R E P U B L I C O F B U L G A R I A
NATIONAL AIR, MARITIME AND RAILWAY ACCIDENTS INVESTIGATION BOARD

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FINAL REPORT

from

Investigation of railway accident – derailment of direct freight train № 30610 between the stations Shivatchevo – Tvarditsa on 12.03.2021

2021

OBJECTIVE OF INVESTIGATION AND EXTENT OF RESPONSIBILITY

The National Air, Maritime and Railway Transport Accidents Investigation Board (NAMRTAIB), which is an independent body performs the investigation of serious accidents and incidents. The National Board is within the Council of Ministers (CM) of the Republic of Bulgaria, and aims to find the circumstances and causes that led to the accidents and incidents occurrence in order to improve the safety and to avoid such in future, without searching personal fault and responsibility.

The investigation is performed in accordance with the requirements of Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety, which is transposed into the Railway Transport Act (RTA), Ordinance No 59 dated 5.12.2006 on the rail transport safety management, and Ordinance No H-32 dated 19.09.2007 on the coordination of the activities and information exchange during the railway accidents and incidents investigation, as well as per Agreement dated 17.04.2018 on the interaction during investigation of accidents and incidents in the air, maritime and railway transport between the Prosecutor's Office of the Republic of Bulgaria, Ministry of Interior, and the Ministry of Transport, Information Technology and Communications. The Reports follow the requirements of Regulation (EU) 2020/572 of 24 April 2020 on the reporting structure for railway accident and incident investigation reports.

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ABBREVIATIONS, USED IN THE REPORT

ABS – Automatic Block System

ALS – Automatic Locomotive Signalling

BDZ PS Ltd. – "BDZ Passenger Services" Ltd.

BDZ-Cargo Ltd. – „BDZ-Cargo" Ltd.

MAS – Main air switch (depending on the context)

MAD – Main air duct (depending on the context)

SE NRIC – State Enterprise "National Railway Infrastructure Company"(railway infrastructure manager)

DFT – Direct freight train

RAEA – Railway Administration Executive Agency

ECM – Entity in Charge of Maintenance

RRI MH-68 – Route Relay Interlocking type MH-68

NAMRTAIB – National Air, Maritime, and Railway Transport Accidents Investigation Board (Independent Specialized National Investigation Body)

TF – Task Force

TOSARRT – Train Operation and Shunting Activity Rules in the Rail Transport

RITOR – Railway Infrastructure Technical Operation Rules

RRS – Rail Rolling Stock

LDP – BDZ-Cargo Ltd. Locomotive Depot Prescription

SMS – Safety Management System

TMIW – Technician-mechanic inspector of wagons

WIS – Wagon-inspection section

DCCM – Device for communications, connections and messages

MRTO – Management and reporting of train operation

RTA – Railway Transport Act

1. Summary

1.1. Brief Description of the Event.

On 12.03.2021 at 16:16 p.m. from Sliven station departs DFT № 30610, consisting of 17 full wagons, 68 axles, 1323 tons, towed by an electric locomotive № 46032 with a locomotive driver and an assistant locomotive driver. The train route is in the direction Sliven - Dabovo - Tulovo - Karlovo - Pirdop. At 16:54 p.m. the train passed Shivachevo station without stopping, the traffic manager on-duty monitored the passage of the train through the station and did not notice any irregularities on the rolling stock. Between the stations Shivachevo and Tvarditsa about km 257^{+160} the locomotive driver found a decrease in the pressure in the main air duct of the train, turned off the MAD of the locomotive and the train stopped at 17:04 p.m. After the inspection performed by the assistant locomotive driver, it was established that the 16th car in a row from the beginning of the train had derailed with the two wheel- sets of the first bogie (Fig. 1.1).

By order of the train dispatcher from 18:05p.m. on 12.03.2021 the operation (movement) between the stations Shivachevo and Tvarditsa was interrupted.

Train locomotive № 46032 towed тhe first fifteen wagons at 03:46 a.m. on 13.03.2021 in Tvarditsa station.

To lift the derailed wagon № 31525400845-3, SE NRIC sent an emergency vehicle "Iveco Magirus" from Stara Zagora station, and an emergency vehicle "Unimog" from Plovdiv station. The wagon was lifted at 06:00 a.m.

After carrying out rehabilitation works on the track at 17:36 p.m. on 25.03.2021, the train movement between Shivachevo and Tvarditsa stations was restored at a speed of 25 km/h.

As a result of the derailment, were caused significant damages to 3400 m of the railway infrastructure and damages to the derailed wagon.

1.2. Location and time of the event occurrence.

Fig. 1.1. Derailed the first bogie of wagon № 31525400845-3 along Shivatchevo – Tvarditsa interstation

The derailment of the wagon from DFT № 30610 occurred between the stations Shivatchevo and Tvarditsa at 17:04 p.m. on km 260^{+302}, where first occurred derailment to the left of the second wheelset, and subsequently of the first wheelset of the first bogie of 16th train wagon (fig. 1.2).

1.3. Factors, defining the event.

Fig. 1.2. Scheme of the accident – derailment of wagon № 31525400845-3 along Shivatchevo – Tvarditsa interstation on 12.03.2021.

As determining factor for the occurrence of the accident was established irregular (asymmetrical) loading of the derailed wagon with respect to its longitudinal axle (fig. 1.3).

Contributing factor to the occurrence of the accident is the combination of unfavourable factors - asymmetrical loading of the wagons and low speed of the train in the curve.

Fig. 1.3. Layout of the load in the wagon № 31525400845-3

1.4. Direct causes and consequences of the event.

The direct cause of the accident occurrence was the uneven distribution of the bulk load in the body shell of the wagon, which led to derailment of the second wheelset of the first bogie of the 16th train wagon, in the following sequence: raising the left wheel of the second wheelset on the left rail, collapse of the right wheel in the track gauge and subsequent collapse of the left wheel on the outer part of the rail.

1.5. Safety recommendation and addresses to which are directed.

Recommendation 1 proposes that SE NRIC and BDZ-Cargo Ltd. acquaint the interested staff with the content of this report.

Recommendation 2 proposes SE NRIC to organize periodic trainings in order to refresh the knowledge of the technical staff, track and structures controller, head of section on track and structure maintenance/joint RRS, technical manager of RRS group and transport construction technician regarding the requirements of "Instructions for construction and maintenance of the track and switches".

Recommendation 3 proposes that BDZ-Cargo Ltd. controls the process of loading the wagons when transporting bulk cargo.

2. Investigation

2.1. Decision for starting the investigation.

The decision to initiate an investigation of the accident has been taken with respect to the seriousness and its impact on the safety. The investigation aims to prevent this type of accidents, which in similar circumstances could lead to significant accidents.

2.2. Motives for the decision to initiate the investigation.

The Decision to initiate the investigation is based on art. 20, paragraph 2, (a) of Directive (EU) 2016/798, art. 115к, paragraph 1, item 2 of RTA, art. 76, par. 1, item 2 of Ordinance No 59 dated 5.12.2006, and by Order of the NAMRATIB for assignment of Commission for investigation of the railway accident.

2.3. Scope and restrictions of the investigation.

Within the scope of the investigation there were considered and analysed the violations of the regulations implemented by the entities (SE NRIC and BDZ-Cargo Ltd.) in the repair and maintenance of the railway infrastructure and in carrying out repairs of freight wagons and transport of bulk cargos in open wagons.

Given the realized damages, the investigation is focused on the circumstances that led to the causes for the derailment of a wagon loaded with bulk cargo from DFT № 30610 between Shivatchevo and Tvarditsa stations.

2.4. Competences of the persons, involved in the investigation.

The composition of the commission includes external independent experts - habilitated persons from the higher scientific circles and experts with free profession with qualification and professional orientation in fields of activity – railway infrastructure, and rail rolling stock.

2.5. Communication and consultations with the persons and entities, involved in the event.

During the investigation, the task force, which includes representatives of both entities, was consulted. The task force has collected all the books and samples, as well as the downloaded records from the recording device of locomotive No 46032. They were handed over to the Chair of the Investigation Commission within the NAMRTAIB. Interviews were conducted with the persons, directly involved in the accident. The entities were requested and then provided information on the rail track maintenance between Shivatchevo and Tvarditsa station and on the repair and maintenance of the derailed wagon and on the bulk cargo loading technology as well. Interviews were conducted with the safety authorities of both entities and the heads of BDZ-Cargo Ltd. railway undertaking.

2.6. Degree of cooperation from the participating entities.

During the investigation, the railway undertaking BDZ-Cargo Ltd. and the persons involved in the accident provided full cooperation to the Investigation Commission.

The representatives of SE NRIC in the Task force did not provide the necessary assistance during the investigation, and they took actions that were not coordinated with the Commission.

2.7. Methods and techniques of investigation and analysis.

After receiving a notification from SE NRIC at 17:30 p.m. on 12.03.2021 on the occurred accident, the member of the Management Board of NAMRTAIB with competence to investigate railway accidents analysed the information, notified the two entities SE NRIC and BDZ-Cargo Ltd. and departed for the place of accident with an external expert. Meetings and talks were held with representatives of the police investigative bodies from the Regional Directorate of the

Ministry of Interior - Tvarditsa in connection with the undertaking of an investigation by them and subsequent actions.

After the performed on-site inspections, a decision was made to undertake an investigation, of which the entities, involved in the accident were informed. The proposal of SE NRIC has been agreed that the first 15 non-derailed wagons with the train locomotive shall be towed to Tvarditsa station. The 16th derailed wagon and the non-derailed 17th wagon attached to it were left on place. The first interviews were conducted with the personnel involved in the accident on behalf of both entities. Initial inspections of the derailed wagon of the DFT № 30610 and the derailment area were performed, as well as of the damaged section in the Shivatchevo - Tvarditsa interstation. A comprehensive inspection of the damaged railway infrastructure along the interstation was carried out. There were required downloaded records from the locomotive's recording device in order to be decrypted.

On 13.03.2021 the manager of the railway infrastructure requested the station documentation and documents on the operational management of the movement of DFT № 30610 from Sliven station to the place of the train derailment, as well as the documents for repair and maintenance of the track between Shivatchevo and Tvarditsa stations. The railway company BDZ-Cargo Ltd. was required to provide the passport with the documentation for the repair and maintenance of the derailed wagon № 31 52 540 0845-3.

On 17.03.2021, the Investigation Commission departed to the Locomotive Depot Stara Zagora, where in the presence of representatives of the two entities and a representative of the company loaded the wagons at Sliven station, a statement of findings was prepared for the technical condition of the derailed wagon. Control measurements of the static load and load distribution on wheels and axles were performed. A visual inspection of the load distribution in the body-shell of the derailed wagon was performed.

The Investigation Commission analysed the data downloaded from the registration device of locomotive № 46032 for the speed of DFT № 30610 on 12.03.2021 from Karnobat station to the stopping point of the locomotive.

On 31.03.2021 the Investigation Commission received the collected documentation, submitted by the task force I-st category in TOSAMD- Plovdiv regarding the derailment of a wagon from the composition of DFT № 30610 on 12.03.2021.

