MINISTRY OF TRANSPORT
ROMANIAN RAILWAY AUTHORITY – AFER
ROMANIAN RAILWAY INVESTIGATING BODY

INVESTIGATING REPORT

on the derailment of the freight train

no. 42612, belonging to the Romanian Railway Freight Company " CFR Marfa " SA

in the railway station Dej Triaj on the 22nd of February 2007

Final edition

February, 12 2008

1. **Short presentation – first step of presentation**

1.1. On the 22nd of February 2007, the freight train no. 42612, belonging to the railway undertaking SNTFM " CFR Marfa " SA was dispatched from the Casei Halt to the station Dej Triaj at the 3.47 hour, according to the automatic block, without remarks. Arriving at the railway station Dej Triaj on the line 4A, with a speed of 13 Km/h, a group of 8 wagons has derailed, starting with the sixth wagon after the locomotive.

1.2. According to the provisions of art. 3 of the Law no. 55/2006 the present event, respectively the derailment of the freight train no. 42612, is a railway accident.

1.3. In order to establish the connections between the real reason and the favoring factors, respectively the reasons, there was necessary to question the involved railway staff, as well as to perform some laboratory tests concerning the measurement of the bogie torque and the establishing of the total torsional rigidity of a wagon similar to those involved in the railway accident. The laboratory tests were not performed because of the lack of financial resources.

Figure 1: The geographical position of the accident

2. The legal framework necessary for the investigating process carried out by the Romanian Railway Investigating Body

2.1. According to the provisions of the art. 19 of the Law no. 55/2006 was set up the Romanian Railway Investigating Body, the permanent and independent body of the Romanian Railway Authority – AFER, that performs the investigation of the serious railway accident, its objective being to improve the railway safety and to prevent the accidents. The Romanian Railway Investigating Body is able to investigate, besides the serious accidents, those accidents and incidents that in the slight different conditions could have lead to serious accidents, inclusively technical problems of the structural systems or of the interoperability constituents belonging to the high speed or European conventional railway systems.

2.2. Taking into account that on the 22nd of February 2007, according to the Law no. 55/2006, concerning the railway safety, occured a railway accident consisting of the derailment of 8 changing gauge wagons belonging to the freight train no. 42612, the Romanian Railway Investigating Body decided to investigate this railway event, the investigating commission consisting of:

- Olaru Mihai – investigator in charge
- Ciobanu Eugeniu – investigator
- Stoian Eduard – investigator
- Sfarlos Dumitru – investigator

2.3. The investigating process is not focus on the establishing of the guilt or of the responsibility and is carried out simultaneously with other controls, inclusively those performed by the authorities responsible for the juridical investigation (in the case of a such investigation).

2.4. The investigation is performed as openly as possible, so that all the parts could be examined and have access to the results. The infrastructure manager and the involved railway undertaking, the Romanian Railway Safety Authority, the victims and their relatives, the owners of the deteriorated goods, producers, the involved emergency services and the staff representatives and the users are regularly informed about the investigation and its course, giving, at their request, the possibility to present their opinions and points of view on the investigating process and having the possibility, at their request, to comment upon the information from the reports projects.

3. The railway accident presentation

3.1. The railway accident occured in the following conditions:

- on the 22nd of February 2007, the freight train no. 42612, consisting of 32 changing gauge wagons, matriculated in the UZ fleet, loaded with 1778 tons vinyl chloride, necessary braked 889/196 tons, real braked 1267/507 tons, 538 m, hauled by the DA 1073 locomotive from Dej Depot, was dispatched from the railway station Caseiu to the railway station Dej Triaj at 3.47 hour, on the basis of the automatic block. At its arrival in the railway station Dej Triaj on the line 4A, at 4.10 hour, with a speed of 13 Km/h speed, 8 wagons derailed, starting from the sixth wagon after the locomotive;

- at 20,2 m after the first joint of the switch tip no. 47A on the connecting rail between the heel of curved blade and the crossing leaf in a curve of 190 m radius, left deviation, at the speed of 13 Km/h the wagon no. 57653776 derailed, the wagon running in these conditions 630 m, when the left wheel meets the check rail and the axle comes on the trackl. During the running with the first axle derailed, the left wheel breaks the lignofolium fish plate from the joint, making a lateral threshold that led to the derailment of the following 3 wagons, no. 57586463, 57653461 and

57653230, that come on the rail in the same conditions as the first wagon;

- because of the running of those 4 derailed wagons, the track was gotten out of shape, so that the following 4 wagons , respectively the wagons no. 51226074, 57655482, 57653420 and 57585952, derailed too, then the train braked because of the air losses in the main pipe, caused by the unbiding of the autocoupler.

Figure 2: The railway station plan where occurred the accident

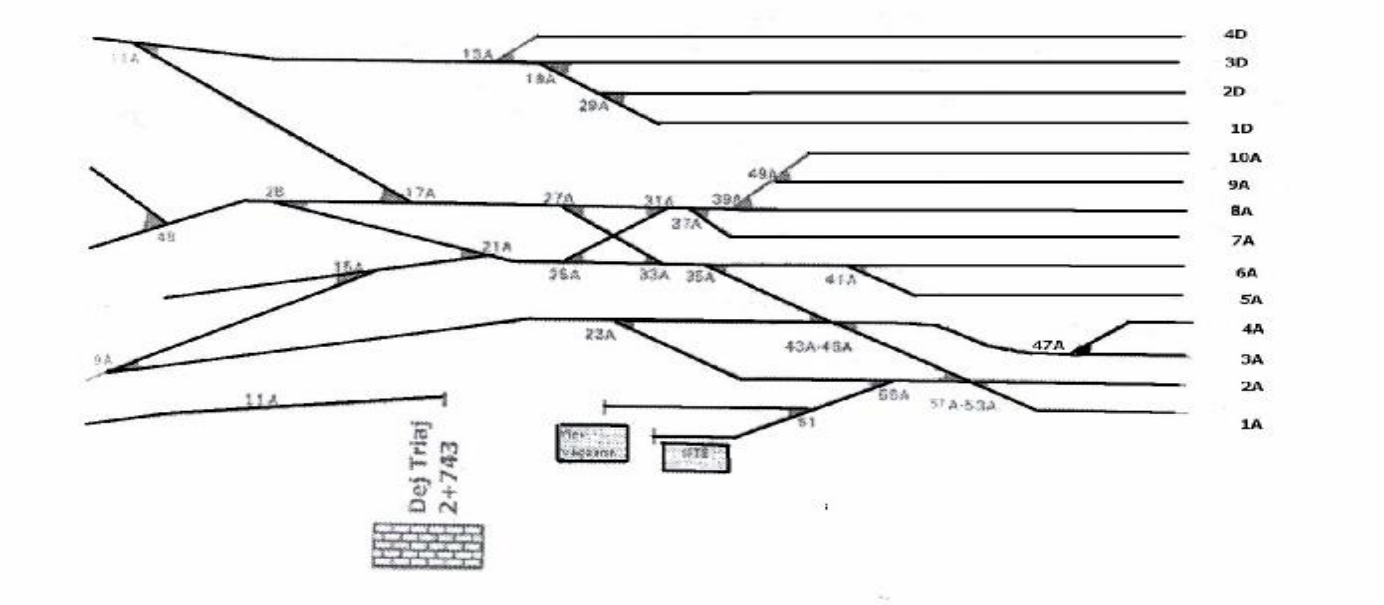


Figure 3 – Lingofolium joint destroyed

4. **Consequences**

4.1. **Victims and casualties** there were no dead or injured persons

4.2. **Material damages**

- at wagons 217,91 lei representing the checking of those 8 wagons.
- at the track 196,81 lei representing the replacement of 2 lignofolium fish plates and of 3 wooden sleeper SB

