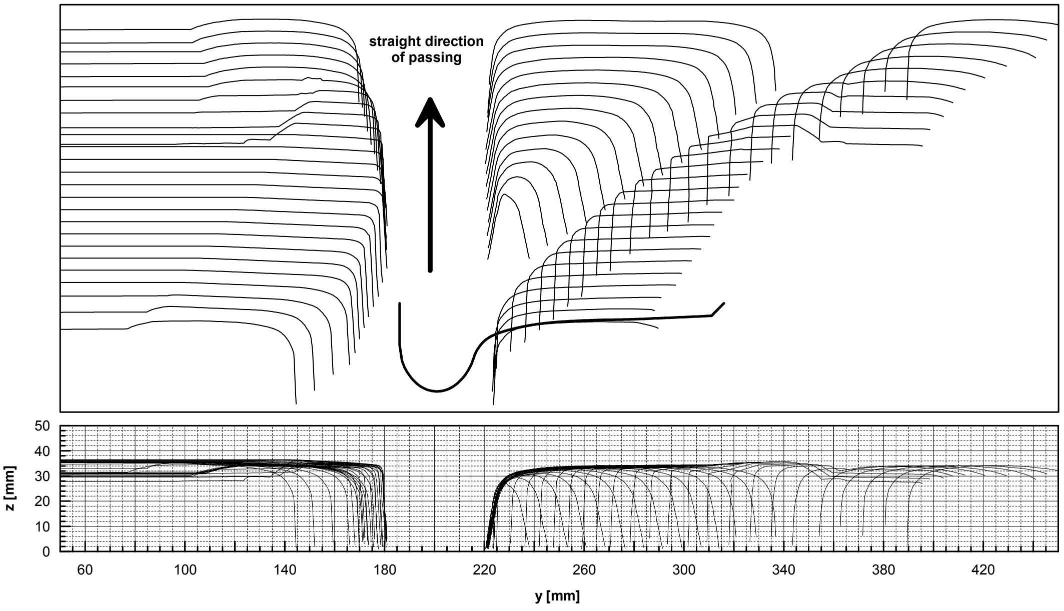


Fig. 10 Frog area lateral profiles of Zaječí's turnout No. 2

There is possible to take cognizance that wing rail surface as well as frog toe is in the same level and therefore a wheelset doesn't have to do fast movement in the vertical direction in the course of passing over frog area, which should results in increased dynamic effects like in the previous case.

After high-speed tests in the 1st corridor track section of A/C traction supply system high-speed tests came after in 1st corridor track section of D/C traction supply system too between stations Pardubice and Zámrsk in the year 2005. Maximum reached speed was 230 km/h as well as in the previous tests. There was executed detecting of vehicle dynamic effects in the course of passing over turnouts at a speed 160 km/h in terms of measuring of traction equipment on the base of experience of previous high-speed tests and results of vehicle dynamic effects detecting in the course of passing over turnouts in order to detect a critical turnouts showing increased vehicle dynamic effects. Results of that measurement are in the form of vehicle dynamic effects displayed in ***fig. 11***.