On 14.04.2021 in RITS - Plovdiv the Investigation Commission received the collected documentation submitted by Task force III category on the subsequent re-derailment of the uninsured from self-propelling and released 16th and 17th wagons of DFT № 30610 and derailed again16th wagon in the interstation Shivachevo - Gavrailovo, around 07:00 a.m. on 13.03.2021

2.8. Difficulties faced during the investigation.

During the investigation, communication between the Investigation Commission and the representatives of the Railway Infrastructure Manager was not at the required level. The activities for the reconstruction of the railway infrastructure start after a written permission from the investigative structures for the specific case by the bodies of the pre-trial proceedings and the NAMRTAIB. The railway infrastructure manager did not respect the requirements of art. 89, para. 2, item 1 of Ordinance № 59 of 5.12.2006 on safety management in railway transport, in which the text is written - „when the investigation is carried out by NAMRTAIB, the head of the task force coordinates the recovery activities with the member of the management Council of NAMRTAIB with competence to investigate railway accidents".

2.9. Interaction with the judicial authorities.

In accordance with the Agreement on Interaction with the judicial authorities, following their inspections of the railway infrastructure and the derailed RRS, it was released from supervision and the Investigation Commission started its independent investigation.

2.10. Other important information for the investigation context.

After the detaching and towing the non-derailed wagons from the DFT № 30610, the derailed 16th wagon and non-derailed 17th wagon remain in place. The 16th wagon № 31525400845-3 is placed on the rail track. Upon arrival of the locomotive for towing the two wagons at Tvarditsa station, their self-movement in the direction of Shivatchevo station followed. The profile of the track follows downhill 14 ‰, due to which their speed increased significantly and followed by re-derailment of the 16th wagon № 31525400845-3 at km 271^{+050} in the interstation Shivatchevo - Gavrailovo. As a result of the wagon re-derailment, was destroyed rail track for 440 meters (Figs. 2.1 and 2.2).

Fig. 2.1. Point of rederailment of 16th wagon

Fig. 2.2. Rail track condition after the rederailment of the 16th wagon

3. Description of the event

3.1. Information on the event and the context.

3.1.1. Description of the event type.

On 12.03.2021, at 4:16 p.m., DFT № 30610 left Sliven station for Pirdop station. The train consists of 17 full wagons, 68 axles, 1323 tons, length 208 meters, total length with the locomotive 228 meters, towed by electric locomotive № 46032. The railway undertaking BDZ-Cargo Ltd. performs the transport of DFT № 30610.

The train passes without stopping at 16:34 p.m. through Gavrailovo station and at 16:54 p.m. through Shivatchevo station at a speed of 52 km/h. Between Shivatchevo and Tvarditsa stations the train moves at a speed of 58 km/h. The permissible speed is 60 km/h. At 16:58 p. m. the speed from 52 km/h gradually decreases to 37 km/h and thus passes 2100 m. In the interval 17:01 ÷ 17:04 p.m. the train moves at 37 km/h and passes 1900 m, after which the speed drops sharply to 0 km/h, due to a decrease in the pressure in the main air duct from 5 bar to 0 bar. The locomotive driver established the decrease of the pressure in the main air duct of the train, turned off the MAD of the locomotive and the train stopped at km 257^{+150} in the interstation Shivatchevo - Tvarditsa. An inspection was carried out by the assistant locomotive driver, who found derailment of the 16th wagon with the two wheel-sets of the first bogie of the wagon. The officials concerned have been informed.

During the movement of the train, the speed on the route from Sliven station to the place of derailment was observed and the operation was accident-free.

3.1.2. Date, punctual time and location of the event.

The derailment of DFT № 30610 occurred on 12.03.2021 at 5:04 p.m. during its movement at a speed of 37 km/h between Shivatchevo and Tvarditsa stations at km 260^{+302}. The train ran on the main railway line № 3: Iliyantsi - Karlovo - Tulovo - Dabovo - Zimnitsa - Karnobat - Komunari - Sindel - Varna ferry in the direction opposite to the increase in mileage, in the section from Karnobat station to Pirdop station (Fig. 3.1).

Fig. 3.1. Map of the movement direction of DFT № 30610

3.1.3. Description of the event location:

3.1.3.1. *Location of the occurred accident.*

Fig. 3.2. Route of movement of DFT № 30610

- Origin station of the train movement (insulated locomotive № 46032);
- Main stations on the train alignment;
- Station, from which the train departed with composition of wagons;
- End destination station for the train movement;
- Place, where the accident occurred;
- Track that the train passed;
- Track that the train did not succeed to pass.

The railway accident occurred between the stations Shivatchevo-Tvarditsa, the raise of the flange of the wagon left wheel on the rail crown occurred at km 260^{+302}, right round, circular curve with radius R=300 m, the track is in excavation with profile 13,7 ‰ in uphill. The stations Shivatchevo and Tvarditsa are located along main railway line № 3 in direction Karnobat –

Fig. 3.3. Booklet-train operation schedule on railway line № 3

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Zimnitsa – Tulovo – Karlovo – Pirdop. The railway line is conventional with movement speed to 130 km/h (fig. 3.2).

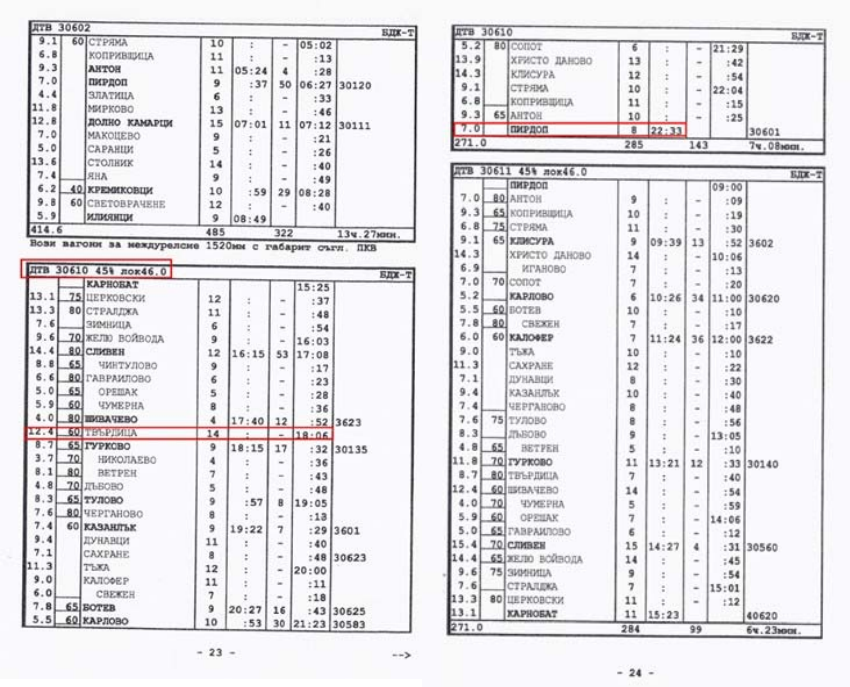


Fig. 3.4. Schedule of DFT № 30610

DFT № 30610 runs under schedule, displayed on figures 3.3 and 3.4.

3.1.3.2. Meteorological and geographical condition at the time of the event.

- in the daylight hours – 17:04 p.m.;
- air temperature +7ºc;
- wind speed 15 km/h;
- weather – cloudy – with normal visibility of the signals;

3.1.3.3. Performance of construction activities on the site or in vicinity.

In the period of the accident occurrence along Shivatchevo-Tvarditsa interstation, there were not performed any repair activities nor on the track neither on the structures.

3.1.4. Fatalities, injuries and material damages:

3.1.4.1. - Employees of the railway infrastructure manager or railway undertaking.

None.

3.1.4.2. Other persons officially connected with the location of the event.

None.

3.1.4.3. Passengers.

None.

3.1.4.4. External persons.

None.

3.1.4.5. Cargo, luggage or other property.

None.

3.1.4.6. Environment.

None.

3.1.4.7. Rolling stock.

Damages caused to the running gear of the derailed wagon № 31 52 5400845-3. Value account that the railway undertaking presented for the damages – 35 409,00 BGN.

3.1.4.8. Railway infrastructure.

Damages caused to the signalling that amount to 8 132,00 BGN.

Value of damages for 3400 m track as a result of the derailment amounting to 408 226,33 BGN in Tvarditsa – Shivatchevo interstation.

Value of damages for 440 meters track as a result of the re-derailment amounting to 324 181,50 BGN in Shivatchevo – Gavrailovo interstation.

Total costs: 740 539,83 BGN.

3.1.5. Description of other consequences, including the event impact on the usual activity of the participants

In the period 12.03 ÷ 25.03.2021 for rehabilitation of the railway infrastructure, the Manager of the railway infrastructure and the railway undertakings have generated additional expenses for modification of the train operation schedule

3.1.5.1. Railway infrastructure:

- Trains deviated from the alignment: 11 816,00 BGN.;
- Cancelled trains along the section: 19 720,00 BGN.;
- Assigned trains in the section: 2 177,00 BGN.;
- Costs for rehabilitation means: 4 259,00 BGN.;
- Total costs: 37 972,00 BGN.

3.1.5.2. *Delayed trains of the railway undertakings amounting to:* 8 885,00 BGN.

3.1.5.3. *Costs for the railway undertaking BDZ-Cargo Ltd.:* 1561,00 BGN.

3.1.6. Identity of the participants and their functions.

3.1.6.1. Railway infrastructure:

- SE National railway infrastructure company has Safety Authorization No № BG 21/2018/0001 valid from 01.07.2018 until 30.06.2023

SE NRIC personnel, involved in the accident:

- Traffic manager on duty in Tvarditsa station;
- Traffic manager on duty in Shivatchevo station;
- Head of Sliven railway section;

3.1.6.2. Railway undertaking:

- „BDZ-Cargo“ Ltd. has:
  - License for performing railway services No 203/31.12.2018;
  - Safety Certificate part A BG 11 2017 0008, valid until 30.12.2022;
  - Safety Certificate part B BG 12 2017 0008, valid until 30.12.2022;

BDZ-Cargo Ltd. personnel, involved in the accident:

- Engine driver, locomotive of locomotive № 46032 within Burgas locomotive depot;
- Assistant engine driver, locomotive of locomotive № 46032 within Burgas locomotive depot;
- Technician-mechanic inspector of wagons within WIS– Stara Zagora;
- Specialist document processing and control within RI – Stara Zagora as per the requirements of art. 82 of the RTA in Sliven departure station.

3.1.7. Description of the respective parts of the railway infrastructure and signalling system:

3.1.7.1. Type of the track, railway switch, rail crossing etc.

Single rail track in interstation, located in right round, circular curve in train movement direction with radius R=300 m.

3.1.7.2. Interstation block system, station installation, type of signalling.

The Shivatchevo – Tvarditsa interstation is equipped with automatic block system (ABS) without passing signals with axle counters.

3.1.7.3. Train protection systems.

Not applicable – There is no train protection system along Shivatchevo – Tvarditsa interstation. The stations Shivatchevo and Tvarditsa are equipped with train dispatching radio connection (TDRC), by which assistance the locomotive driver performs radio connection with train dispatcher, with single stations, with the trains along the respective section. The incoming and outgoing messages are performed by Device for communications, connections and messages (DCCM-8).

