DIAGNOSTIC INFORMATION MODEL OF A MILITARY VEHICLE

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Abstract

This study presents a diagnostic concept, the cybernetic structure and the physical model of the Autonomic Logistics System, a diagnostic sub-system implemented in the Tarpan Honker military vehicle. The system supports the driver in the process of making decisions regarding the vehicle's condition and key operating parameters. The information model reporting on the status and faults of power transmission system components will not identify limit state values. Limit state values will be identified after the vehicle has been tested with an implemented diagnostic system. An RS-485 type communication and data transmission system with linear (serial) half-duplex technology was designed for the proposed monitoring and diagnostic system.

The developed data transmission topology (number of transmitters and receivers) accounts for the vehicle's unique structure, operating requirements, system functionalities and structural feasibility. The proposed transmission system supports quick data transfer between modules (devices) monitoring selected systems and mechanisms.

The system minimizes the number of sensors and signal cables through the multiple use of measuring sensor signals. The proposed system is an open structure which supports data transfer between control devices supplied by different manufacturers;

Keywords: *transport, diagnostic, transmission system, transmission topology, RS-485*

1. Introduction

Contemporary military vehicles are technically and functionally complex machines. Vehicle design has to meet the following requirements: simple structure, high mobility, reliability and operational durability. Designers find it very difficult to combine the above attributes which can be mutually exclusive in certain areas. When deployed for combat purposes, a military vehicle has to perform a given task regardless of its technical condition. The crew should have access to information indicating whether the military operation has any chances of success in view of the vehicle's condition. A contemporary combat vehicle should be equipped with tools that support decision-making during mission performance. Such tools should provide the crew with vital information about the vehicle's technical condition and functional parameters that determine the operation's success.

The results of structural and functional analyses of multi-purpose military vehicles suggest that factory built-in devices for communicating data to the driver are often functionally deficient and illegible under difficult combat conditions. They are unable to prognosticate the vehicle's status or identify the technical condition of the vehicle's key structural systems, thus minimizing the efficiency of the decision-making process.

The presented diagnostic information model is modular logistics platform that gathers data and supplies the driver with crucial information about the vehicle's technical condition and functional status with the use of various stimuli (visual and audio signals).

2. Structure of the diagnostic model

The principles and methods for developing a diagnostic model of a military vehicle have been described in detail in studies [2,3,4]. This paper will discuss the efforts to identify and build a physical model of a diagnostic system for identifying the technical condition of the power transmission system in the Tarpan Honker vehicle with the involvement of the Autonomous Logistics System (ALS). As part of the diagnostic process, the power transmission system of the investigated military vehicle has been split into five decomposition levels. A homogenous five-level structural model of the studied vehicle has been developed. Level 5 combines basic components, and it describes the depth of structural penetration. Damage localization takes place at level 5.

A set of basic components has been created on the assumption that a diagnosis of all vehicle elements is possible but not justified. The set accounts for basic components which, in the authors' opinion, need to be diagnosed to determine the vehicle's general ability to perform a combat mission. The methodology for developing vectors of diagnostic parameters, describing information models and their characteristics has been presented in papers [2, 4]. In the modelled diagnostic system, faults are identified in a two-fold classification system, which is identical for all symptoms. The vehicle's condition may be determined during diagnostic tests. In the proposed diagnostic sub-system, a given set of checks are performed (signal parameters are measured with the use of sensors), and the resulting data are analyzed.

The following diagnostic methods have been deployed in the modelled system for diagnosing the vehicle's power transmission system:

- periodic – for the transfer case, final drives and differential gear of driving axles (identification of excessive clearance in toothed gear);
- continuous – for the other elements of the power transmission system and electrical wiring.

In line with the methodology of building hierarchical diagnostic models of military vehicles, a set of diagnostic parameters has been created for the investigated object. A set of physical measurement values was developed, including a multi-dimensional set with a cybernetic model where a diagnostic information algorithm was implemented for the Tarpan Honker vehicle [2].

3. Cybernetic structure of actuating elements in the diagnostic system

An RS-485 type communication and data transmission system with linear (serial) half-duplex technology was designed for the proposed monitoring and diagnostic system. RS-485 is a standard data transmission system designed for multipoint transmission lines. Unlike other standards, which usually contain comprehensive specifications, RS-485 defines and limits only the electrical characteristics of the system [5]. The RS-485 standard was developed in the 1980s as an Electronics Industries Association (EIA) specification [1], and it quickly found a variety of industrial, medical, automotive and utility applications. The standard RS-485 topology comprises a data bus with half-duplex transmission where devices take turns in receiving and transmitting data.

Interface implementation requires a protocol that controls all nodes with the use of control signals that identify the device's status and its readiness to receive or transmit data. The above solution eliminates situations in which more than one device requests network access at the same time. The described protocol has to be implemented to prevent several devices from competing for the ability to transmit data.

