The operation of trams on a tramway track in Košice, and their technical issues

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Abstract. Public passenger transport in the city of Košice is using the Vario LF2 + trams. However, there have been dangerous accidents of brake disc rupture during operation of the tram in operation and in the following article we analyzed the causes and suggested a solution to eliminate this dangerous phenomenon in the transport process.

1. Introduction

There in Košice the public passenger transport is besides others carried out by means of trams operated with Dopravný podnik mesta Košice (DPMK a.s.). The modernisation of old vehicles with new ones was financed with the EU funds through the Operational Programme "Transport" in the program period 2007-2013 and through the Operational Programme "Integrated Infrastructure" in the program period 2014-2020. There were 46 trams provided altogether. Technical issues began to show up in case of trams with serial numbers 841 and 832 [6].

A tram of a Vario LF2+ type is a six-axle two-unit tram intended for a one-way operation. Its prototype was manufactured in 2009. From the conceptual point of view it comes out from the Vario LF2 type, and the main difference lies in a new type of chassis thanks to which the high-floor part could have been lowered. Both entrances between chassis of the vehicle are barrier-free, and there is one step at the marginal entrances into the vehicle. Fig. 1. represents the tram of the Vario LF2+ type, and technical parameters of the vehicle are listed in Table 1.

Figure 1. The Tram of the Vario LF2+ Type [6].

2. Description of the Tram

The support structure of VarCB3 - LF2+ body is welded; it is a light steel construction with an anticorrosive finish with laminated heads of Pelikán design [15]. The outermost body-sides are made of polyester glass laminate mounted via a glue application on the body shell. The head sections of outermost units are reinforced. The cabinets of the tram are carried with three driving chassis
Komfort+ which are conceptually designed as rotational ones with a two-stage spring loading and a bolster which handles a mechanical coupling of the cabinet with the chassis. The coupling of cabinets on the middle chassis is at the same time created with a tram joint and it carries the interior parts of both tram cabinets.

Each chassis is driven with two asynchronous engines. The current collection is provided with a half-pantograph Lekov EPDE 17-2600. In case of braking the energy is recuperated to auxiliary consumptions of the vehicle and to the trolley network with priority. On the roof of the vehicle there are 3 containers of drive placed in total; on the unit A there is one container, and on the unit B two containers provide the power supply of traction engines.

The entrances of outermost units from outer sides of chassis have one step which is 250 mm high; a sill is 350 mm high from the top of the rail. The other entrances have the entry level height of 350 mm from the top of the rail and they are without any steps. The interior steps there in passages of A and B units and there above chassis are created with one step overrunning a difference in height of 190 mm. A low-floor part creates 43% of the overall floor area of the tram. All windows on the body feature a structural glazing; windows away from the vehicle's head and windows with monitoring panels are sliding ones. There are 4 doors serving for the entrance into the vehicle. The interior of the vehicle is equipped with anti-slip flooring and with seats STER MX with textile upholstery covers [6]. Technical parameters of the tram are represented in Table 1.

### Table 1. Technical Parameters of the Vehicle [6].

| Parameter                        | Value                        |
|----------------------------------|------------------------------|
| Length                           | 22,600 mm                    |
| Length with Couplings            | 23,700 mm                    |
| Width                            | 2,480 mm                     |
| Height                           | 3,185 mm                     |
| Operating Height                 | 3,590 mm                     |
| Height of Floor                  |                             |
| 350 mm (door No. 2 and 3)        |                             |
| 650 mm (door No. 1 and 4)        |                             |
| Wheelbase                        | 1,900 mm                     |
| No. of Doors                     | 4                            |
| No. of Seats                     | 44                           |
| Standing Capacity                | 131 (5 persons/m²)           |
|                                  | 210 (8 persons/m³)           |
| Total Capacity                   | 254                          |
| Kerb Weight                      | 30,000 kg                    |
| Gross Weight                     | 47,780 kg                    |
| Electric Equipment               | Škoda Electric, with an      |
|                                  | asynchronous transition of   |
|                                  | power                        |
| Engine                           | Pragoimex TAM 1003C/K        |
|                                  | (600 V), 4-pole asynchronous  |
| Engine Power                     | 70 kW                        |
| Number of Engines                | 6                            |
| Total Power                      | 420 kW                       |
| Maximum Speed                    | 65 km/h                      |

3. A Proposal for Solving the Arisen Issue of the Brake Disc's Destruction during a Drive

To find out the reasons why the incidents mentioned above arose there was an investigative committee established; it included representatives of Pragoimex a.s.; Škoda Electric a.s.; the Ministry of Transport and Construction of the Slovak Republic; DPMK, a.s., and two independent experts. The committee held meetings on 21 February 2019, 7 March 2019, 22 March 2019, 27 March 2019, 28
March 2019, 15 April 2019 and 29 April 2019; step by step it analysed all available materials: recordings from cameras in the vehicles, records from the tachographs, records from the vehicles' GPS, records from the diagnostic devices, records on failures, results of metallurgical tests of the brake disc, witness statements of respective employees of DPMK, a.s., and other expert data regarding the incidents in order to reach the reason for incidents in the rail vehicles of the VARIO LF2+ type with the Reg. No. 841 and No. 832 [2, 14]. On 29 April 2019 a burst test was performed on the vehicle with the Reg. No. 832 in order to verify the function of protective elements preventing any part of the chassis to get to the interior of the vehicle. During the burst test the audio and light alarm of the drive with non-released brakes of the chassis was working.