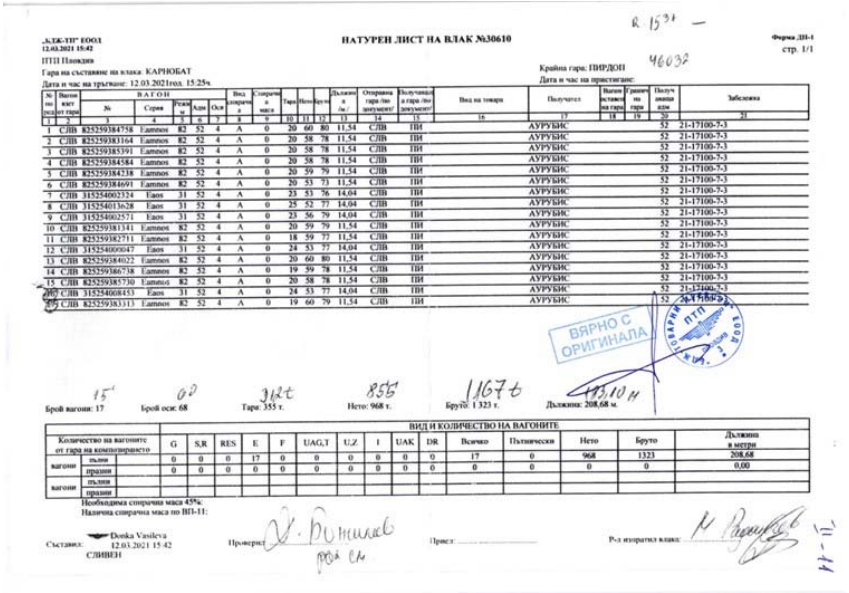
Locomotive № 46032 is equipped with warning device active type, registering speedometer type „Hasler“ RT9 and non-registering speedometer type „Hasler“ A16.

3.1.8. Other information referring the event.

The train documents „Way-bill“, „Nature sheet“ and „Authorization for brake mass“ (fig. 3.5, 3.6, 3.7) correspond to the hours of the actual movement of DFT № 30610 according to the data presented by ROVR and the speedometer tape of the locomotive.

Fig. 3.5. Way-bill of locomotive 46032

3.2. *Factual description of the occurred.*



НАТУРЕН ЛИСТ НА ВЛАК №30610

Fig. 3.6. Nature sheet of DFT № 30610

„БДЖ - Товарни превози" ЕООД

УДОСТОВЕРЕНИЕ ЗА СПИРАЧНАТА МАСА

Гара Сливен

Дата 12. 03 2021 г.

Влак № 30610

Маса на влака 1323 t

Спирачен процент 45 %

Необходима спирачна маса 596 t

	ABC* Спирачна маса, t	Оси, бр.	PC** Спирачна маса, t	Оси, бр.	Забележка
Начална/Остана маса/оси	728	56			
Допълнителна маса/оси					
Всичко: налична спир. маса/оси	728	56			

Неплътност на локомотива 0,0 bar/min

Неплътност на влака 0,2 bar/min (bar/0,5 min)

Влака натегнат/ненатегнат

Дежурен ръков. движение

Извършил пробата на спирачките

Атанас Славов Атанасов Т.М.Р.В. ВПД - Любеново пр.

Забележки: Ненужното се зачерква
* Автоматична влакова
** Ръчна спирачка

№ на вагона	Спир. маса	№ на вагона	Спир. маса

Fig. 3.7. Brake-mass Authorization of DFT № 30610

3.2.1. Immediate sequence of events that led to the accident, including:

3.2.1.1. Actions that the involved in the event persons undertook.

DFT № 30610 passed through Shivatchevo station at 16:54 p.m. without stopping. The traffic manager on duty monitored the passage of the train through the station and did not notice any damage to the rolling stock. Around 17:02 p. m. the train was running at a speed of about 37 km/h. At that moment the pressure in the main air duct decreased from 5 bar to 0 bar, the speed dropped sharply to 0 km/h, and the train stopped at the Shivatchevo - Tvarditsa interstation at 17:04 p.m.

After the train stopping, the locomotive driver ordered the assistant locomotive driver to inspect the train, which found that the 16th wagon of the train derailed with the two wheel-sets of the first bogie.

3.2.1.2. Rolling stock and technical facilities functioning.

The rolling stock has been regular with proper function until the moment of the accident.

The track along Shivatchevo – Tvarditsa interstation was in proper condition at the time of the derailment.

3.2.1.3. Operational system functioning.

The operational system is regular with proper functions.

3.2.2. Sequence of events from the beginning of the accident to the end of the rescue services actions:

At 17:04 p. m. derailed wagon № 31525400845-3 from the composition of DFT № 30610 while running along Shivatchevo – Tvarditsa interstation at km 260^{+302};

3.2.2.1. Undertaken measures for protecting and guarding the event location.

There have not been undertaken any.

3.2.2.2. *Actions of the emergency rescue services.*

No actions from the emergency rescue services were required/necessary.

3.2.2.3. Actions of the emergency rehabilitation services.

- The train operation along Tvarditsa – Shivatchevo interstation was interrupted from 12.03.2021 to 25.03.2021.
- The first fifteen wagons from the composition of DFT ДТВ № 30610 were towed in Tvarditsa station by the train locomotive № 46032 at 03:46 a.m. on 13.03.2021.
- The railway infrastructure manager sent rehabilitation means from Stara Zagora and Plovdiv stations to lift the derailed wagon № 31525400845-3.
- Wagon № 31525400845-3 was lifted on 13.03.2021 at 06:45 a.m.
- At 13:39 p. m. DFT № 30610 with train locomotive № 43551 departed from Tvarditsa station on its route to Pirdop station.
- The train operation was restored on 25.03.2021 at 17:36 p.m. with speed 25 km/h from kilometer 257^{+250} to kilometer 260^{+650} with 3400 meters length.

4. Analysis of the event

4.1. Participation and responsibilities of the entities, involved in the event:

4.1.1. Railway undertaking.

Locomotive № 46032 performs its first movements in Karnobat locomotive depot at 14:11 p. m. with speed to 10 km/h, and then it increased to 20 km/h, and after another several shunting movements to 20 km/h and at 14:25 p.m. it is placed on station track in Karnobat Western District station (fig. 4.1, pos. 1). After stopping for one minute, it departed at 14:26 p.m. from Karnobat

Fig. 4.1. Registration of movement of locomotive № 46032 (as DFT № 30610) from Karnobat to Zimnitsa station.

Western District station, and develops 22 km/h, then decreases to 12 km/h, passes through the exit switches of Karnobat station, and then increases to 70 km/h. So, moving at a speed of up to 77-78 km/h, the

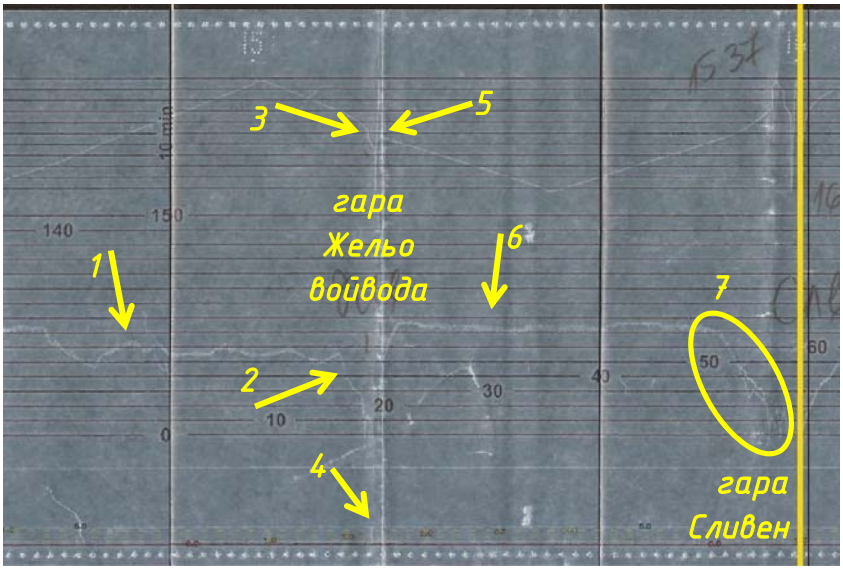


Fig. 4.2. Registration of movement of locomotive № 46032 (as DFT 30610) from Zimnitsa to Sliven station.

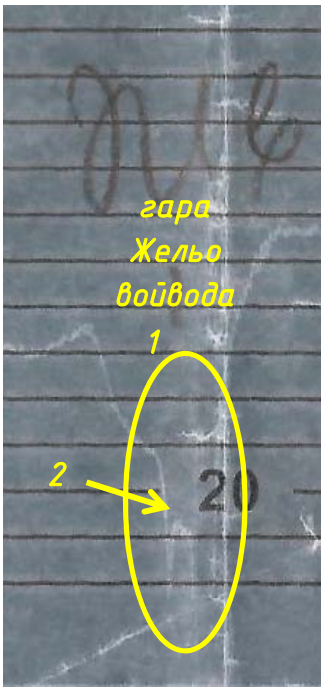


Fig. 4.3

locomotive passess 31,7 km, where at 14:52 p.m. the speed of 73 km/h starts to decrease smoothly and after 1800 meters at 14:54 p.m. reaches 47 km/h (fig. 4.1, pos. 2). The place corresponds to Zimnitsa station.

Then the speed starts to increase again to 64 km/h (Fig. 4.2, pos. 1). It changes smoothly between 64 km/h and 50 km/h, and thus the locomotive moves to Zhelyo Voyvoda station. After passing 8900 meters at 15:03 p.m., the speed is 56 km/h and begins to decrease - initially at a faster pace to reach a value of 40 km/h, after which the rate of descent becomes slower and reaches 28 km/h it intensifies again until the complete stop of the locomotive at Zhelyo Voyvoda station at 15:04p. m. (Fig. 4.2, pos. 2). Apparently, the locomotive driver initially held the locomotive with the direct brake of the locomotive until it reaches a speed of 40 km/h, then he loosenes it, the reduction continues due to the natural resistance in its movement and when it reaches 28 km/h, it holds it again until it reaches 0 km/h. After the locomotive stopping at 15:05 p.m., there is a stop for about 30 seconds (Fig. 4.2, pos. 3). A departure follows, in which the locomotive develops 11-12 km/h, travels about 300 meters and stops again at 15:06 p.m., this time it stays until 15:25 p.m. for 21 minutes (Fig. 4.3, items 1 and 2). During the second stop at Zhelyo Voyvoda station, a pressure drop of up to 0 bar is noted in the area of pressure registration in the main air duct, which means that most likely the locomotive driver checked the registration of the speedometer by opening its cover (fig. 4.2, item 4).