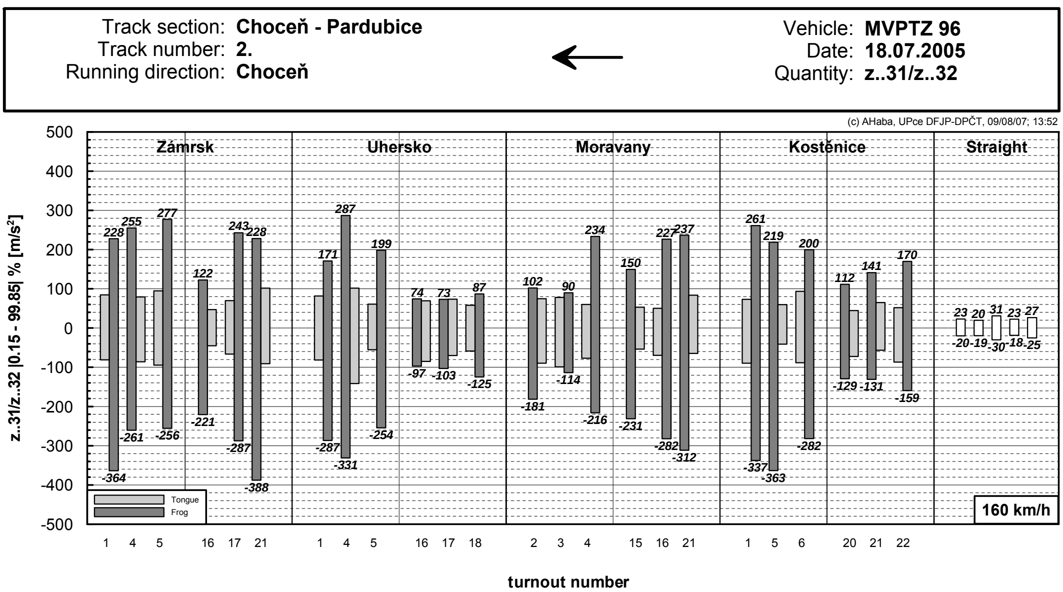


Fig. 11 *Vertical dynamic effects of measuring car for fixed traction equipment in the course of passing over turnouts at a speed 160 kmph in track section Pardubice - Zámrsk*

There is noticeable in ***fig. 11*** that all turnouts of station Zámrsk and turnouts of Zámrsk's throat of station Uhersko shows increased dynamic effects. However passing over these turnouts was permitted at a maximum speed 160 kmph (station Zámrsk) and 170 km/h (Zámrsk's throat of station Uhersko) in the terms of the high-speed tests. Nevertheless other turnouts were passed over at a speed up to 230 kmph and there is noticeable that turnout No. 1 and 5 of station Kostěnice also shows increased dynamic effects comparing with others. Therefore there was measured frog area rail lateral profiles of both mentioned turnouts before the high-speed tests and on the base of that measurement the turnouts were arranged. Then there weren't registered increased dynamic effects in the course of passing over turnouts at an increased speed at high-speed tests (see ***fig. 12***). Contrariwise some turnouts show even stopping of dynamic effects growth with growing with regard to passing speed namely at a speed about 200 km/h (see ***fig. 13***).

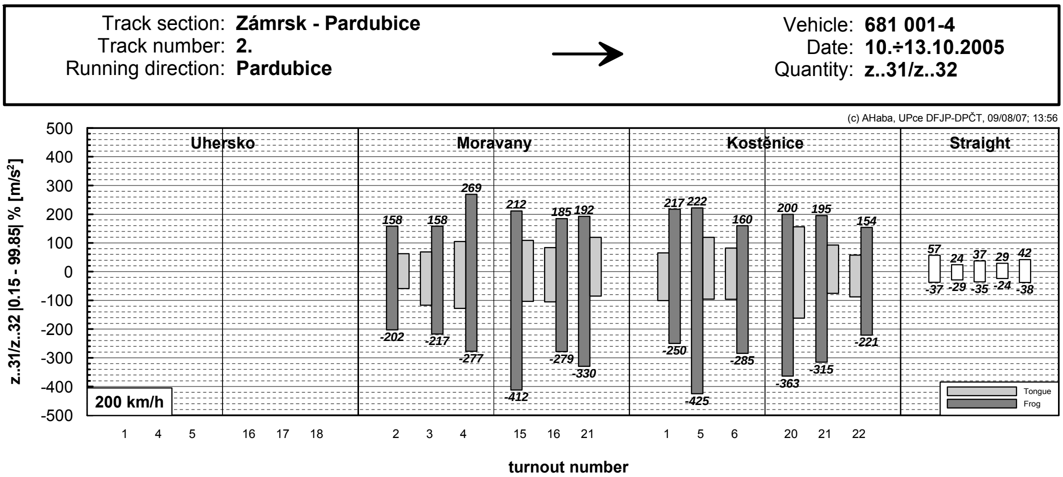


Fig. 12 *Dynamic effects of unit 680 head coach 681 001-4 in the course of passing over turnouts in track section Zámrsk – Pardubice at a speed 200 kmph*