Total **414,72 lei**

5. **Technical reasons – the results of the measurements, controls, performed tests.**

5.1. **Technical reasons at the tracks**

- **data resulted from the measurements performed by the safety circulation regional inspector and by the head of L7 Dej track section and written down in a minute – piece at the control file drawn up by the control commission set up at CNCF "CFR" SA** level, according to the provisions of the "Instructions for the prevention and investigation of the railway accidents and events" no. 003/2000:

Point	-9 pj	-8 vf	-7	-6	-5 c.ac	-4 cm	-3	-2	-1	0	
E (mm)	19	23	28	22	25	22	23	25	24	21	Track got out of shape after de derailment
N (mm)	12	15	7	3	6	8	10	8	10	6	

pj = first joint
vf=tip of switch
c.ac=heel of blade
cm=curve at the middle point
0=derailment place.

In that minute is written down that the metallic pieces for fastening are complete and active, the wooden sleepers are suitable, the broken stone prism is clogged up about 30%. Also, in the same document is written down that the measurements are carried out with the track measure gauge from 2,5 m to 2,5 m.

- The data resulted from the carried out investigations on the spot by the investigating commission and from the analysis of the documents asked from the railway infrastructure administrator:
  - **on the spot**

i. the tracks and the points and crossings from the railway station Dej Triaj Group A are maintained by the District 4 Dej Triaj, that is the sub-unit of the L7 Track Section Dej.
ii. the railway running and the shunting over the switch no. 47A was closed, affecting the end X of the tracks 4A and 3A (the end at the switch no. 47A).
iii. From the watchings, the broken stone prism from the end X of the group A was clogged up about 80%;

iv. The joints from the tip of switch no. 47A weren't squared, the right stock rail being 718 mm shorter (without affecting the planning area) as a result of removing of the fault 53.1c through the cutting of this stock rail on the 17th of April 2000;

v. One established the vertical and lateral wears of the connecting rails through their measurement with the gauge for the wears checking. After processing, the results have no values higher than those accepted by the Instruction no. 314/1989 concerning the norms and the limits for the track construction and the maintenance – tracks with normal gauge.

vi. One checked with ORE gauge the wears of the points switch and stock rail and there were no wears that lead to their replacement;

vii. One checked the records of the District Dej Triaj and resulted that at the last checking on the 30th of January 2007 the limits at the gauge were exceeded in the points first joint, heel of blade deviation, curve middle, switch diamond direct and switch diamond deviation with +3 mm, +6 mm, +4 mm, + 3 mm and +1 mm;

viii. In the time elapsed from the 30th of January 2007 to the 22nd of February 2007, when occurred the railway event, the switch no. 47A wasn't repaired;

ix. Following the control of the situation plans and of the presented drawings one couldn't establish if in the railway station Dej Triaj Group A there was a draining system. On the spot one noticed construction works specific to a draining system (one couldn't notice water draining ditches, inspection chambers, platforms).

x. The measurement of the gauge and of the transversal level were performed neither according to the regulations art. 7 of the Instruction no. 314/1989 nor on the measuring basis of 2,5 m, as is mentioned in the chapter I of the Investigating Report drawn up following the railway event occurrence. From the commission president explanations resulted that the switch no. 47A was measured in 9 points from witch only 4 points were in accordance with the stipulations of the Instruction 314/1989 (first joint, point of switch tongue, heel of blade deviation, curve middle), the position of the other point of measuring being not in accordance with the equidistance of 2,5 m

ix. The measurements of the gauge and of the transversal level were performed also on the areas influenced by the derailment.

o Documents analysis

i. The District 4 Dej Triaj – Track Section L7 Dej has for maintenance 61,228 km, for that it should to have, according to the reviewed works, 51 employees skilled to carry out maintenance and track repair work.

ii. From the beginning of 2007 and to the investigation moment the daily average of the district staff was 21 employees from whom 9 employees (track workers) represented by the own staff and 12 employees (blue workers) hired according to the contract concluded with the firm SC 2 INVEST SRL Cluj.

iii. From the track materials belonging by the District 4 Dej Triaj for 2007:
- for the switch no. 47A of the railway station Dej Triaj group A (involved in the derailment occurrence) were reviewed 24 special sleepers (from a total of 264 pieces of special sleepers reviewed at the district level);
- no out of order components in the switch no. 47A were reviewed;
- given the last review the number of the special sleepers increased with 5 pieces;
- during the time between the 2 reviews in the switch no. 47A was replaced only a special sleeper with a length of 3,7 m;

iv. Following the presentation of the plan for the replacement of the switches, drawn up by the Track Section L7 Dej, studied by the Track Division Cluj and submitted to the Track Direction was found that the switch no. 47A from the railway station Dej Triaj wasn't included in the program of 2007 for replacement with a new switch or with a

switch brought back to the condition SB. Also, this switch wasn't find in the replacement plan of the metallic parts.

- **Other remarks**

i In 2006 the track section L7 Dej achieved the works plan that it proposed only from the quantitative point of view, at a more careful analysis was noticed:

- The maintenance works plan for 2006 was drawing up without to comply with the provisions of the annex 5 of the Instruction no. 300/1972 concerning the average works quantities on 1 Km track, so that for some specific services of the maintenance activities weren't planed works.