At 15:26 p. m. locomotive № 46032 departs from Zhelyo Voivoda station and develops a speed between 78 and 70 km/h (Fig. 4.2, items 5 and 6). At this speed, the locomotive travels 12.2 km. At 15:34 p. m. the speed of 71 km/h began to decrease gradually, after 1250 meters it reaches 25 km/h, then briefly increases to 31 km/h, it decreases again to 0 km/h after 700 meters and at 15:37 p.m. it is established at Sliven station (Fig. 4.2, pos. 7). During its movement from Karnobat station to Sliven station the locomotive driver observes the section speeds and the reductions on the track.

At Sliven station, 17 full open wagons with a total mass of 1323 tons, length 208 meters with 68 axles are attached to the locomotive. During its stay at Sliven station the locomotive makes several shunting movements up to 18 km/h.

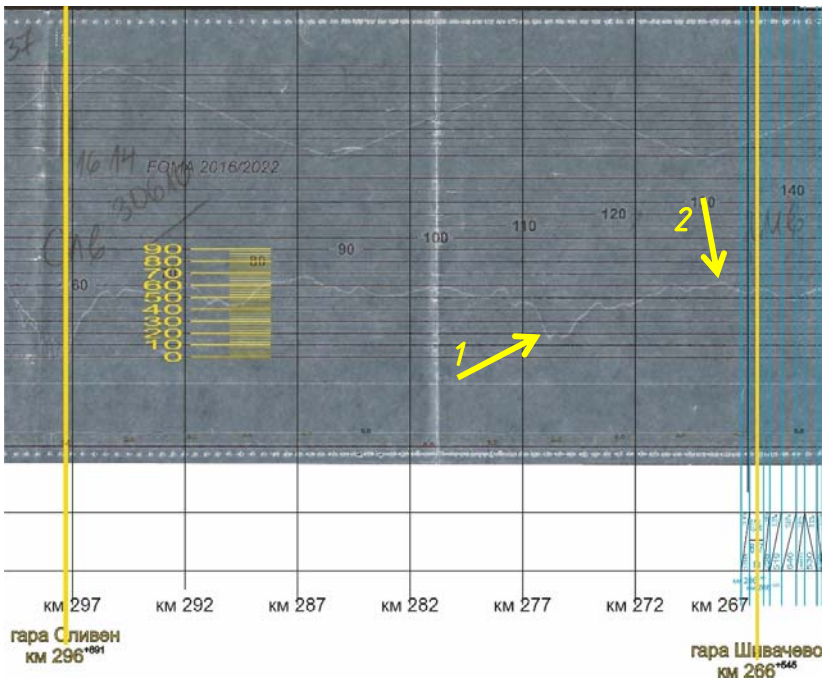


Fig. 4.4. Registering the movement of DFT 30610 from Sliven station to Shivatchevo station.

DFT № 30610 led by locomotive № 46032 departs from Sliven station at 16:14 p.m. (speedometer time). The speed varies between 42 and 78 km/h and thus the train travels 21.4 km (Fig. 4.4). At this point (Fig. 4.4, pos. 1) at 16:40 p.m. the speed decreases to 16 km/h and for 1000 meters in 2.5 minutes it changes between 16 and 22 km/h. After passing this section, the speed increases, and its maximum value reaches 63 km/h (Fig. 4.4, pos. 2).

At 16:57 p. m. DFT № 30610 passes without stopping Shivatchevo station at a speed of 57 km/h (Fig. 4.5, pos. 1).

After passing Shivatchevo station the speed of DFT № 30610 changes between 57 and 49 km/h (Fig. 4.5, pos. 2). The speed varies within such wide limits due to the diverse profile of the track along the section. In this mode, the train travels 5950 meters. This happens at 4:58 p.m. The speed is 50 km/h and from that moment, it starts to decrease gradually, passing 2000 meters, reaching 38 km/h (Fig. 4.5, pos. 3). The decrease in speed is due to the movement of the train in uphill 13 ‰. From km 257^{+000} the speed of the train is set at a constant value of 37 km/h until the moment of derailment.

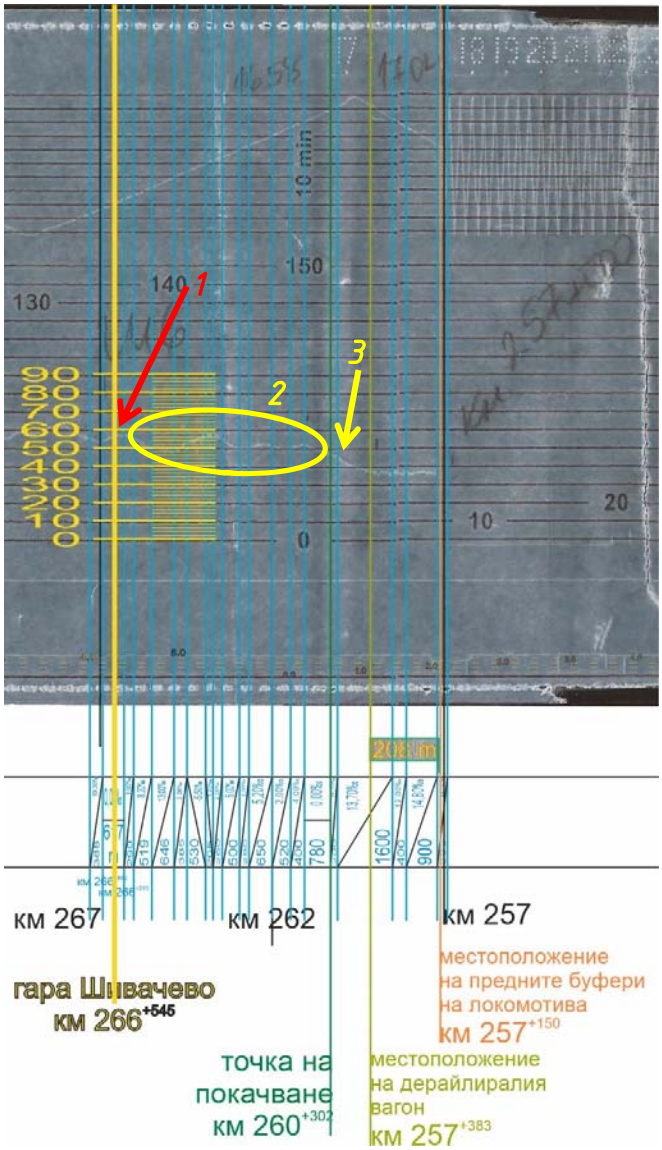


Fig. 4.5. Registration of movement of DFT 30610 from Shivatchevo station to km 257^{+150}.

At 17:03, when the locomotive is located at km 257^{+450}, the pressure in the main air duct begins to decrease (Fig. 4.6, pos. 1). The reduction of the pressure in the main air duct is due to the splitting of the train because of the derailment of wagon № 31525400845-3. After another 200 meters, the speed of the train decreases to 0 km/h, and the train stops (Fig. 4.6, pos. 2). The front buffers of the locomotive are located at km 257^{+150}, and the derailed wagon - at km 257^{+383}.

4.1.2. *Railway infrastructure manager.*

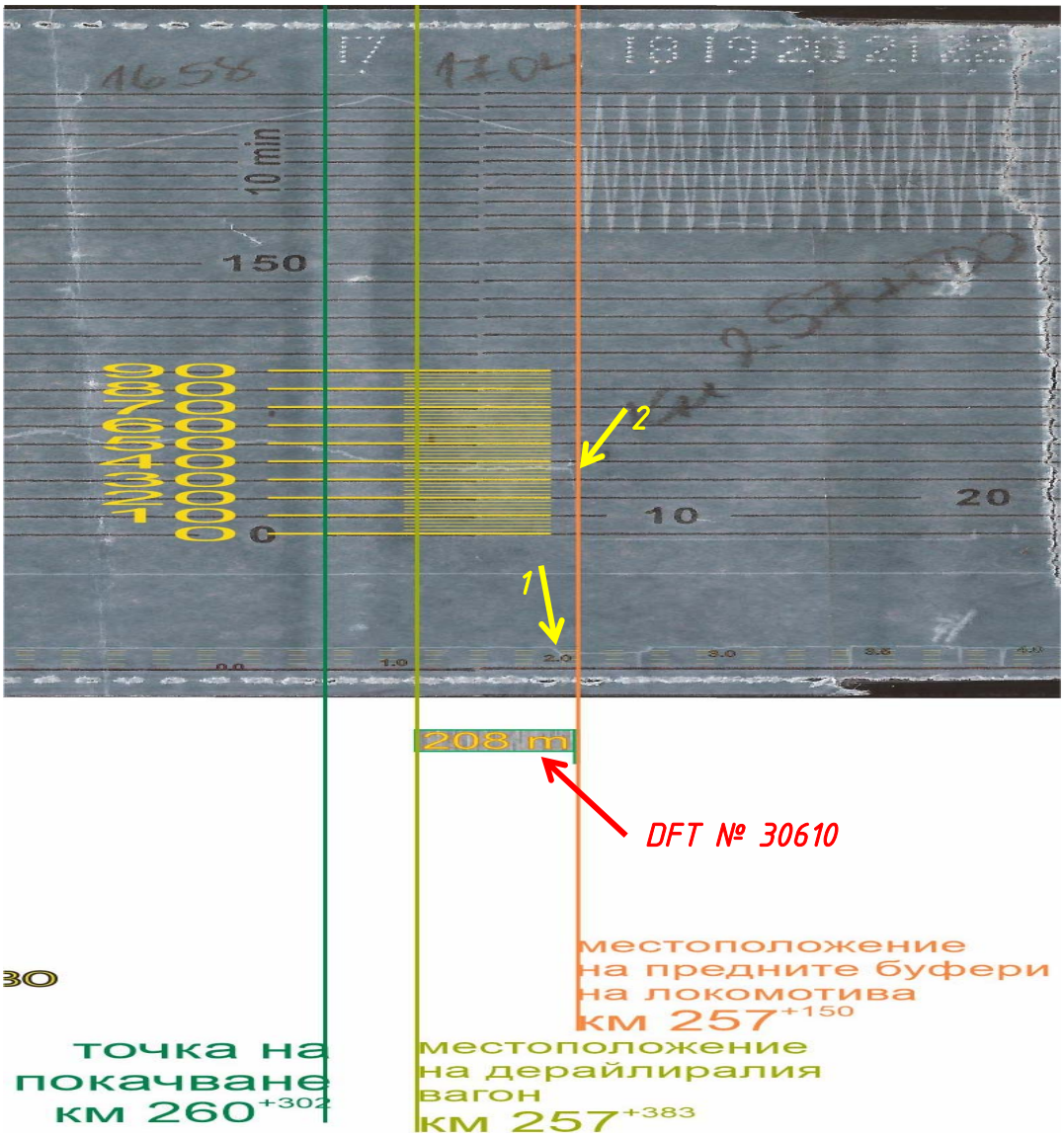


Fig. 4.6. Registration of movement of locomotive of DFT 30610 from Shivatchevo station to km 257^{+150}.

To clarify the causes of the accident, it is necessary to make a full analysis of the technical condition of the rail track, as well as the technical condition of the wagon and its load. Also an analysis of the speed of the train. The movement was in an uphill slope of 11.7 ‰.