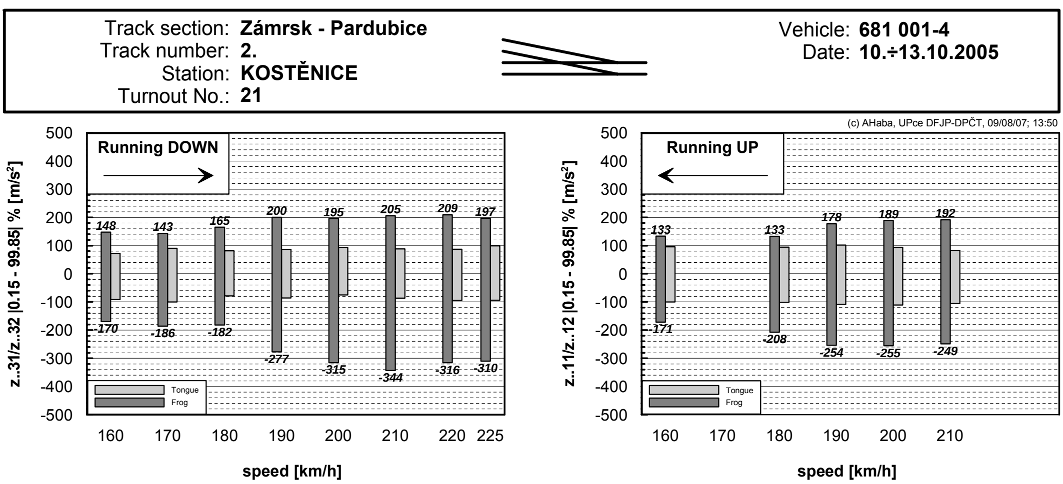


Fig. 13 *Dynamic effects of unit 680 head coach 681 001-4 in the course of passing over Kostěnice's turnout No. 21 at a different speed*

In the year 2006 a verification of the chosen 2^{nd} corridor track section regarding operation of unit 680 at an increased speed in curves with using tilting body technology. There were also detected dynamic effects of the unit head coach in the course of passing over curved turnouts of chosen stations throats in terms of the tests with a view to the possibility to prospective increasing of passing speed over those throats. Lateral vehicle dynamic effects were evaluated in the course of running over curved turnouts. There are displayed lateral dynamic effects of unit 680 head coach 681 001-4 in the course of passing over turnouts of stations Krasíkov and Třebovice v Čechách in additional track section of 2nd corridor line Zábřeh na Moravě – Česká Třebová in ***fig. 14***. There was set a cant deficiency as a criterium for comparison.

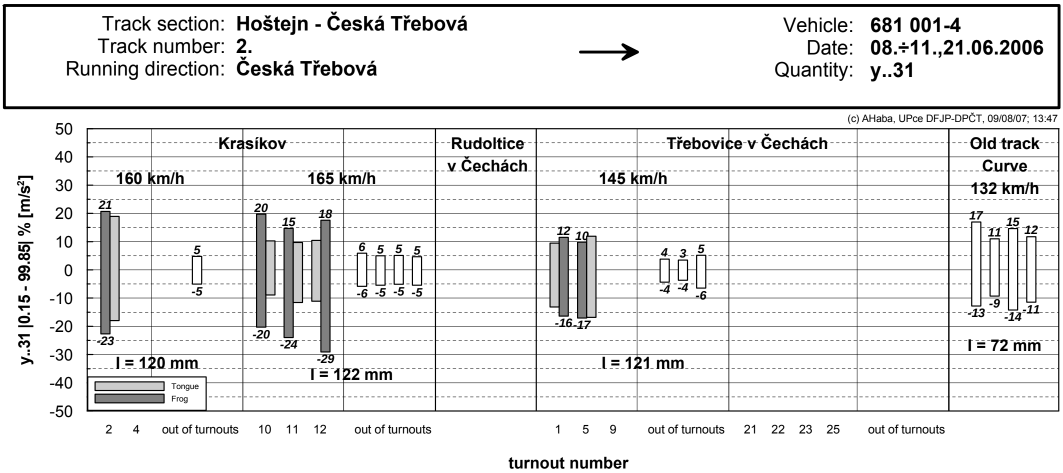


__Fig. 14__ Dynamic effects of unit 680 head coach 681 001-4 in the course of passing over 2nd track line curved turnouts of station Krasíkov and Třebovice v Čechách