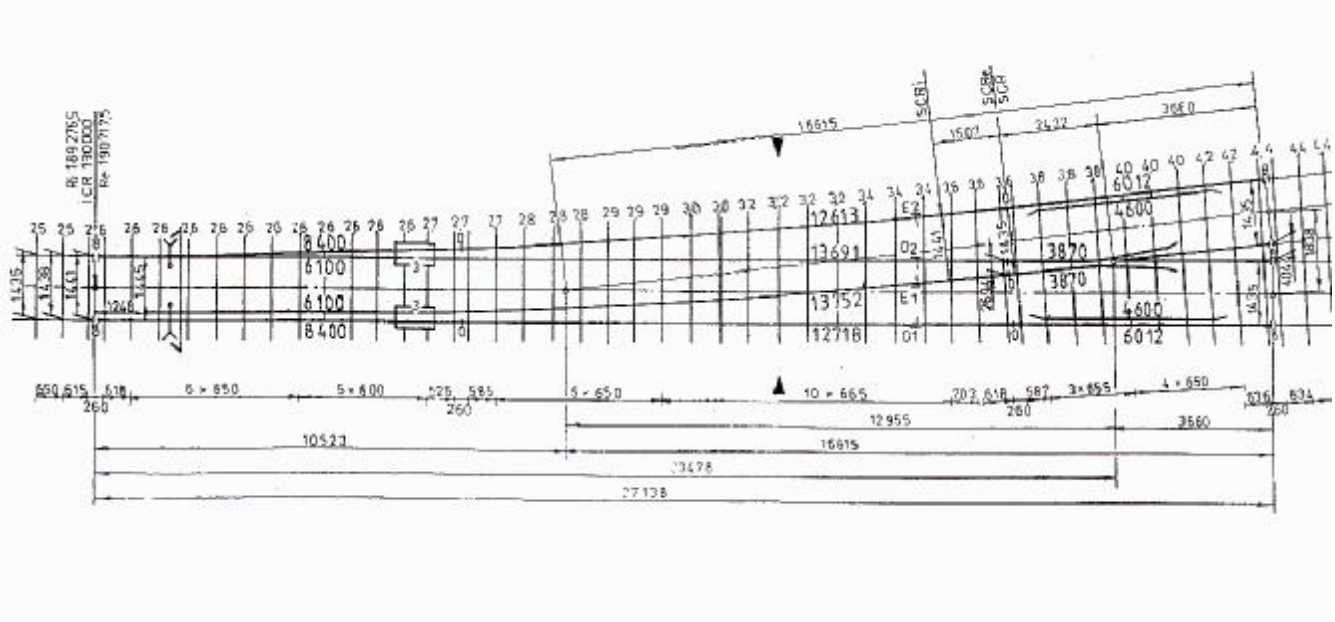
Example:

No.	Service	U/M	Average procent/1 Km of running track according to annex 5 from the Instruction no. 300/1972	Total of the planed works by Section L7 Dej
0	1	2	3	4
1	Level rectification through the packing of sleepers	Pieces of sleepers	25-45%	0%
2	Rectification of the track gauge	Sleepers ends	1,5-3%	0%
3	Fastening of the vertical bolts	piece.	35%	0%
4	Fastening of the coach screw	piece.	30-40%	0%

- at the chapter "achieved" for 2006 one remarked that the labor percentage necessary to replace the out of order parts is generally 10% and the labor percentage for the works that weren't planed is 90% (this majority didn't need the use of materials).
- one performed a series of services that weren't planed, this supports the achievement of the total conventional Km for the current maintenance, but that does not represent services with direct incident on the track maintenance.

ii The funds asked for the purchase (raw materials) of the materials and for execution of the services contracts on hour tariff weren't completely assured, the expenses and incomes budget being seriously changed.

Figure 4: Points and crossing plan



5.2. **Wagons technical aspects**

- Building characteristics data for the wagon no. 5765377:
  - 4 axles, tare 34,1 t, load limit 48,9 t
  - wheel base between the pivots 9500 mm;
  - wheel base between the axles 1800 mm;
  - wagon length (over the coupler) 14600 mm;
  - distance from the rail to the chassis 1200 mm.

Data resulted from the commission measurements at the wagon no. 57653776 (the first derailed wagon) on the 22nd of February 2007:

i. bogies type Diamond CSI with the wheel base 1,80m
ii. RP : 2 REV on the 9th of April 2006 (862)
iii RP bogie 1:2 REV on the 30th of May 2006 (857)
iv. RP bogie 2:2 REV on the 29th of July 2006 (857)
v automatic brake type Matrosov
vi. centre casting ensemble from the first bogie in the direction of traffic:

- plane centre casting without wear plate, with well marked traces of friction and lack of material (about 3 mm on 2 surfaces of about 40 x 50 mm) from the superior centre casting, and the shoulder of the inferior centre casting got out of shape about 5 mm because of the friction in the ribs of the superior centre casting to the left side of the direction of traffic.
- at the inferior centre casting there is a well marked contact surface of about 40x50mm, with depths of 2 -3 mm;

vii. the centre casting ensemble from the second bogie in the direction of traffic:

a. plane centre casting, without wear plate, with well marked traces of friction and with a burrs of about 40 mm and with a depth of 5 mm (without to specify where);
b. wears in the superior centre casting of about 2 mm to the right side of the bogie frame;

	BOGIE 1				BOGIE 2			
	Right side		Left side		Right side		Left side	
	The measured value mm	The accepted value mm	The measured value mm	The accepted value mm	The measured value mm	The accepted value mm	The measured value mm	The accepted value mm
The height of the spiral spring after taking the wagon	250	250	250	250	250	250	250	250

	Bogie 1				Bogie 2			
	right side	left side	right+ left side	right+ left side	right side	left side	right+ left side	right+ left side
	the measured value mm	the measured value mm	the measured value mm	The accepted value mm	the measured value mm	the measured value mm	the measured value mm	The accepted value mm
Plays between the friction stones	6	0	6	2-20	0	7	7	2-20

	axle 1		axle 2		axle 3		axle 4	
	Measured value mm	Measured value mm	Measured value mm	Measured value mm	Measured value mm	Measured value mm	Measured value mm	Measured value mm
The distance betwen the interior surfaces of the rims measured in 3 points	1359 1359 1359	1360 +/-3	1358 1358 1358	1360 +/-3	1357,5 1358 1359	1360 +/-3	1357,5 1358 1358	1360 +/-3

	Axle 1			
	right wheel		left wheel	
	Measured value mm	Accepted value mm	Measured value mm	Accepted value mm
The rim width	130	133-140	131,5	133-140
Qr	8,5	>6,5	9	>6,5
The height of the wheel flange	28,5	25-36	28	25-36
The thickness of the whell flange	28,5	22-34	28,5	22-34

	Axle 2			
	right wheel		left wheel	
	Measured value mm	Accepted value mm	Measured value mm	Accepted value mm
The rim width	130	133-140	132	133-140
Qr	9	>6,5	8,5	>6,5
The height of the wheel flange	28	25-36	29	25-36
The thickness of the whell flange	29	22-34	29	22-34

	Axle 3			
	right wheel		right wheel	
	Measured value mm	Measured value mm	Measured value mm	Measured value mm
The rim width	137	133-140	134	133-140
Qr	9,5	>6,5	9	>6,5
The height of the wheel flange	30	25-36	28,5	25-36
The thickness of the whell flange	30	22-34	29	22-34

	Axle 4			
	right wheel		right wheel	
	Measured value mm	Measured value mm	Measured value mm	Measured value mm
The rim width	137	133-140	135	133-140
Qr	9,5	>6,5	9,5	>6,5
The height of the wheel flange	27	25-36	29,5	25-36
The thickness of the whell flange	30	22-34	31	22-34