The good interaction between the wheels of the rolling stock and the rails of the track is a guarantee for the safe movement of the trains.

4.1.2.1. *Analysis on the rail track condition in the round, circular curve, in and around the point of raise and derailment of the 16th wagon from the train composition.*

The accident occurred in a round, circular curve with a radius of 300 meters. The rails are type 49 with a length of 25 meters. They are connected to each other in the joints with steel connections with four adjusting bolts in order to prevent vertical and horizontal divergence of the rails between them. In a unit with a length of 25 meters, there are 40 reinforced concrete sleepers

and a double joint wooden sleeper, which serves as a support in the joints. The fastening is elastic SKL-14.

In order to make a complete description of the rail track, it is necessary to determine all its parameters, namely:

4.1.2.2. Analysis of the rail track on level

Transverse level of the track at minimum of 20 meters before and 20 meters, after the point of ascent of the left wheel from the second wheel-set on the 16th wagon of the first bogie on the head of the left outer rail, movement of the flange on the same and collapse of the wheel from the outer side of the rail (to the left). To compensate the lateral accelerations and uniformity of the load of the two rail threads in the rail curves, cants are given to guarantee safe speeds of up to 120 km/h.

$$\boldsymbol{H}_{\text{н}} = \frac{8\boldsymbol{V}_{\boldsymbol{max}}^{2}}{\boldsymbol{R}} = \frac{8.75^{2}}{300} = 150\ \boldsymbol{mm}$$

Within this cant the lateral acceleration is as follows:

Within cant of approximately 140 mm;

Within speed 60 km/h and cant H = 140 mm;

The speed for the passenger trains is 75 km/h, and the speed for freight trains is 60 km/h for the interstation Tvarditsa – Shivatchevo, as per the „Technical parameters and standards".

The minimum permissible cant is the cant, where the passengers travelling comfort is respected, and it is calculated under the formula:

For $\boldsymbol{V_{max}}$ = 75 km/h:

$$\boldsymbol{H_{min}} = 11{,}8\frac{\boldsymbol{V}_{\boldsymbol{max}}^{2}}{\boldsymbol{R}} - 100 = 125\ \boldsymbol{mm}$$

For $\boldsymbol{V_{max}}$ = 60 km/h:

From all calculations, it is evident that at the minimum cant it is favorable for the movement of trains up to a value of 0,65 m/s^2 for passenger and up to 0,85 m/s^2 for freight trains.

The generally accepted rule is the cant in the curves to be given for the higher movement speed.

The cant transitions based on the wheelbase in a bogie and between the center bolts are as follows:

Calculated transitions based on wheelbase of the bogie - 1800 mm:

- Before increase:
  - Point 0: H = 128 mm; point 2: H = 130 mm; $H_0 - H_2 = 2$ mm;

$$\boldsymbol{K} = \frac{\boldsymbol{L}}{\boldsymbol{H}} = \frac{1800}{2} = 900 \rightarrow \boldsymbol{inclination}\text{: } 1\text{: } 900\ \boldsymbol{mm}$$

- After increase:
  - Point 0: H = 128 mm; point -2: H = 130 mm; $H_0 - H_2 = 2$ mm;

$$\boldsymbol{K} = \frac{\boldsymbol{L}}{\boldsymbol{H}} = \frac{1800}{2} = 900 \rightarrow \boldsymbol{inclination}\text{: } 1\text{: } 900\ \boldsymbol{mm}$$

Calculated transitions based on central bearings – 9000 mm:

- Before increase:
  - Point 0: H = 128 mm; point 9: H = 148 mm; $H_0 - H_2 = 20$ mm;

$$\boldsymbol{K = \frac{L}{H} = \frac{9000}{20} = 450 \rightarrow inclination: 1:450\ mm}$$

- After increase:
  - Point 0: H = 128 mm; point -9: H = 144 mm; $H_0 - H_2 = 16$ mm;

$$\boldsymbol{K = \frac{L}{H} = \frac{9000}{16} = 562 \rightarrow inclination: 1:562\ mm}$$

From the measured values of the level in a total of 21 points from +20 to 0, an arithmetic mean cant in the curve of 143 mm is obtained. On this basis, the measured values for the level of the trak, reaching up to 155 mm and a minimum value of 128 mm in the zero point with a difference of 27 mm, meet the requirements of ± 15 mm for speeds up to 60 km/h. It is also evident that the inclinations of the transitions are within the permissible norms - greater than 1: 400. The cited cant in the Statement of Findings on the condition of the rail track of 125 mm is the minimum permissible for a curve with a radius of 300 m and a maximum speed of V = 75 km / h. The specified value of 125 mm is for the minimum limit for a curve with a radius of 300 m and for the same speed.

The requirements of item 3.2.4.10 are met. (Permissible tolerances in the cant) from the "Instruction for current maintenance of the rail track and switches".

Due to the lift of rail track for its renewal, the railway infrastructure manager did not allow

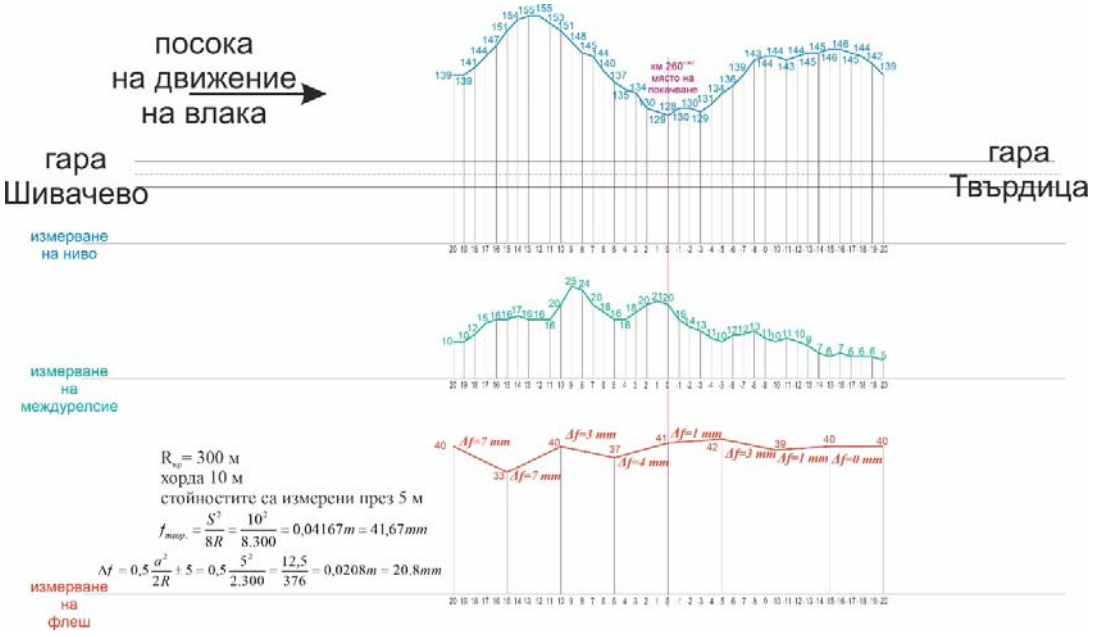


Fig. 4.7. ДDiagrams of the values of separate track parameters along Shivatchevo-Tvarditsa interstation, measured on 12.03.2021.

the task force to perform measurements for hidden failures/twists of the rail track in the area of derailment of the wagon; therefore, no records of measured hidden failures/twists are reflected in the Statement of findings (Fig. 4.7, Diagram of rail track measurement under level).

4.1.2.3. Analysis of the rail track under rail gauge.

From the measured values of this parameter, registered in the Statement of Findings for the condition of the rail track, it is evident that the maximum registered track gauge is at point № 9 with a value of 1460 mm and does not violate the requirements described in the “Instructions

for construction and maintenance of the rail track and switches superstructure.“, where the maximum permissible track gauge is 1465 mm for first and second class railway lines (Fig. 4.7, Diagram of track measurement under rail gauge).

4.1.2.4. Analysis of the rail track in plan (under axis).

The position of the rail track in plan is controlled by the alignment differences. As the curve is with radius R=300 m, for the alignment measurement has been used a chord with lenght S = 10 m and measured alignments at 5 m.

The theorethical alignment is defined under the formula:

$$\boldsymbol{f}_{\text{T}} = \frac{\boldsymbol{S}^2}{8\boldsymbol{R}} = \frac{10^2}{8.300} \approx 42\ \boldsymbol{mm}$$

The difference in the alignment in two neighbouring points for the round circular curve is defined under the formula:

$$\Delta\boldsymbol{f} = (\boldsymbol{f}_1 - \boldsymbol{f}_2) - \boldsymbol{absolute\ value}$$

In the case the higher difference is 7 mm between point 20 and point 15 within permissible 15 mm for speed from 60 to 80 km/h, and 24 mm for speed 60 km/h, as per Table 4.11 of the Instruction. (Fig. 4.7, Diagram of track measurement under axis).

4.1.2.5. Analysis of the rail fatigue – outer left to the train direction.

According to the Statement of Findings for measuring the rail track, the maximum vertical wear is 0 mm and the maximum lateral wear is 6 mm at points 19, 11 (-1) with a permissible 13.5 mm according to the Instruction.

The sleepers gird is made of reinforced concrete sleepers with elastic fastening SKL-14. Longitudinal cracks up to 1 mm width and without transverse cracks can be seen on individual sleepers (not in groups).

The ballast prism is full size. Before and in the derailment zone, a process of "hardening" is observed. A more advanced phase of pollution is observed from km 260^{+250} to 260^{+100}, and in some places manual cleaning and tamping has been performed. Control over the condition of the rail track was performed as follows:

- On 02.03.2021 control rail track measurements have been performed;
- On 10.03.2021 from the last coach of passenger train has been performed an inspection from Tulovo to Sliven station with the following findings:
  - Slight variations around km 260^{+250};
  - Individual ballast prism hardening at km 260^{+250} and 260^{+350};
- On 12.03.2021 was worked on the ballast prism cleaning/sifting and repair of the level at km 260^{+250};
- On 12.03.2021 the track was measured by Track measuring laboratory EM-120 in loaded condition with the following findings:
  - At km 260^{+217}, 260^{+286} and 260^{+293} rail gauge +24 mm;
  - At km 260^{+347} twist based on 3,2 m;

The irregularities have been eliminated and are outside the place of the accident.

The rail track was renewed in 1995.

Medium repair, including sifting and tamping with TM in 2016.

4.1.3. *Entities in charge of the technical maintenance.*

Not applicable.

4.1.4. Manufacturers or providers of rolling stock and railway products.

Not applicable.

4.1.5. National Safety Authority.

Railway Administration Executive Agency is the National Safety Authority for railway transport in the Republic of Bulgaria.

4.1.6. Notified bodies or Risk assessment bodies.

Not applicable.

4.1.7. Certifying bodies of the entities in charge of maintenance.

The Railway Administration Executive Agency as the National Safety Authority for railway transport performs certification of the entities in charge of the vehicles maintenance (ECM) in accordance with Directive 2004/49/EC and Regulation (EU) 445/2011, as per Ordinance No 59 on the railway transport safety management and on the maintenance functions in accordance with Directive 2004/49/EC and Regulation (EU) 445/2011.