There is noticeable in ***fig. 14*** that none of the turnouts shows the increased vehicle dynamic effects in the course of cant deficiency 120÷122 mm. In addition vehicle dynamic effects level in lateral direction in the course of passing over turnouts is comparable in size to dynamic effects in the course of running on track of older design technology (identified as “old track” in the right graph part) and namely moreover in the course of lower cant deficiency. However cant deficiency is nowhere only factor influencing size of vehicle dynamic effects in the course of passing over a curved turnout. Also passing speed acts indispensable role which is partly confirmed by ***fig. 14*** where vehicle dynamic effects are lower in the course of passing over Hoštejn’s throat of station Třebovice v Čechách than in the course of passing over both Krasíkov’s throats at a higher speed but in the course of same cant deficiency.

4. Conclusion

Vehicle dynamic effects in the course of passing over a turnout in straight direction in high speed are greatly influenced by lateral rail profiles in the frog area. Unsuitable geometry results in higher stress of turnout’s parts as well as especially unsuspended vehicle parts. An extensive research activity proved that increasing of vehicle dynamic effects in the course of passing over turnouts with unsuitable geometry is shown up to speed 160 km/h. Verification of turnout’s state in lower speed is not arguable, which is proved in ***fig. 15***. There are vehicle dynamic effects of locomotive class 263 in the course of passing over turnouts in the track section Brno – Břeclav in speed 120 km/h.

There is not shown higher dynamic effects at any turnout in the ***fig. 15*** with comparison with ***fig. 8***.

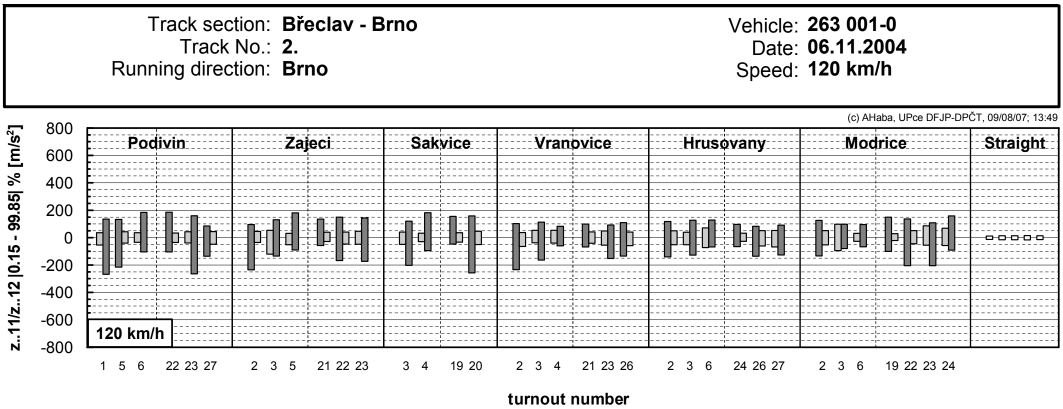


Fig. 15 *Dynamic effects of locomotive class 263 in the course of passing over turnouts in the track section Brno – Břeclav*

On that account there are two possible ways for monitoring of turnout's state with respect to vehicle dynamic effects. The first possibility means to use the measuring car for fixed traction equipment, which regularly twice a year monitors corridors tracks in maximum speed. The second possibility means to measure in the operation (It means the case of curved station's throats in the course of unit 680 running in higher speed with using tilting body system).