Figure 4 – The centre casting from the first derailed vagon

6.The comment of the resulted elements

6.1 At the tracks:

ii. the broken stone prism was clogged up about 80% and not 30% how was written down in the minute;

iii. the measurement carried out according to the measuring table in the point first joint is E/N=19/12 (the maximum accepted value 11/10), passing beyond the gauge with 8 mm and the transversal level with 2mm. In this case the provisions of the art. 19, points 2 and 6 of the table 17 from the Instructions 314/1989 concerning the norms and the limits for the track constructions and maintenance – standard gauge weren't respected.;

iv. the measurement performed according to the measuring table in the point of switch tongues is E/N=23/15 (the maximum accepted value 9/10), passing beyond the gauge with 14 mm and the transversal level with 5mm. In this case the provisions of the art. 19, points 2 and 6 of the table 17 from the Instructions 314/1989 concerning the norms and the limits for the track constructions and maintenance – standard gauge weren't respected.;

v. the deviations at the gauge in the points "first joint" and " points of switch tongues " are coming from the inadequate maintenance of the switch.

vi. the performed measurement according to the measuring table in the point of the switch deviation is E/N=25/6 (the maximum accepted value 11/10), passing beyond the gauge with 15 mm. In this case the provisions of the art. 19, point 2 of the table 17 from the Instructions 314/1989 concerning the norms and the limits for the track constructions and maintenance – standard gauge weren't respected.;

vii. the measurement performed according to the measuring table in the point middle of curve is E/N= 22/8 (maximum accepted value 11/10), passing beyond the gauge with 11 mm. In this case the provisions of the art. 19, point 2 of the table 17 from the Instructions 314/1989 concerning the norms and the limits for the track constructions and maintenance – standard gauge weren't respected.;

viii. the deviations at the gauge in the points "heel of blade" and "middle of curve" can come from the buckling of the connected rails of the point switch, at the derailment.

ix. in the measuring table the position of the points -7, -3, -2, -1 does not appear as specific points in witch the measurement of the points and crossing had to be done according to the provisions of the art 19 point 2 and the table 17 from the Instruction no. 314/1989 concerning the norms and the limits for the track construction and maintenance – standard gauge tracks and consequently the results analysis can not be done;

x. the measurement performed according to the measuring table in the derailment point (it is not a specific point for the points and crossing measurement) situated between the heel of blade deviation and joint switch diamond deviation is E/N=21/6 (maximum accepted value 11/10), passing beyond the gauge with 10mm. In this case the provisions of the art. 19, point 2 of the table 17 from the Instructions 314/1989 concerning the norms and the limits for the track constructions and maintenance – standard gauge weren't respected.;

xi. all the measurements were performed after the derailment. The nonconformities found after measuring point heel of blade can be consequence of the derailment.

b. At the wagon:
   i. lack of lubrication at the centre casting. So the Ukrainian regulations concerning the lubrication with graphite vaseline УСсА ГОСТ 3333 – 80 (or substitutes, that is vaseline with 10% graphite or vaseline processed Л3 – ЦНИИ) of the centre casting ensemble at the placing of the bogie under the wagon were not complied with;
   ii. the tyre breadth from the first bogie wheels of the wagon was 130 mm, with 3 mm under the minimum value stipulated in the annex 5, point 2.3 from PPV.
   iii. the clearances at the friction stones on the diagonal of the wagon were 0.

The PPV regulations as well as the instructions concerning the technical checking and the maintenance of the operated wagons have not any rule concerning the value of the friction stones clearences on the diagonal, for the wagon running on the tracks with 1435 mm gauge..

7. **The achievement of the further proposed objectives**

7.1. Establishing of the influence of the lack lubrication of the centre casting in the railway event occurrence through the measurement of the the torque of the bearing bogie type Diamond used in order to move the freight wagons with large gauge (1520 mm) on regular gauge (1435 mm) in this 2 possibilities, respectively with lubricated centre casting and non lubricated centre casting.

ICPV SA Arad in the paper no. 209/29.03.2007 informed us that it is able to perform tests of the torque of the bogie for the empty wagon and for the loaded wagon, with the mention that the leaflet UIC 510-1 establishes the value of the torque for a UIC standard wagon with the tare of about 20t; for a UIC loaded wagon is not mentioned the value of the torque.

Also, in order to extend the investigation, it proposed the test for the calculation of the total torsion rigidity of the wagon in order to establish the impact of the frictions on the wheels loads.

Because of the funds lack, OIFR director , Mr. Dumitru Laurentiu carried out a theoretic study (presented in the annex 1) on the conduct from the safety viewpoint against the derailment depending on the torque of the centre casting of the railway vehicles (lubricated centre casting, respectively non lubricated)

The conclusion of this theoretic study is that between the lubricated centre casting and the non lubricated centre casting, the control force P1 increase with 6,03% and the safety coefficient against the derailment (Y/Q report) increases with 0,02, so one can establish that the non lubrication of the centre casting is a favoring factor and not a direct cause of the wagon derailment.

7.2. The questioning of the staff involved in the measurements at the switch no. 47A in order to clear up the resulted nonconformities.
The results were included in the report.

7.3. The settlement of the way for the water draining , respectively of the capacities for the maintenance works performance by the subunit that assures the maintenance of the tracks and of the switches in the railway station Dej Triaj group A.
The results were included in the report.

8. Conclusions

8.1. **Direct cause** – the railway accident occurred becouse of the derailment of the first axle of the wagon no. 57653776. It happened because of the exceeding of the stability limit at the derailment through the load discharge of the attack wheel, corroborated with the taking down of the contact point between the wheel flange and the active lateral side of the rail (flank) (at the attacked wheel in the running on the switch curve), it led to the rail scaling from the right side and the fall of the right wheel inside the track.
The derailment cause is considered to be the underlying causes ensemble.

8.2. **Underlying causes**:

- the chocking of the broken stone prism in the derailment area permited uncontroled settlements of the broken stone prism and the appearance of a free space between the bottom base of the sleepers and the broken stone prism;
- at the approval of the plan for the tracks and switches maintenance were not done realistic foreseeing concerning the possibilities for the material supply as well as the labor supply;
- at the end of 2006 was not done a realistic analysis of the services performance because the resulted situation presented as follows:
  - the real quantity of new necessary parts was not supplied for the replacement of those out of order, this situation was confirmed by the works that proved the degradation of some parts. Ex. Sleepers – "rectification of the track gauge " work, where the achievements are more over the necessary for planning according to the Instruction 300 or the census;
  - the works that prove the degradation of some parts, as the sleepers, are performed a long time after planning or necessary for planning according to the Instruction 300 – ex " rectification of the track gauge;
  - comparing the quantities of the planed works with the achieved works quantities is noticed that in some cases there is no connection between those two groups of data in the final result expressed in conventional Km;
  - in the chapter replacement of the special sleepers on switches for 2006, were supplied very small quantities given the necessary. The similar situation was met in the case of the broken stone;
- after the analysis of the documents belonging to District 4 Dej Triaj concerning the establishing of the necessary labor for 2007 was found out that for the maintenance of these 61,228 conventional Km the track section has only 50% from the resulted staff ;
- the services for whose performance is necessary skilled workers, were performed with blue workers, their weight in the staff structure of the sub-unit being between 53% and 65%, exceeding with more the maximum percentage of 5% ;
- after a realistic analysis of the staff situation at the Track Section L7 Dej was found out that the real number of the necessary workers for the tracks maintenance and repairing (according to the reviewed works) was 335, more than 290 as resulted from the calculation done according to the provisions of the Instruction 300/1972 ; given this necessary, at the end of April the section had only 90 workers ;
- the keeping of the inadequate sleepers into the points and crossing is not accepted by the Instruction no. 314/1989, chapter II, art. 15, paragraph 11. The instruction provision stipulates that, after the exceeding of the term of 12 months for the keeping in the track of the inadequate sleepers, the unique safety measure should be the traffic closure on these points and crossing;
- the exceeding of the instruction replacement term of the inadequate special sleepers into the points and crossing is one of the causes that led to the situation in witch an important percentage of the railway events and accidents happen on the switches of the Romanian Railway Network;

- the lack of lubrication in the centre castings contrary to the Ukrainian and Romanian rules had a contribution at the lack of the bogie turning in the curve;
- the breadth of the tyre from the wheels of the first bogie of the wagon is 3 mm smaller than the minimum value stipulated in the annex 5, paragraph 2.3 from the PPV.