From June 16, 2020 the RAEA performs certification of the ECM as per the Commission Implementing Regulation (EU) 2019/779 of 16 May 2019 laying down detailed provisions on a system of certification of entities in charge of maintenance of vehicles pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulation (EU) No 445/2011

4.1.8. Persons or entities involved in the event, documented or not in the respective safety management systems or indicated in register.

Not applicable.

4.2. Rolling stock and technical facilities:

4.2.1. Factors, deriving from the design of the rolling stock, railway infrastructure or technical facilities.

Not applicable.

4.2.2. Factors deriving from the installation and placing into service of the rolling stock, railway infrastructure and technical facilities.

Not applicable.

4.2.3. Factors deriving from manufacturers or another provider of railway products.

Not applicable.

4.2.4. Factors, deriving from the technical maintenance and/or modification of the rolling stock or the technical facilities.

Not applicable.

4.2.5. Factors due to the entity in charge of the technical maintenance, workshops for technical maintenance and other technical maintenance service providers.

Not applicable.

4.2.6. Other factors or consequences considered as involved within the investigation objectives.

4.2.6.1. Loading of the wagons.

Uneven loading of wagon № 31525400845-3, 16th in a row in the composition of DFT № 30610, with mobile scales on wheels and axles, was found, which led to displacement of the mass center of the wagon. Therefore, the load is unevenly distributed on the individual wheels and axles, i. e. the left wheels in the direction of travel are less loaded than the right ones. This caused the left wheel to rise on the outer left rail.

4.3. Human factor:

4.3.1. Individual human characteristics:

4.3.1.1. Training and development, including skills and experience.

Railway undertaking:

Locomotive driver – License No 17209 for obtaining professional qualification „Locomotive driver", training performed within the period 03.02÷14.10.2014, issued by Professional Training Center (PTC) of Bulgarian State Railways (BDZ);

Locomotive driving license BG 71 2017 1337 issued by RAEA;

License № 603 of position Locomotive driver at Cargo Division – Plovidv from 20.10.2017

Assistant locomotive driver – License No 4576 for obtaining professional qualification „Assistant locomotive driver", training performed within the period 19.06. ÷13.09.2006, issued by Professional Training Center (PTC) of Bulgarian State Railways (BDZ);

License № 756 of position Assistant locomotive driver at Cargo Division – Plovidv from 20.01.2019.

Technician-mechanic inspector of wagons – License No 15521 for obtaining professional qualification, Inspector of wagons", training performed within the period 01.04. ÷ 15.07.2013, issued by Professional Training Center (PTC) of Bulgarian State Railways (BDZ).

License № 167 of position Technician-mechanic inspector of wagons at Cargo Division – Plovidv from 10.03.2014.

Railway infrastructure:

Traffic manager in Tvarditsa station – Certificate of qualification № 7473 for „Traffic manager", training performed within the period 02.04.÷17.10.2007, issued by the Professional Training Center at NRIC;

Certificate № 1879 for position Traffic manager at TOSAD – Plovdiv from 22.12.2008.

Traffic manager in Shivatchevo station – Certificate of qualification № 8999 for „Traffic manager and TE", training performed within the period 06.01.÷05.12.1986, issued by ST BDZ;

Certificate № 1750 for position Traffic manager at TOSAD – Plovdiv from 23.10.2007.

Head of rail track section Sliven – Certificate of qualification № 051904 for „Head of group",training performed within the period 12.04.÷02.09.1999, issued by Professional Training Center within Second railway section – Sofia.

Certificate № 161 for position Head of section within Burgas railway section from 14.02.2018.

4.3.1.2. Medical and personal circumstances, which influence the event, including the presence of physical and psychological stress.

Railway undertaking:

Locomotive driver:

Medical exam card dated 19.02.2020, issued by Plovdiv Multi-profile Transport Hospital– conclusion: suitable for locomotive driver.

Physiological exam No 1008/11.09.2017, issued by Laboratory for physiological expertise at Plovdiv Multi-profile Transport Hospital for locomotive driver. Conclusion: accepted for a 5-year period.

Assistant locomotive driver:

Medical exam card dated 26.02.2020, issued by Plovdiv Multi-profile Transport Hospital:

Conclusion: suitable for assistant locomotive driver.

Physiological exam No 129/04.02.2019 issued by Laboratory for physiological expertise at Plovdiv Multi-profile Transport Hospital for assistant locomotive driver.

Conclusion: accepted for a 3-year period.

Railway infrastructure:

Traffic manager in Tvarditsa station:

Medical obligatory periodical exam card dated 03.06.2020, issued by Plovdiv Multi-profile Transport Hospital, conclusion – suitable.

Physiological exam № 294/21.03.2017, issued by Laboratory for physiological expertise at Plovdiv Multi-profile Transport Hospital for traffic manager.

Conclusion: accepted for a 5-year period.

Traffic manager in Shivatchevo station:

Medical obligatory periodical exam card dated 09.06.2020, issued by Plovdiv Multi-profile Transport Hospital, conclusion – suitable.

Physiological exam № 128/13.11.2018, issued by Laboratory for physiological expertise at Plovdiv Multi-profile Transport Hospital for traffic manager.

Conclusion: accepted for a 3-year period.

Head of Sliven track section:

Medical obligatory periodical exam card dated 05.10.2020, issued by Plovdiv Multi-profile Transport Hospital, conclusion – suitable.

4.3.1.3. Fatigue.

Railway undertaking:

Locomotive driver:

Break/rest: from 00:50 a.m. on 11.03.2021 to 14:10 p.m. on 12.03.2021 (37 hours and 20 minutes);

Assistant locomotive driver:

Break/rest: from 01:30 a.m. on 11.03.2021 to 14:10 p.m. on 12.03.2021 (37 hours and 50 minutes);

Technician mechanic inspector of wagons:

Break/rest: from 19:00 p.m. on 09.03.2021 to 07:00 a.m. on 12.03.2021 (60 hours and 00 minutes);

Railway infrastructure:

Traffic manager in Tvarditsa station:

Break/rest: from 07:00 a.m. on 07.03.2021 to 07:00 a.m. on 12.03.2021 (120 hours and 00 minutes);

Traffic manager in Shivatchevo station:

Break/rest: from 18:30 p.m. on 11.03.2021 to 06:50 a.m. on 12.03.2021 (12 hours and 20 minutes);

Head of Sliven track section:

Full working time 40 hours a week.

4.3.1.4. Motivation and attitudes.

Not applicable.

4.3.2. Work related factors:

4.3.2.1. Tasks planning.

"BDZ-Cargo"Ltd. performs the traffic under a Plan for train composition and they are carried out as per the Train Operation Schedule.

4.3.2.2. Constructive particularities of the facilities that influence the connection human-machine.

Not applicable.

4.3.2.3. Communication means.

Not applicable.

4.3.2.4. Practices and processes.

Not applicable.

4.3.2.5. Operation rules, local instructions, staff requirements, prescriptions for technical maintenance and applicable standards.

Application of the national normative acts and internal standards.

4.3.2.6. Working time of the involved personnel.

In accordance with the requirements of the normative acts - Labour Code and Ordinance № 50 of 28.12.2001 for the working hours of the managerial and executive staff, engaged in providing the transportation of passengers and freights in the railway transport. The staff of both entities works in shifts/suspension (when servicing a train or a vehicle - with a variable start and different working hours), in which a summary calculation of the working time shift in a 12-hour work shift and full working week are applied.

4.3.2.7. *Risk treatment practices.*

SE NRIC applies safety procedure SP 2.09 „Methods of evaluation, assessment and management of the risk „version 05 effective from 01.03.2019, which is part of the SMS.

BDZ-Cargo Ltd. Applies a procedure „Methods of analysis and assessment of the risk within BDZ-Cargo Ltd" effective from 2013 as part of the SMS.

4.3.2.8. Context, machinery, equipment and indications for shaping the working practices.

Not applicable.

4.3.3. Organizational factors and tasks:

4.3.3.1. Planning of the working force and the working load.

As per the requirements of the normative documents and best practices.

4.3.3.2. Communications, information and teamwork.

Not applicable.

4.3.3.3. Recruitment, staffing requirements, resources.

Not applicable.

4.3.3.4. Implementation management and supervision.

Not applicable.

4.3.3.5. Compensation (remuneration).

Not applicable.

4.3.3.6. Leadership, powers related issues.

Not applicable.

4.3.3.7. Organizational culture.

Not applicable.

4.3.3.8. Legal issues (including the respective European and national rules and provisions).

The requirements of Art. 89, para. 2, item 1 of Ordinance № 59 of 5.12.2006 for safety management in the railway transport by the manager of the railway infrastructure before the completion of the work of the Investigation Commission are not met.

4.3.3.9. Regulatory framework conditions and safety management system application.

Railway undertaking.

- Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety;
- Commission Delegated Regulation (EU) 2018/762 of 8 March 2018 establishing common safety methods on safety management system requirements pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulations (EU) No 1158/2010 and (EU) No 1169/2010;

- COMMISSION IMPLEMENTING REGULATION (EU) 2019/779 of 16 May 2019 laying down detailed provisions on a system of certification of entities in charge of maintenance of vehicles pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulation (EU) No 445/2011;
- COMMISSION IMPLEMENTING REGULATION (EU) No 402/2013 of 30 April 2013 on the common safety method for risk evaluation and assessment and repealing Regulation (EC) No 352/2009;
- Railway Transport Act;
- ORDINANCE No 59 dated 5.12.2006 on the railway transport safety management;
- TOR and TOSAR.

Railway infrastructure.

- Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety;
- Commission Delegated Regulation (EU) 2018/762 of 8 March 2018 establishing common safety methods on safety management system requirements pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulations (EU) No 1158/2010 and (EU) No 1169/2010;
- COMMISSION IMPLEMENTING REGULATION (EU) 2019/779 of 16 May 2019 laying down detailed provisions on a system of certification of entities in charge of maintenance of vehicles pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulation (EU) No 445/2011;
- COMMISSION IMPLEMENTING REGULATION (EU) No 402/2013 of 30 April 2013 on the common safety method for risk evaluation and assessment and repealing Regulation (EC) No 352/2009;
- Railway Transport Act;
- ORDINANCE No 59 dated 5.12.2006 on the railway transport safety management;
- TOR and TOSAR.

4.3.4. Environmental factors:

4.3.4.1. Labour conditions (noise, illumination, vibrations).

Not applicable.

4.3.4.2. Meteorological and geographic conditions.

Not applicable.

4.3.4.3. Construction works, performed on the spot or in very proximity.

Not applicable.

4.3.5. Any other significant factor for the investigation objectives.

Not applicable.

4.4. Feedback and control mechanisms, including risk and safety management, as well as monitoring processes:

4.4.1. Regulatory framework conditions.

Commission Delegated Regulation (EU) 2018/761 of 16 February 2018 establishing common safety methods for supervision by national safety authorities after the issue of a single safety certificate or a safety authorisation pursuant to Directive (EU) 2016/798 of the European Parliament and of the Council and repealing Commission Regulation (EU) No 1077/2012;

ORDINANCE No 59 of 5.12.2006 on the railway transport safety management.

