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ANALYSIS OF DEFECTS DISTRIBUTION OF FLEET OF HYBRID BUSSES

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Abstract
The paper presents analysis of defects distribution for the fleet of hybrid busses. The research was conducted in public transport company with the fleet of innovative milti-hybrid busses. The busses were eqipped with CNG diesel engine and electric engine. It was innovative construction based on CNG busses. The scope of research contained period of exploatation about 2 years.

Keywords
Hybrid bus, defect, fleet management

1 INTRODUCTION

Urban transport emits around 25% of CO_2 from total transport. More than 11,000 travels on the roads of Polish cities buses. Currently, the main source of the drive of public transport vehicles are self-ignition engines powered by diesel oil derived from crude oil processing [1]. Thus nowadays direction of development is focused on eco-friendly vehicles. An important direction for the development of the electric bus market is the creation of uniform interfaces available to all manufacturers. Agreement on this issue was signed by European electric bus manufacturers - Irizar, Solaris, VDL and Volvo along with suppliers of ABB, Heliox and Siemens charging systems [2]. One of the other solutions that limits CO_2 emissions to the atmosphere is the introduction of alternative compressed natural gas (CNG) as a fuel. Public transport vehicles are increasingly driven by CNG compressed engines stored up to 20 MPa stored in a vehicle in specially designed steel or lighter composite cylinders. The percent of gas-powered buses (LNG) is also growing. In these solutions, a hybrid drive is used with an opposite strategy to diversify the use of energy sources. The electric drive is used when starting off, while the rest of the road is overcome by means of an internal combustion engine.

The most ecological (zero-emission) vehicle used in public transport is an electric bus powered by high-powered lithium-ion batteries. There are three main methods of battery charging in electric buses: through the pantograph, induction loop and plug-in or battery charger. Due to the specific conditions of use of public transport vehicles, which are characterized by a high frequency of stops and starts and driving on short distances, often under congested traffic conditions, the principle of hybrid drives allows a significant reduction in fuel and energy consumption [3].

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2 HYBRID BUSSES

In a hybrid bus, the combustion engine operates under a lower load and is supported by an electric motor, which results in lower fuel consumption and the intensity of engine wear and lower operating costs.

Currently, many innovative solutions in the field of hybrid multirike vehicles can be found on the market [4,5]. An example is a multi-drive hybrid city bus that has 3 power sources: a ZS engine, a CNG installation and an electric motor. The construction is based on the concept of a series hybrid fueled with CNG fuel. The combustion engine has no connection to the propeller shaft, it is responsible only for the drive of the electric generator. In addition, installed supercapacitors accumulate surplus energy from recuperation. The principle of operation is as follows. During normal driving, the combustion engine acts as a generator that powers the electric motor. Thanks to that, the combustion engine most of the time works at a speed of approx. 1550 rpm, which ensures optimal consumption of CNG. Additionally, the recuperation mechanism was used as energy recovery during the braking process [6]. An electric motor acts like a generator and generates electricity that is stored in supercapacitors. When driving using energy stored in supercapacitors, the electric motor uses the energy stored in the capacitors. In addition, when stationary at stops, when the combustion engine is running at a speed of 550 rpm, additional electrical energy is generated and stored in capacitors (supercaps). The basic elements of the drive and power systems are shown in Fig. 1.

Fig. 1 Elements of a hybrid bus with drives: ZS-CNG-electric

3 RESEARCH AND ANALYSIS

The research was conducted in big public transport company in Poland. Due to trends, the company has extended its fleet with new hybrid busses [7-9]. The aim of the research was analysis of reliability and defect on early stage of operation for the vehicles until 30000 km mileage. As part of the research, a detailed analysis of emergency conditions occurring in hybrid buses in the initial period of their operation was made. Additionally, an analysis of repair activities carried out by the manufacturer's factory service as well as mechanics employed in the communication company was carried out. On the basis of the workshop records, the most frequently occurring symptoms of failure were identified as well as information on methods and methods of their removal were obtained.

As the results, the defect distribution matrixes have been obtained. Such collection of data enable to conduct many statistical analyses and to observe technical issues important for fleet management.

The example of collected report of defects for two exemplary busses have been depicted in table 1. For the analysis, the group of 15 articulated hybrid busses were observed. The defects distribution for this group of fleet have been depicted in figure 2.