8.3. **Factors that had contribution**:
- the difficult drainage of the water resulted from the rains;
- the leakage of the powder goods from the wagons.

9. Proposals

1. Finding of the funds in order to assure o draining system of the pluvial water from the railway stations and marshalling yards;
2. Revision of the Instruction 300/1972 in order to achieve the real size of the maintenance and repairing activities;
3. Reanalysis of the possibilities of the sub-units involved in the tracks maintenance and repairing to perform specific works, correlating the existed staff with the total conventional Km for maintenance and repairing;
4. Reanalysis of the staff structure used in the tracks maintenance and repairing (in the section and at the railway suppliers) in order to assure the skilled workers and blue workers necessary (handicraftsman I, handicraftsman II and blue workers);
5. Revision of the sleepers census in order to draw up a plan for the replacement of the inadequate sleepers and for the establishing of the running conditions for;
6. At the next meeting between the Romanian Railway Freight Company – SNTFM CFR Marfa and the representatives of the Ukrainian Railway Network , they will be asked to comply with the provisions concerning the lubrication of the centre casting with the occasion of the transposing of the freight wagon with large gauge;
7. The Romanian Railway Freight Company – SNTFM CFR Marfa SA will take from the Ukrainian Railway Network only wagons with axles that comply with the provisions of the annex 5, paragraph 2.3 of PPV .

Annex 1

Study concerning the behaviour from the safety viewpoint against the derailment depending on the centre casting torque of the railway vehicles (lubricated plane centre casting, respectively non lubricated)

Because of the differences between the torque in the centre casting of the railway vehicles in the curve running , appeared at the lubricated or non lubricated plane centre casting, there is a consequence on the guiding force Y and implicitly on the report Y/Q. The purpose of this study is to establish the influence of a lubricated plane centre casting, respectively non lubricated, on the report Y/Q (the safety value against the derailment).

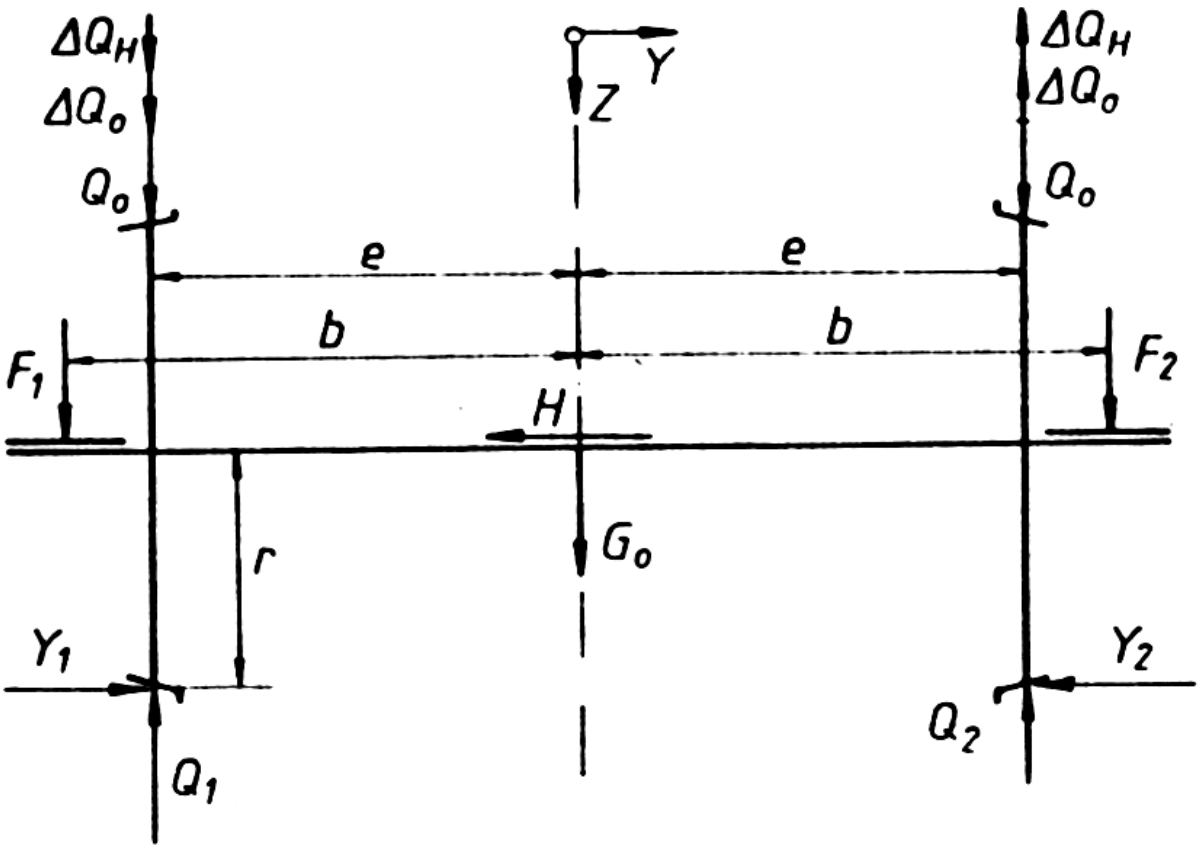


Figure 1. Load transfers on the vehicle axle

Calculation hypothesis:

- one takes the wear profile case “S78”, pointed, for witch the radius values depending on the movement against the medium axle of the track y_c are obtained through the Lagrange interpolation with three points (that has the same error as the square interpolation)
- one does not take into account the vertical elements of the friction forces at the wheel - rail contact,
- one takes into account the load transfer from one wheel on another.