Reviewed by: doc. Ing. Jan Kout, CSc.; Ing. Vladimír Igielski

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Resumé

DYNAMICKÉ ÚČINKY VOZIDEL PŘI PRŮJEZDU VÝHYBEK V PŘÍMÉM SMĚRU

Jaromír ZELENKA, Aleš HÁBA, Martin KOHOUT

V příspěvku je prezentována metodika zjišťování dynamických účinků vozidla ve svislém a příčném směru při průjezdu výhybkou, která je založena na měření zrychlení na ložiskových skříních vozidla. Dynamické účinky jsou hodnoceny na základě statistických charakteristik vypočtených z naměřených hodnot zrychlení při průjezdu oblastí jazyku a srdcovky výhybky, které jsou graficky vyhodnocovány různými způsoby s ohledem na zjišťování příčin zvýšených dynamických účinků vozidla při průjezdu výhybkou. Dále jsou v příspěvku prezentovány výsledky zjišťování dynamických účinků jednotky řady 680 při průjezdu výhybek zvýšenou rychlostí ve vybraných úsecích koridorových tratí Českých drah, a. s. Měření byla realizována v letech 2004÷2006 v rámci vysokorychlostních zkoušek této jednotky a v rámci verifikace některých traťových úseků ČD, a. s. Hodnoceny jsou dynamické účinky ve svislém směru při průjezdu přímými výhybkami vysokou rychlostí (až 230 km/h) a dále dynamické účinky v příčném směru při průjezdu obloukovými výhybkami zvýšenou rychlostí (s vyšším nedostatkem převýšení) při naklápění vozidlové skříně.

Summary

RAILWAY VEHICLE DYNAMIC EFFECTS IN THE COURSE OF PASSING OVER TURNOUTS IN STRAIGTH DIRECTION

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There is projected a method of railway vehicle dynamic effects detection in vertical and lateral direction in the course of passing over a turnout in this contribution. The method is based on acceleration measuring on vehicle axle boxes. Dynamic effects are valuated on the basis of statistical characteristics computed from measured accelerate values in the course of passing over a turnout tongue and frog. They are graphically evaluated in different ways with respect to investigation of higher vehicle dynamic effects in the course of passing over a turnout in this contribution. There are results of unit class 680 dynamic effects in the course of passing over Czech Railways chosen corridor tracks turnouts in higher speed condition projected next in this contribution. The measurements were carried out in 2004÷2006 in terms of high-speed tests of the unit and in the terms of chosen ČD, a. s. track sections verification. There are dynamic effects in lateral direction in the course of passing over a straight turnouts in high speed condition (up to 230 kmph) and also dynamic effects in lateral direction in the course of passing over curved turnouts in higher speed condition (in higher cant deficiency condition) with tilting of vehicle body together evaluated.

Zusammenfassung

DYNAMISCHE EINWIRKUNG VON FAHRZEUGEN BEI WEICHENDURCHFAHRT IM GERADEN RICHTUNG (STAMMGLEIS)

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Im Artikel wird Versuchsmethodik zur Erkennung der dynamischen Einwirkung von Fahrzeugen in der Horizontal- und Vertikalrichtung bei der Weichendurchfahrt präsentiert. Diese Methodik ist auf Beschleunigungsmessungen auf Radsatzlagergehäuse aufgebaut. Dynamische Einwirkung wird auf Grund der statistischen Charakteristiken, die aus den gemessenen Daten der Beschleunigungen bei Zunge- und Herzstücküberfahrt ausgerechtet sind, qualifiziert. Grafische Präsentation wird im Hinblick auf vorausgesetzte Ursache bearbeitet. Im Artikel werden Ergebnisse

der dynamischen Einwirkung von Neigezug Reihe 680 bei Weichendurchfahrt mit erhöhter Geschwindigkeit auf ausgewählten Korridorstreckenabschnitten in der Tschechischen Republik, die in den Jahren 2004÷2006 bei Hochgeschwindigkeitszulassungsversuchen der Neigezüge und bei Verifizierung einigen Streckenabschnitten gemessen wurden, erwähnt. Es wird Einwirkung von Fahrzeugen in der Vertikalrichtung bei Durchfahrt durch gerade Weichen mit großer Geschwindigkeit (230 km/h) und Einwirkung in der Horizontalrichtung bei Durchfahrt durch Bogenweichen mit erhöhtem Überhöhungsfehlbetrag ausgewertet.