The committee agreed on facts which could have led to the destruction of the brake disc (Figure 2). The most probable initiatory defect was a leakage in traction engines' terminal boxes, caused with splashing water from vehicle's chassis wheels. This fact is also supported with the state of the railway tramway track in Figure 3. There was no alarm signalling the failure of brakes, however, a failure of the engine unit 3 was signalled. Thus, the tram driver did not pay attention to the failure and continued in the drive with two traction units on two chassis. Besides the monitors of the diagnostic system often display unreal failures which the drivers use to ignore in the course of time. A drive with a stalled chassis should definitely be prohibited, but the manufacturer of the electric part, Škoda Electric, enables it in order for a tram to get out of a crossing or even to the depot for a repair in a state of emergency. This failure was provably detected; there on multiple sections of the tram's drive the brakes were applied and they stopped working after some time. The tram's drive enables a passage even in case of a higher water level up to the depth of 60 mm on the tramway, but in fact there even occurred conditions with the water depth up to 100 mm. In Figure 4 we can see the placement of the brake disc on the tram axle and the placement of a protective cover above the brake disc.

Based on the inspection of the suggested protection of the tram floor there were also conducted mathematical-model re-calculations of resistance of the protective stainless plate below the floor per the software support in Abaqus program, which are represented in Figure 5 [1, 4, 5]. Subsequently on the basis of an expert analysis of the given materials the following solutions were suggested; they should ensure a safe and smooth operation of vehicles in DPMK. The following measures were suggested:

- to carry out a replacement of terminal boxes for traction asynchronous engines on individual chassis of vehicles with the Reg. No. 832 – 846 and to prevent water leakage into them [9],
- a technological and geometric adjustment of the track was suggested in order to remove steady water on the tramway,
- upon the approval of the SW update in the Ministry of Transport and Construction of the Slovak Republic and the subsequent installation into vehicles to unlock the SW of vehicles for the speed of 65 km.h\(^{-1}\); the handbook of vehicles was updated,
- new technological procedures were implemented for each type of vehicles' maintenance, upon the consultation with the manufacturer to re-evaluate operations and km run for the sake of the maintenance of the brake disc M1,
- to update all technological procedures for each type of maintenance of the rail vehicle, VARIO LF2+ type, upon the consultation with the manufacturer [7, 8],
- due to a potential destructive state of the brake disc there was a cover plate installed on the floor below the vehicle. This cover plate was mounted on all vehicles. A cover plate is a sheet with 3 mm in thickness made of austenitic corrosion proof steel X5CrNi18-10, Figure 6 [13],
- a check of the ERB2 brake control unit's setting was conducted and a function of an increased voltage for a brake valve was added [10, 11, 12].
Figure 2. The brake disc damaged with cracks source.

Figure 3. The condition of the tramway track on days when the incident happened [3].

Figure 4. The brake disc on the tram's axle.
4. Conclusion

On the basis of detected facts the cause of the failure could have been identified and removed. Such failures have not occurred anymore since this adjustment and the trams mentioned above have been driving without any failures so far.
References

[1] Bocko J 2019 Simulácia deštrukcie brzdového kotúča v softvérivom prostredí Abaqus, Research report (Košice)

[2] Kováč M, Hinčica L 2020 Incidenty na električkách TWT Vario LF2+ v Košiciach Československý dopravák, http://www.cs-dopravak.cz/

[3] Minutes of the sitting of the committee regarding the reasons of exceptional occurrences (incidents) in case of vehicles Vario LF2 plus with the Reg. No. 841 and 832 of 20 January 2019 and 25 January 2019

[4] Trebuňa F, Bocko J, Pástor M, Lengvarský P, Prada E 2018 strojnický Casopis Open Access 68(4) 41

[5] Trebuňa F, Šimčák F, Bocko J, Lengvarský P, Pástor M 2016 EAN 2016 - 54th International Conference on Experimental Stress Analysis 123122

[6] TWT Pragoimex VarioLF2+ https://imhd.sk/ke/popis-typu-vozidla/763/TWT-Pragoimex-VarioLF2

[7] Bartosova V, Majercak P, Hraskova V 2015 ICOAE 2015 24

[8] Majercak P, Majercakova E, Nedeliakova E 2014 Transport Means 2014, Kaunas, Lithuania

[9] Nedeliakova E, Nedeliak I, Majercak P 2014 ICMIBI 2014 Bangkok, Thailand

[10] Majercak P, Kliestik T, Masarova G et al 2013 Nase more 60 5-6

[11] Majercak P, Cisko S, Majercakova E 2013 The impact of theory of constraints on the management accounting. 7th International Days of Statistics and Economics (Praque)

[12] Majercak P, Majercak J 2015 Conference: 3rd International Conference on Education Reform and Management Innovation (ERMI 2015) Pt 1 Book Series: Advances in Education Research 78 151

[13] Kudlac S, Majercak J, Majercak P 2017 Transportation Research Procedia 28 45

[14] Kudlac S, Majercak J, Mankowski C 2017 Procedia Engineering 192 510

[15] Kurbatova A et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 403 012231