Over-widening

R[m]	100-150	151-250	251-350
S[mm]	25	20	10

Over – raising

-for R < 350 m , $h[mm]=\frac{R[m]-50}{2}$;

-for R $\geq$ 350 m, $h=150mm$;

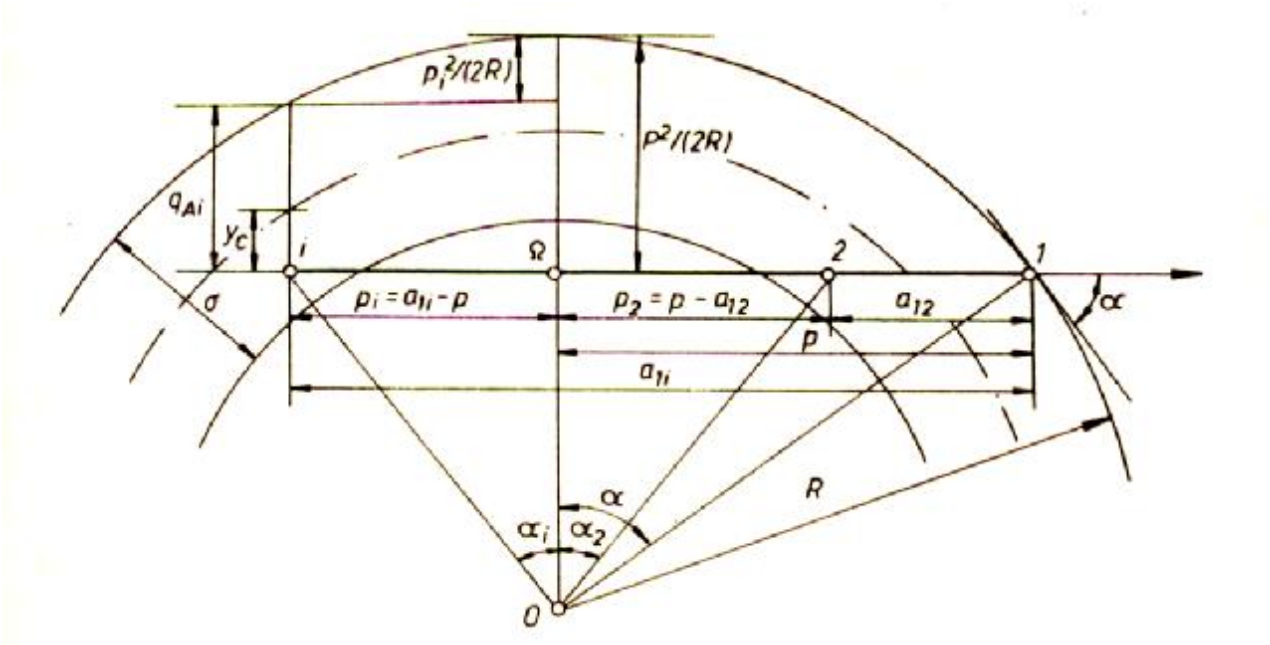


Figure 2. Impact of the clearance on the geometrical placing of the vehicle

The Ω base of the perpendicular line drawn from the curve centre of the track on the longitudinal axle of the vehicle is named pole, and the perpendicular line on this - polar centre

The distance from the first axle to the pole Ω is named polar distance

For the study of vehicle placing in curves one determines first the distance y between the pole Ω and the exterior stretches of rails of radius R

$$y=\frac{p^2}{(2R)};$$

q_{Ai} – the axle distance against its exterior stretch of rails, that establi its position in track ($q_{Amax}=\sigma$), that is the distance between the point A_{10} of the exterior wheel lip and the interior flank of the rail from the exterior stretch of rails

One takes a vehicle with n axles, a wheel base, placed in the curve with radius R, in free position.

Approaching to the exterior stretch of rails of an intermediary axle (figure 2) will be:

$$q_{Ai} = \left(p^2 - p_i^2\right)/(2R) = \left[p^2 - (a_{1i} - p)^2\right]/(2R) = (a_{1i}/R)\cdot(p - a_{1i}/2);$$

y_{ci} – transversal displacement against the medium centre of the track at the axle I, with positive sign at the movement to the curve exterior;

From here results the polar distance depending on the q_{Al}:

$$p = \frac{a_{1i}}{2} + \frac{R \cdot q_{Ai}}{a_{1i}};$$

The insufficient maximum over-raising accepted I=90 mm in our country.

s - gauge clearance;

$s = 10 + S$;

a_{1i} - distance between the axle 1 and the axle i;

$a = a_{1n}$ - wheel flange;

p_i - polar distance of the axle I, that is the distance from the axle I to the pole Ώ. The Sigh is positive if the pole is after the axle in the direction of traffic and negative if it is in front of the axle;

$p = p_1$ - polar distance of the axle 1, that is just the polar distance of the bogie;

$p_i = p_1 - a_{1i}$;

$p_c = \frac{a_{1n}}{2}$ - polar distance in the case of cord position;

$p_s = \frac{a_{1n}}{2} + \frac{R \cdot s}{a_{1n}}$ - polar distance in the case of secant position;

Sliding speeds between the wheels and the rails

$\Delta r_{e,i}$ - radius difference because of the movement with y_c on the exterior stretch of rails , respectively interior.

The signs convention is the next:

- on the exterior stretch of rails, at a positive movement of y_c (to the exterior of the curves) is obtained a positive movement Δr_e (to the wheel flange);

- on the interior , at a positive movement of y_c (to te exterior of the curve) is obtained a negative movement Δr_i (contrary to the wheel flange).At the movement y_c on the interior stretch of rails is also added the over – widening S.

$\Delta r_{e,i}$ is obtained through the interpolation with the polynominal Lagrange.

$$w_{e_x} = V\left[(1-K) + \left(\frac{e}{r} - K\frac{\Delta r_e}{r}\right)\right];$$

$$w_{i_x} = V\left[(1-K) + \left(\frac{e}{r} - K\frac{\Delta r_i}{r}\right)\right];$$

K – regime value;

$w_y = \frac{V}{r}$ - for free axle case;

$w_y = K\frac{V}{r}$ - for free axle in hauled or braking condition.

K = 1 - for the free axle case;
0 < K < 1 - for the axle in braking conditions;
1 < K < ∞ - for axle in braking conditions;

h - transversal distance against the transversal centre of the axle, where the running cone meets the rotation cone in hauling or braking conditions and of the taking into account of the load transfer between the two wheels of the same axle (there is a offset).

s - the height of the running cone;

$s = \frac{2(e + \sup ral \arg irea)}{\Delta r_e - \Delta r_i}$ This formula is valid for the wear profile and results from the similitude of the triangles formed by the running cone . The sign from the denominator is due to the signs convention adopted for $\Delta r_{e,j}$

$h = \frac{\Delta Q_0}{Q_0} e$; $K = \frac{s}{R}\frac{R+h}{s+h}$;

$w_{e_y} = w_{i_y} = -(p_1 - a_{1i})\frac{V}{R}$;

Sliding values

$g_{e,i_x} = \frac{w_{e,i_x}}{V}$ - sliding values on the in the direction x, on the exterior stretch of rails , respectively interior;

$g_{e,i_y} = \frac{w_{e,i_y}}{V}$ - sliding values in the direction y, on the exterior stretch of rails, respectively interior;

$g_{e,i} = \sqrt{g^2_{e,i_x} + g^2_{e,i_y}}$ - resulted sliding values;

Hertz values

$$(A+B)_{e,i} = \frac{r_{e,i} + r_s}{r_{e,i} - r_s} \quad ; \quad (A-B)_{e,i} = \frac{r_s - r_{e,i}}{r_{e,i} - r_s} \quad ; \quad \cos b_{e,i} = \frac{\left|(A-B)_{e,i}\right|}{(A+B)_{e,i}} \quad ;$$

where:
r - the radius of the nominal running tread;
r_s - the radius of the rail running surface; ρ_s=0,3 m.