4.4.2. Processes, methods and results from the activities on the risk assessment and monitoring that the involved entities performed:

4.4.2.1. Railway undertakings.

"BDZ-Cargo" Ltd. applies a procedure „Methods of risk analysis and assessment within BDZ-Cargo Ltd. "effective from 2013 as a part of SMS.

4.4.2.2. Railway infrastructure.

SE NRIC applies a safety procedure SP 2.09 „Methods of risk evaluation and assessment „version 05 effective from 01.03.2019, which is a part of SMS.

4.4.2.3. Entities in charge of the technical maintenance.

SE NRIC and "BDZ-Cargo" Ltd. are certified ECM.

SE NRIC applies a safety procedure SP 2.09 „Methods of risk evaluation and assessment"version 05 effective from 01.03.2019, which is a part of SMS.

"BDZ-Cargo" Ltd. applies a procedure „Methods of risk analysis and assessment within BDZ-Cargo Ltd. "effective from 2013 as a part of SMS.

4.4.2.4. Manufacturers and all other participants.

Not applicable.

4.4.2.5. Reports on independent risk assessment.

There have not been performed an assessment by independent Assessment Body (AsBo) on changes/modifications performed in operational conditions and factors that refer to the occurred accident.

4.4.3. Safety Management System of the involved:

4.4.3.1. Railway Undertakings.

The latest annual planned supervision of the SMS of "BDZ-Cargo" Ltd. was performed in the period from 13.01.2020 to 31.01.2020. In 2020, "BDZ-Cargo" Ltd. had several specialized audits performed- in terms of communication with train dispatchers of SE NRIC and on complaints of incorrectly reported delays.

4.4.3.2. Railway Infrastructure.

The latest annual planned supervision of the SMS of SE NRIC was performed in the period from 19.10.2020 to 30.10.2020.

4.4.4. Safety Management System of the entities in charge of the technical maintenance.

Not applicable.

4.4.5. Results from the supervision, performed by the National Safety Authority.

The results from the performed audits and inspections referring the functionality of the Safety Management System of SE NRIC and "BDZ-Cargo" Ltd. as per the requirements of Regulation (EU) 2018/761, Regulation (EU) No 1169/2010, Ordinance No 56 and Ordinance No 59 on respect of the specific requirements of the European legislation and national rules for design, maintenance and operation of the managed railway infrastructure demonstrate that the entities maintain SMS and are able to respect the requirements, envisaged in the respective normative documents.

4.4.6. Permits, certificates and assessment reports, provided by the National Safety Authority or other Conformity Assessment Bodies:

4.4.6.1. Safety certificates of the involved railway infrastructure managers.

Safety Authorization No BG 21/2018/0001 valid from 01.07.2018 to 30.06.2023.

4.4.6.2. Safety certificates of the involved railway undertakings.

Safety Certificate part A BG 11 2017 0008, valid to 30.12.2022;

Safety Certificate part B BG 12 2017 0008, valid to 30.12.2022;

4.4.6.3. Authorizations for placing in service of permanently fixed equipment and permits for placing on the market of vehicles.

Not applicable.

4.4.6.4. Entities in charge of the technical maintenance.

"BDZ-Cargo" Ltd. has an ECM Certificate for railway vehicles BGRA/2017/0003 valid to 30.12.2022;

SE NRIC is in charge of the repair, maintenance and operation of the national railway infrastructure.

4.4.7. Other system factors.

Not applicable.

4.5. Previous similar cases.

Similar cases were investigated in similar and identical circumstances, which were the subject of reports in a form appropriate to the type and severity of the accident in which safety recommendations were formulated.

5. Conclusions

5.1. Summary of the analysis for the event causes.

The Investigation Commission of visited the place of the accident several times and were acquainted with the technical condition of the rail track. The Commission has also been acquainted in detail with the documentation for the technical condition of wagon № 31525400845-3, which derailed with the two wheel-sets of the first bogie in the direction of traffic at km 260^{+302}. On 17.03.2021 in the Locomotive depot Stara Zagora the Commission carried out a thorough inspection of the derailed wagon № 31525400845-3, as well as of the wagon after it № 82525938331-3. Control measurements were also performed for the distribution of the load in the body-shell of the wagons under wheels

Fig. 5.1. Distribution of the load in 16th wagon № 31525400845-3

Table 1

№ in a row order of the train composition	**№ of the wagon**	**Wheel-set №**	**Loading in kg**			**Proportion right to left wheel**	**Note**
			ляво колело	**дясно колело**	**колоос, общо**		
15th	82525938573-0	1	9 600	10 150	**19 750**	**1,06**	
		2	9 650	11 050	**20 700**	**1,15**	
		3	7 000	13 150	**20 150**	**1,88**	
		4	7 800	12 700	**20 500**	**1,63**	
16th	31525400845-3	1	8 600	10 500	**19 100**	**1,22**	Derailed wagon[1]
		2	7 700	11 500	**19 200**	**1,49**	
		3	7 300	11 900	**19 200**	**1,63**	
		4	8 750	11 400	**20 150**	**1,30**	
17th	82525938331-3	1	8 450	11 150	**19 600**	**1,32**	
		2	8 500	11 850	**20 350**	**1,39**	
		3	8 250	11 300	**19 550**	**1,37**	
		4	8 900	12 050	**20 950**	**1,35**	
Normative difference in the wheels load:						**до 1,25**	

After the inspection, it was found that the load in these wagons was unevenly distributed along the transverse and longitudinal axles of the wagons, as most of it was located in the right longitudinal half of the wagons in the train movement direction (Fig. 5.1).

[1] The measurements were performed after change of the derailed bogie with regular one.

The Investigation Commission carried out a detailed analysis of the technical condition and location of the cargo in wagons № 31525400845-3 (derailed) and № 82525938331-3 (after the derailed wagon)

On 24.03.2021 in Stara Zagora station on a certified mobile railway weigher measurements were performed on the last three wagons of the DFT № 30610 with № 82525938573-0 - before the derailed one; № 31525400845-3 - the derailed one; № 82525938331-3 after the derailed during towing and pushing with locomotive № 52-119 and the following results were obtained in (Table 1):

The requirements for the admissible differences in the vertical loads of wheels and axles of wagons are described in the Safety Management System, FP - 4.10 Working procedure "Instruction for loading and transportation of oversized and heavy loads on the railway network of the Republic of Bulgaria", NRIC, Date of issue: October 1, 2018.

"SECTION I GENERAL REQUIREMENTS FOR WAGON LOADING

Article 46, para. 3 *The load must be distributed as evenly as possible, observing the following proportions:*

1. the proportion of the load of the wheels of the same wheel-set in the transverse direction is ***maximum of 1.25:1*** *(lateral displacement of the load);*

2. proportion of the axle (bogie) loads in the longitudinal direction is:

a) for two-axle wagons - maximum 2:1;

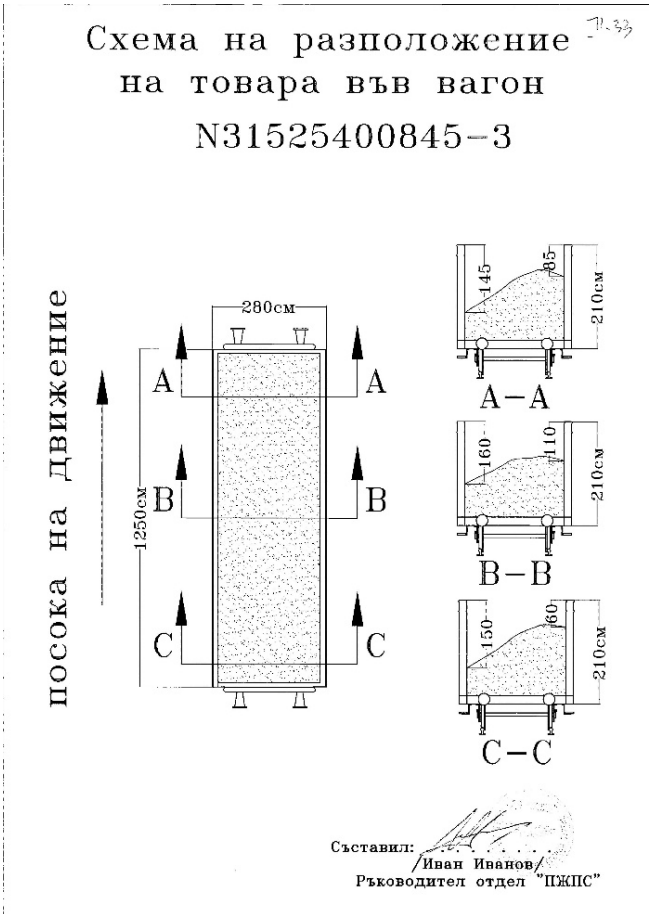


Fig. 5.2. Scheme of load layout in 16th wagon № 31525400845-3

б) for bogie wagons – ***maximum 3:1****.*"

Based on numerical data from the measurement of the load in the wheels with a mobile wheigher (Service protocol № 2000000010 from 24.03.2021 from the company "BALANCE SYSTEMS“ Ltd.) Table 1 has been prepared.

Therefore were found non-compliance with the requirements of Art. 46, para. 3, item 1 of the 2nd and 3rd wheel-sets of the 15th wagon; on the 2nd, 3rd, and 4th wheel-set of the 16th wagon (derailed) and on all the wheels of the 17th wagon.

It is obvious that the differences in the loads of the individual wheels of the derailed wagon correspond to the normative values only for the first wheel-set, and for all the others they exceed them, which is a proof of the unevenly distributed load in the three wagons.

From the point of view of the mechanics, the movement of the wagon on the rail track can be considered stable when at any moment of its movement it remains on the rails. The derailment can be caused by various factors affecting its resilience. Taking into account the results of the measurement of the rail track in the area of the wheel rise on the rail, can be noted that the technical condition of the rail track cannot be considered as the main cause for the derailment of the wagon. On the other hand, the shape and dimensions of the bandage profile also meet the technical requirements, which can be considered that the wagon also meets the technical conditions for movement on the railway infrastructure.