Tab. 1 Hybrid busses defects reports

l.p.	bus number	date of defect	defect type - reported																										
			It does not charge condensers	Disconnects the drive	The engine can not be started	During braking, the electric engine fault lamp lights up. "M" (yellow)	The "M" engine malfunction indicator is lit (red)	The fault lamp for the electric motor illuminates. "M" (yellow)	Displays the fault of the electric motor "M"	Displays the fault of the combustion engine	No power, driving with limited speed	Automatic shutdown of the internal combustion engine	Discharging super condensers too fast	Incomplete charging of super condensers	No charging or the possibility of discharging the condensers	Uneven operation of the internal combustion engine	E Auto Component Error Display (09)	The condenser control lights up	Gas leak from the heating installation	Disrupts gears while driving	Puncture on condensers	An unskilled computer	Fire in the engine compartment	Articulation failure	Failure of the wrist driver	Damaged attachment of the turbocharger	Cash register failure	Failure of monitoring
1	1	2016-01-18																									1	
2		2016-03-03		1																								
3		2016-03-16																					1					
4		2016-07-22		1			1	1																				
5		2016-07-26																									1	
6		2016-08-02																									1	
7		2016-08-04						1																				
8		2016-08-05								1																		
9		2016-08-18		1																								
10		2016-09-02		1							1																	
11		2016-09-15							1																			
12		2016-09-27		1							1																	
13		2016-10-14		1																								
14		2016-10-29		1																								
15		2016-11-04			1																							
16		2016-11-06		1																								1
17		2016-11-07	1																									
18		2016-11-23	1	1	1			1																				
19		2016-12-16			1																							
20		2016-12-18		1									1															
21		2016-12-20			1																							
22		2017-03-02												1														
23		2017-03-03		1																								
24		2017-03-26		1																								
25		2017-03-31										1																
26		2017-04-04		1																								
27		2017-04-06		1																								
28		2017-04-24											1	1														
Sum			2	14	4	0	1	3	1	1	2	1	1	2	0	0	0	0	0	0	0	0	1	0	0	0	3	1
1	2	2016-01-18																									1	
2		2016-01-25		1	1													1										
3		2016-03-02			1																							
4		2016-03-04		1					1																			
5		2016-03-10					1		1																			
6		2016-04-14			1																							
7		2016-04-29			1																							
8		2016-07-05					1																					
9		2016-07-06			1																							
10		2016-07-14		1										1														
11		2016-07-21		1										1														
12		2016-07-29		1			1	1																				
13		2016-08-01		1																								
14		2016-08-30		1																								
15		2016-09-09		1				1																				
16		2016-09-19															1											
17		2016-09-24		1																								
Sum			0	8	4	0	2	2	2	0	0	0	0	2	0	0	1	1	0	0	0	0	0	1	0	0	1	0

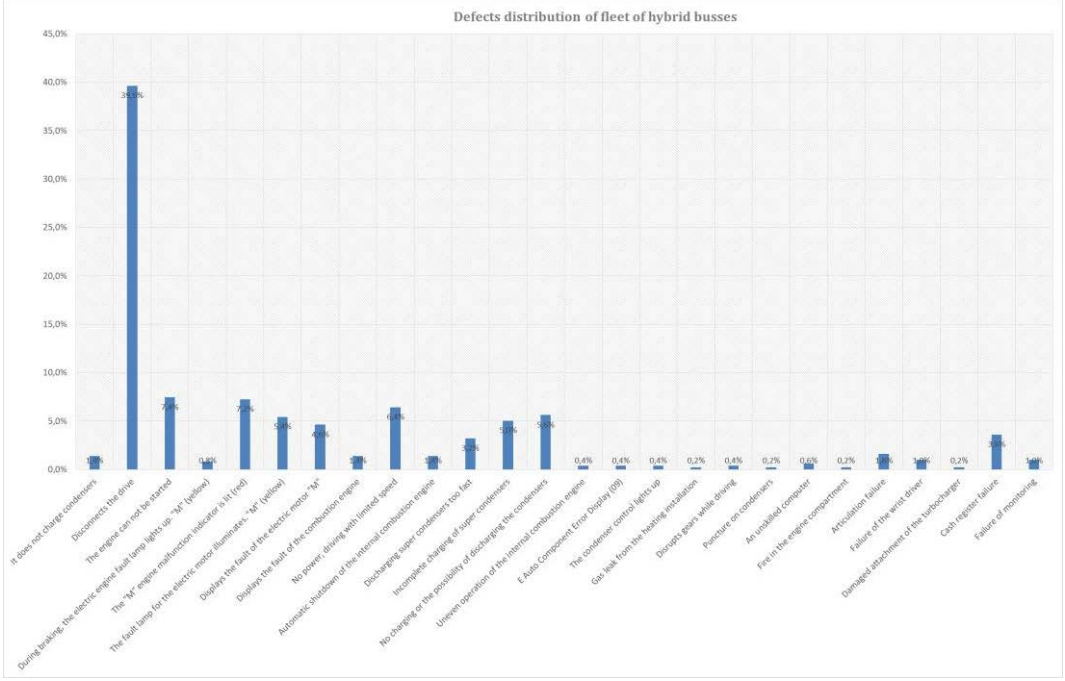

Fig. 2 Defects distribution of fleet of hybrid busses

4 CONCLUSION

The paper presents the preliminary research on fleet management issues of new hybrid busses in public transport company. Innovative technologies and new eco-friendly busses require new view in the reliability and maintenance issues for the fleet management. The concept of defects matrix as big data collection is simple method for data base analysis. Emergency state matrix prepared on the basis of the bus repair and maintenance records was developed. On its basis, the indicators of failure symptoms and indicators of failure removal methods presented in the following charts were determined.

On the basis of conducted analyzes carried out for the selected group of hybrid articulated busses, especially in the frequency of their occurrence, it can be noticed that failures revealed in particular construction and execution faults occurring at the stage of production of these vehicles resulting in shutting down vehicles as well as collision situations posing a direct threat to the safety of other vehicles and transported passengers.

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