$b[^o]$	90	80	70	60	50	40	30	20	10	0

m	1	1,128	1,284	1,486	1,754	2,136	2,731	3,778	6,612	∞
n	1	0,893	0,802	0,717	0,641	0,567	0,493	0,408	0,319	0

One does the interpolation with the polynominal Lagrange through three points, having the β angle value and will obtain the values m and n (on the exterior and interior stretch of rails)

$$g_{e,i} = \frac{a_{e,i}}{b_{e,i}} = \frac{n_{e,i}}{m_{e,i}} \quad ;$$

$a_{e,i}, b_{e,i}$ - semiaxis of contact ellipses on the exterior stretch of rails, respectively interior

g	1	0,9	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1
c_{11}	4,3	4,4	4,54	4,72	4,96	5,27	5,74	6,52	7,97	11,92
c_{22}	3,72	3,87	4,06	4,29	4,6	5,02	5,63	6,59	8,43	13,35

Also, through the interpolation with the polynominal Lagrange through 3 points are obtained c_{11} and c_{22}.

Interpolation with the polynominal Lagrange

Generally there is:

$$y = \sum_{i=1}^{n} \prod_{j=1}^{n} \frac{(x - x_j)}{(x_i - x_j)} y_i \quad ;$$

For the Lagrange interpolation through 3 points there is:

$$y = \frac{(x-x_2)(x-x_3)}{(x_1-x_2)(x_1-x_3)} y_1 + \frac{(x-x_1)(x-x_3)}{(x_2-x_1)(x_2-x_3)} y_2 + \frac{(x-x_1)(x-x_2)}{(x_3-x_1)(x_3-x_2)} y_3 \quad ;$$

Pofile constant value

$$K_{e,i} = m_{e,i} \cdot n_{e,i} \left[\frac{3\sqrt{G}(1-s)}{2(A+B)_{e,i}} \right]^{2/3} \quad ;$$

Where:

s = 0,3 - Poisson value;

G = 840 tf/cm^2 - transversal flexibility mode;

$G \cdot (a \cdot b)_{e,i} = K N_{e,i}^{2/3}$;

$N_{e,i} \cong Q_{0_{e,i}}$ - wheel load;

Decreased coefficient of pseudo-sliding χ

$$c_{e,i} = \frac{G \cdot (a \cdot b)_{e,i}}{N} \cdot \frac{c_{11} + c_{22}}{2} \quad ;$$

Friction coefficient m

$$m_{e,i} = 0{,}35 - 0{,}02425 Q_{0_{e,i}} + 0{,}001 Q_{0_{e,i}}^2 \ ;$$

Friction coefficients with pseudo-sliding

$$t_{e,i_x} = \frac{c_{e,i} g_{e,i_x}}{\sqrt{1 + \left(\frac{c_{e,i} g_{e,i}}{m_{e,i}} \right)^2}}$$ - on the exterior stretch of rails;

$$t_{e,i_y} = \frac{c_{e,i} g_{e,i_y}}{\sqrt{1 + \left(\frac{c_{e,i} g_{e,i}}{m_{e,i}} \right)^2}}$$ - on the interior stretch of rails;

$$t_{e,i} = \sqrt{t_{e,i_x}^2 + t_{e,i_y}^2}$$ - resultant.

Friction forces at the wheel-rail contact

$$T_{e,i_x} = -t_{e,i_x} \cdot N_{e,i} \ ; \qquad T_{e,i_y} = -t_{e,i_y} \cdot N_{e,i} \ ;$$

Friction moment in the plane centre casting

$$M_{FC} = D_{mediu} \cdot F_{FCrapodină} = \frac{D_{EC} - D_{IC}}{2} \cdot m \cdot \frac{M_{vagon} - 2 \cdot M_{boghiu}}{2} ;$$

The calculation will be done in 2 cases

1) without taking into account the friction moment in the centre casting (lubricated centre casting);

2) m =0.5 - non lubricated centre casting, so with a friction moment M_{FC} applied in the centre casting (actually one considers an increase of the friction coefficient with 0,5 in each case).

Equilibrium equations (of forces and moments) on the bogie generally

One writes the forces and moments equations, taking into account the load transfer, so the differences between the interior and exterior stretch of rails, for these 3 possible cases of placing the bogie in curve: free, secant and chord.

The signs convention is this classic: axis x has the direction of the track centre and the positive sign in the vehicle direction of traffic, axis y has the transversal direction of the track and the positive sign to the exterior of the curve, and the axis z has vertical direction and positive sign down.

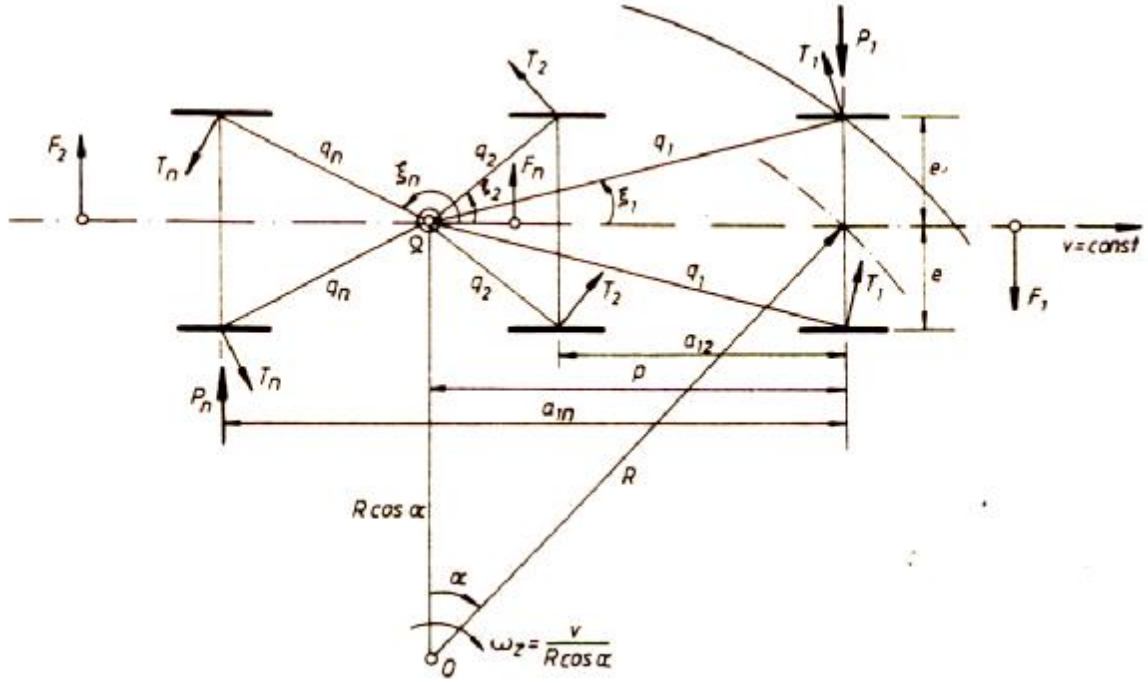


Figure 3. Model for the curve negotiation study of the of the bogie

Free position

$$-P_1+\sum_{i=1}^{n}T_{ey_i}+\sum_{i=1}^{n}T_{iy_i}+F_{cn}+F_v=0 \quad ;$$

$$M_{FC}-P_1p_1-\sum_{i=1}^{n}T_{ey_i}p_i-\sum_{i=1}^{n}T_{iy_i}p_i+(e-h)\sum_{i=1}^{n}T_{ex_i}p_i+(e+h)\sum_{i=1}^{n}T_{ix_i}p_i+(F_{cn}+F_v)\left(p_1-\frac{a_{1n}}{2}\right)=0 \quad ;$$