The wagon can become unstable due to additional factors influencing its behavior in contact of the wheels with the rails, namely its displaced mass center. During the performed analysis, it was found that the load was placed in the basket (body-shell) of the wagon so that it shifted its center of mass to the right in the direction of movement of the train 0.35 m from its longitudinal axle (Fig. 5.2). Additionally, an analysis was made of the load distribution and the location of the mass center in section A-A, i.e. in the area of the first bogie - where the derailed

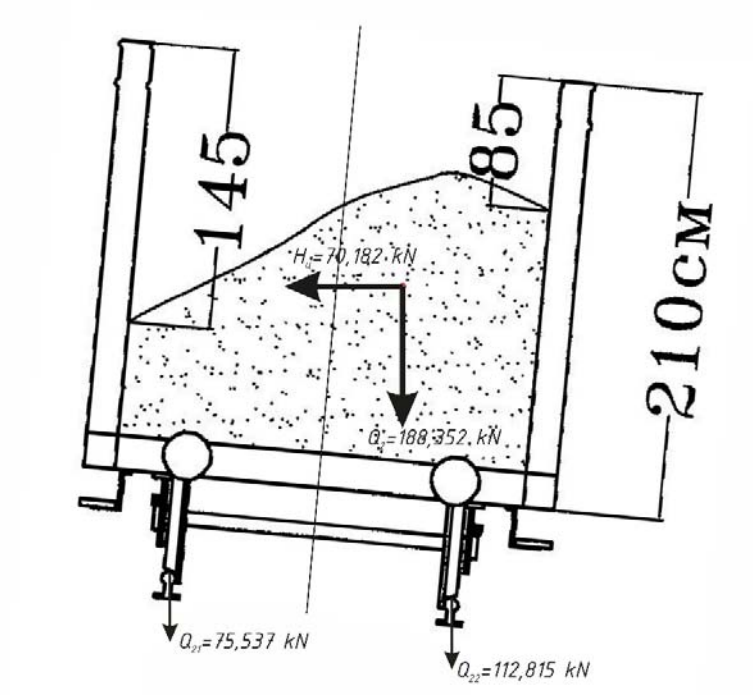


Fig. 5.3. Distribution of the forces acting on the second wheel-set of the first bogie of wagon № 31525400845-3

second wheel-set is located (Fig. 5.3). The center of mass is shifted to the right of the longitudinal axle of the wagon in the direction of train movement, which is logical given the results obtained when measuring the load on the individual wheels (Table 1). The measurements also show that the right wheel is loaded 49% more than the left one.

In order to determine the condition under which the wagon has a steady movement, it is assumed that when passing curved sections, a certain horizontal force $\boldsymbol{H_ц}$ and a vertical force $\boldsymbol{Q_1}$ act on the flange, the projections of which on the tangent and the normal at the point of contact between the flange and the head. the rail will be (Fig. 5.4):

- On the tangent *AB*:
  - $\boldsymbol{Q_1 \cos(90 - \beta) = Q_1 \sin \beta}$
  - $\boldsymbol{H_ц \cos \beta}$
- On the normal *MN*:
  - $\boldsymbol{Q_1 \cos \beta}$
  - $\boldsymbol{H_ц \cos(90 - \beta) = H_ц \sin \beta}$

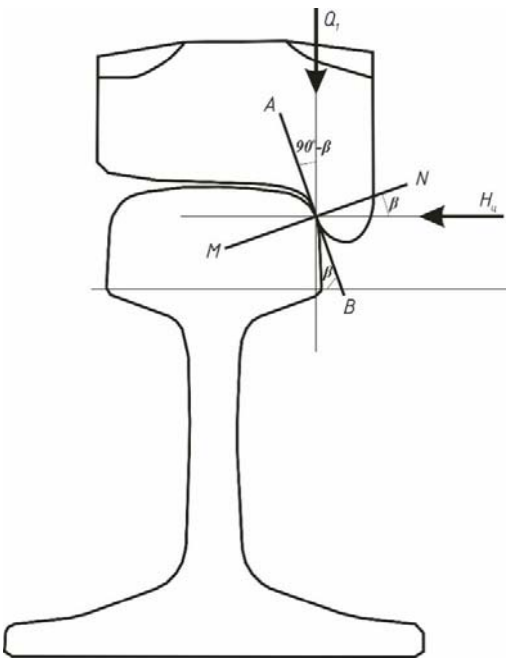


Fig. 5.4. Forces, acting in the contact point wheel-rail

The amount of the projections of the forces on the normal *MN* cause a friction force, which is determined by the expression:

$$\boldsymbol{\mu(Q_1 \cos \beta + H_ц \sin \beta)},$$

where $\boldsymbol{\mu}$ is the coefficient of friction between the flange and the rail. In this case, the friction force will have the direction of the tangent *AB*. Its direction is determined by the fact that it is a resistance force. To prevent the wheel from derailing, you need the force that returns the wheel to its original position $\boldsymbol{Q_1 \sin \beta}$ to be greater than the force, which aims to take out the wheel from the rails$\boldsymbol{H_ц \cos \beta}$.

The force of friction between the rail and the flange is also opposed to the recoil force:

$$\boldsymbol{Q_1 \sin \beta > H_ц \cos \beta + \mu(Q_1 \cos \beta + H_ц \sin \beta)}$$

In turn, the centrifugal force that loads the wheel in a horizontal plane transverse to its motion is equal to:

$$\boldsymbol{H_ц = 2Q_1\left(\frac{V^2}{gR} - \frac{h}{2S}\right)}$$

The speed of the train at the time of derailment is 37 km/h, the mass center is at a height of 0.92 m from the floor level of the wagon, and the radius of the curve is 300 m. According to these values, the centrifugal force is 71.182 kN.

The speed of the train at the time of derailment is 37 km / h, the mass center is at a height of 0.92 m from the floor level of the wagon, and the radius of the curve is 300 m. According to these values, the centrifugal force is 71,182 kN.

Assuming that $\boldsymbol{\beta}$=70° and $\boldsymbol{Q_2}$=1,49$\boldsymbol{Q_1}$, $\boldsymbol{H_ц/Q_1}$=0,93 is obtained. For stable movement it is necessary to fulfill the condition $\boldsymbol{H_ц/Q_1}$≤0,8. Therefore, the horizontal transverse force caused by the centrifugal force in the movement of the train in the curve has a greater influence than the vertical load acting on the wheel, which violates the condition of stable wheel movement and leads to derailment of the respective wheel. These results, combined with the lower value of the level of the rail track (which is within the permissible limits) at the point of ascent (Fig. 5.5: 0.128 m (Fig. 5.5, pos. 1) compared to the first wheel - 0, 13 m (Fig. 5.5, pos. 2) and the third wheel-set - 0.144

m (Fig. 5.5, pos. 3) have contributed to the rise of the wagon on the rail head at the specified point and its subsequent derailment.

In conclusion, the Investigation Commission considers that the main cause for the derailment of the second wheel-set of wagon № 31525400845-3, 16th in a row in the composition of DFT № 30610 along Shivatchevo – Tvarditsa interstation, is the uneven load of the wagon. This has led to a displacement of its center of mass, as the load was unevenly distributed on the individual wheels (the load on the left in the movement direction was less than the load on the right one). The combination of movement in right curve with a small radius, low speed and deviations in the level of the rail track, has contributed to the rise of the left wheel on the second

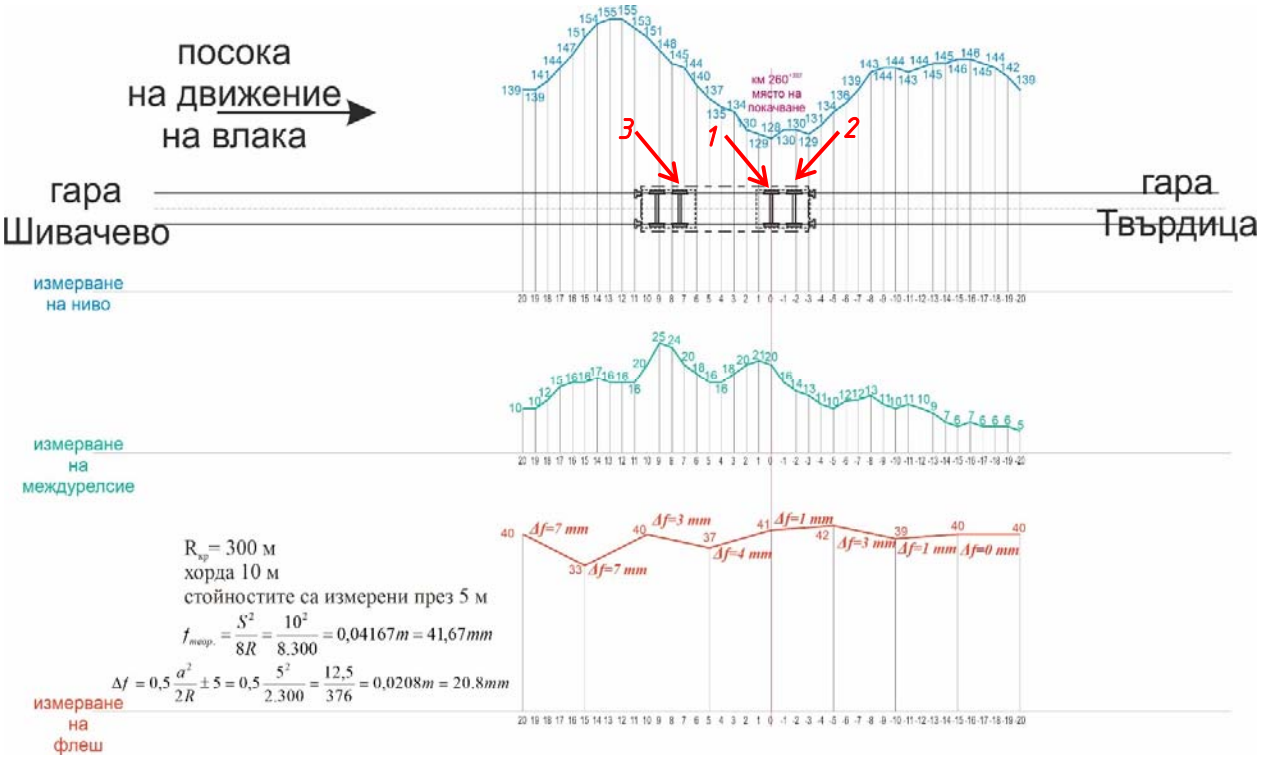


Fig. 5.5. Layout of wagon № 31525400845-3 with respect to the track

wheel-set from the first bogie of the wagon on the rail crown of the outer rail and its subsequent derailment.

5.2. Undertaken measures after the event occurrence.
Not applicable.

5.3. *Additional findings.*
There are no any.

6. Safety recommendations

In order to improve the safety in the rail transport, the Investigation Commission at NAMRATIB proposes to the Railway Administration Executive Agency the following safety recommendations adapted to SE NRIC and „BDZ-Cargo“ Ltd.

- Recommendation 1 proposes that SE NRIC and „BDZ-Cargo“ Ltd. acquaint the interested staff with the content of this report.
- Recommendation 2 proposes SE NRIC to organize periodic trainings in order to refresh the knowledge of the technical staff, rail track and structures controller, head of section on rail track and structures maintenance unit/joint RRS, technician head of group RRS and technician transport construction regarding the requirements of "Instructions for construction and maintenance of the rail track and switches".
- Recommendation 3 proposes that „BDZ-Cargo“ Ltd. controls the process of loading the wagons when transporting bulk cargo.

With reference to the requirements of art. 91, paragraph 3 and art. 94 par. 1 and par. 4 of Ordinance No 59 dated 5.12.2006, the NAMRTAIB Investigation Commission provides a final report, which contains information from the conducted investigation with recommendations for improving the safety in railway transport.

The NAMRTAIB Commission proposes a final report with safety recommendations dated 20.08.2021.

Chair:

Dr. Eng. Boycho Skrobanski
Deputy President of the NAMRTAIB AB