Secant position

$$-P_1+\sum_{i=1}^{n}T_{ey_i}+\sum_{i=1}^{n}T_{iy_i}+F_{cn}+F_v+P_n=0 \quad ;$$

$$M_{FC}-P_1p_1+\sum_{i=1}^{n}T_{ey_i}p_i+\sum_{i=1}^{n}T_{iy_i}p_i+(e-h)\sum_{i=1}^{n}T_{ex_i}p_i+(e+h)\sum_{i=1}^{n}T_{ix_i}p_i+(F_{cn}+F_v)\left(p_1-\frac{a_{1n}}{2}\right)-P_n(a_{1n}-p_1)=0$$

Chord position

$$-P_1+\sum_{i=1}^{n}T_{ey_i}+\sum_{i=1}^{n}T_{iy_i}+F_{cn}+F_v-P_n=0 \quad ;$$

$$M_{FC}-P_1p_1+\sum_{i=1}^{n}T_{ey_i}p_i+\sum_{i=1}^{n}T_{iy_i}p_i+(e-h)\sum_{i=1}^{n}T_{ex_i}p_i+(e+h)\sum_{i=1}^{n}T_{ix_i}p_i+(F_{cn}+F_v)\left(p_1-\frac{a_{1n}}{2}\right)+P_n(a_{1n}-p_1)=0$$

The unknowns are the polar distance p_1 and the guiding forces P_1 , respectively P_n for the secant and chord positions. One has only two equations, so the system can not be directly solved in the cases of secant and chord positions. But in the free position one has no guiding force at the last axle, so the system can be solved in this case. This system has the particularity that although the friction forces are known for each position occupied by the bogie through the polar distance that comes into the calculation formula, has no linear variation, being used the interpolation during the calculation of the Hertz coefficients. That means that only one approximate solved method can be found. A solved way is this graphic graphic, with the curves M D Z. Another way is given by the numerical methods for calculation, approximate way at witch is established the desired precision , and then, through successive iterations is determined the solution. In this application was used the bisection method or the interval reducing to one half method.

So, solving the system of free position one obtains the value of the polar distance.

After that, one will discuss:

- if $p_c<p<p_s$ results that the bogie in free position, so one can establish directly P_1 and p_1.
- if $p<p_c$, results that the bogie is in chord position and replacing in the system of the chord position the value of the polar distance $p=p_c$, result the guiding forces $P_1$and P_n.
- if $p>p_s$, results that the bogie is in secant position and replacing in the system of the secant position the value of the polar distance $p=p_s$, result the guiding forces P_1 and P_n

Guiding force: $Y = P_1 - T_{ey_1} - T_{iy_1}$;

Maximum running speed in curve: $V_{\max} = \sqrt{\frac{R}{11,8}(h+I)}$;

Total uncompensated Centrifugal force distributed on the bogie will be

$$F_{cn} = F_{cn_{boghiu}} + F_{cn_{cutie}} = \left(\frac{V^2}{3,6^2 \cdot R} - g\frac{h}{2e} \right) \left[G_{s_{boghiu}} + \frac{G_{cs}}{2}(1+S) \right] ;$$

S – vehicle flexibility coefficient. One considers S=0,3

The force given by the pressure of the wind, distributed on the bogie: $F_v = \frac{F_{cv}}{2} + F_{bv} = \frac{S_c}{2}W + S_b W$;

W - specific pressure of the wind ;

Load transfer: $\Delta Q = \frac{F_{cn}h_c + F_v h_v}{2e}$;

In this study one considers the tank wagon on the bogies type Diamond CSI, no. 82535765377-6, involved in the investigated derailment , occurred on the 22nd of February 2007 on the switch 47A in the railway station Dej Triaj, with the next characteristics:

- bogies type Diamond CSI with the pitch of 1,80 m;
- the exterior diameter of the centre casting D_{EC}=0,308 m
- the interior diameter of the centre casting DI_C=0,073 m
- the medium diameter of the centre casting D_{medium}=0,1905 m
- the radius of the nominal running tread r=0,6 m
- wagon tare =34,1 t
- load limit of the wagon=48,9 t
- total weight of the wagon M_{wagon}=83t

- load on wheel Q_0=10,375 t
- bogie weight M_{bogie}= 4,6 t
- axle weight M_{axle}= 1,1 t
- weight of the bogie lateral frame $m_{lateral\ frame}$ =0,7 t
- sprung weight of the wagon $M_{body} = M_{wago} - 2xM_{bogie}$ = 83 – 2x4,6=73,8 t
- lateral surface of the (tank wagon) body=30m^2;

The data resulted from the commission measurements at the switch 47 A in the railway station Dej Triaj

- gauge on curve (measured in point. 2) 1435+25=1460mm
- R=190m

The calculation was done in these 2 cases:

1) **without taking into account the friction moment in the centre casting (lubricated centre casting).**

The following values resulted:

- maximum running speed in a curve with a radius of 190m=50,76 km/h; the calculation speed (according to the regulations for the running on switches) = 30km/h
- centrifugal force on the bogie = 3,85 kN
- force given by the wind pressure =7,90 kN
- guiding force at the axle 1 = P_1 = -45,58 kN
- guidance force of the axle 1:
- load on the wheel from the exterior of the curve at the axle 1
- safety coefficient against the derailment

2) **μ=0,5 – non lubricated centre casting, so with friction moment M_{FC} applied to the centre casting (actually is considered an increase of the friction value with 0,5 in this case**).

The following values resulted:

- maximum running speed in a curve with the radius of 190m=50,76 km/h; the calculation speed (according to the regulations for the running on switches) = 30km/h
- centrifugal force on the bogie = 3,85 kN
- force given by the wind pressure = 7,90 kN
- guiding force at the axle 1 = P_1 = -48,33 kN
- guiding force of the axle 1:
- load on the wheel from the exterior of the curve at the axle 1;
- safety coefficient against the derailment

The conclusion is that between the lubricated centre casting case and this of non lubricated one, the leading force increases with 6,03 % and the safety coefficient against the derailment (report Y/Q) increases with 0,02, that allows to consider that the non lubrication of the centre casting is a favoring factor and not a direct cause of the wagon derailment.

Study drawn up by
Laurențiu Dumitru
Director of the Romanian Railway Investigating Body

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