The receiver and the transmitter communicate as follows: the transmitter has differential output voltage of minimum 1.5 V, whereas the receiver picks up differential signals with a minimum value of 200 mV. Those values guarantee reliable transmissions, even if significant signal loss is reported along different components of the transmission path.

Differential signalling that involves a twisted pair (similarly to CAN network) is an advantage of the proposed solution and the RS-485 standard because external noise has an identical effect on both signal lines. The common mode signal is eliminated in the receiver's differential input. This is the main reason why the RS-485 standard is used in wide area networks and under difficult industrial conditions where data transmission may be disrupted by external sources of noise.

The functional structure of the proposed diagnostic system and data transmission topology are presented in Figure 1. The data transmission structure relies on the RS-485 standards for which five transmission-receiver modules have been designed (module No. 5 is the master module).

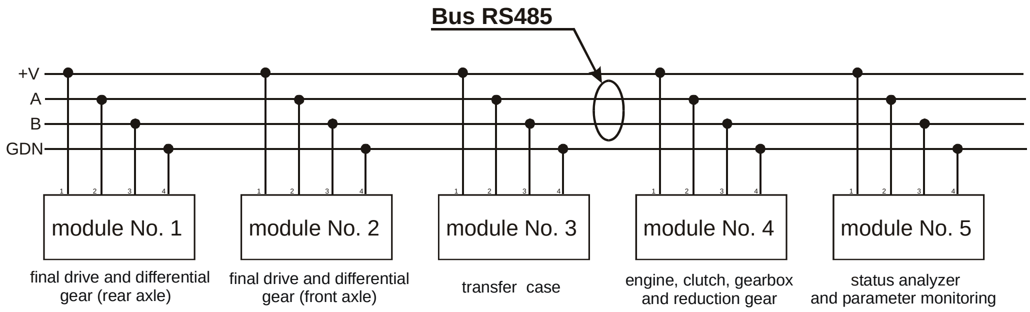

Fig. 1. Functional structure of the diagnostic system and the data transmission system with an indication of the main system components, +V – power supply, GDN – ground, A, B – bus signal line

3.1. Structure of communication protocols

Based on the data (information) supplied by the internal protocol (RS 485 standard), each module (receiver and transmitter) generates an electrical signal which is transmitted to the data bus (data bus bar or data transmission network). In the designed system, data are transmitted to the data bus every 250 ms. According to the authors, in the monitored systems, this time interval is sufficient to identify the fault and the observed parameters. According to estimates, the computing power of the Atmega2560 control processor in each module will be deployed in 50%. The operation of the RS-485 data bus is described on the example of module No. 1, which monitors the final drive, and the differential gear of the vehicle's rear axle. The data protocol generated by any module connected to the bus is fed to both bus cables with opposing signals to protect the signal from interruptions caused by other electrical devices or magnetic fields. The data transmission protocol comprises several fields (data frames). A graphic interpretation of the data protocol for module No. 1 is presented in Figure 2.

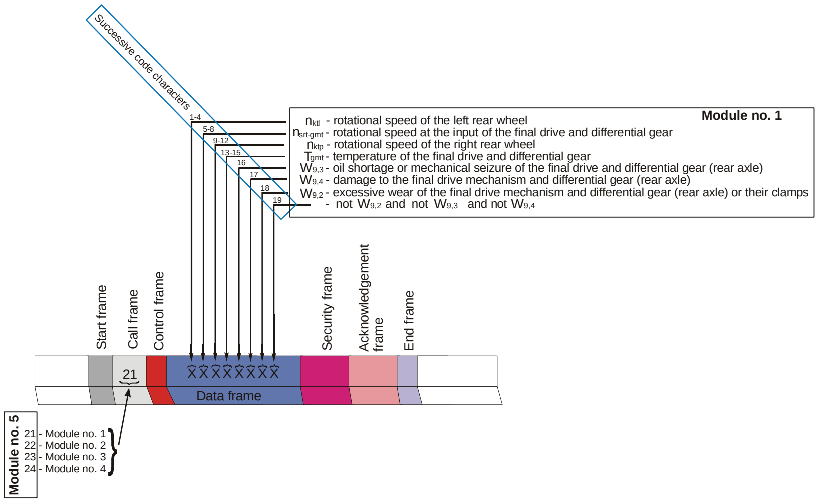

Fig. 2. Principal structure of the data protocol generated by module No. 1

The information confirming that data have been transmitted to a selected module is sent via the call frame. In the analyzed example, module No. 5 fills the data frame with code "21" and sends the inquiry to module No. 1. Code "21" means that module No. 1 can transmit data, and a data frame comprising a sequence of 19 characters describing the parameters or statuses monitored by module No. 1 appears in the data signal frame. The code is encrypted by receiver-transmitter module No. 5, and the relevant information is displayed in the graphic interface. Figure 2 frames that are not described above are part of the internal structure of the RS-485 transmission standard, and they are not programmable.

4. General structure of a diagnostic system

A physical model of an on-board diagnostic and monitoring system for the Tarpan Honker military vehicle has been developed. The location of actuating modules in the vehicle is presented in Figure 3.

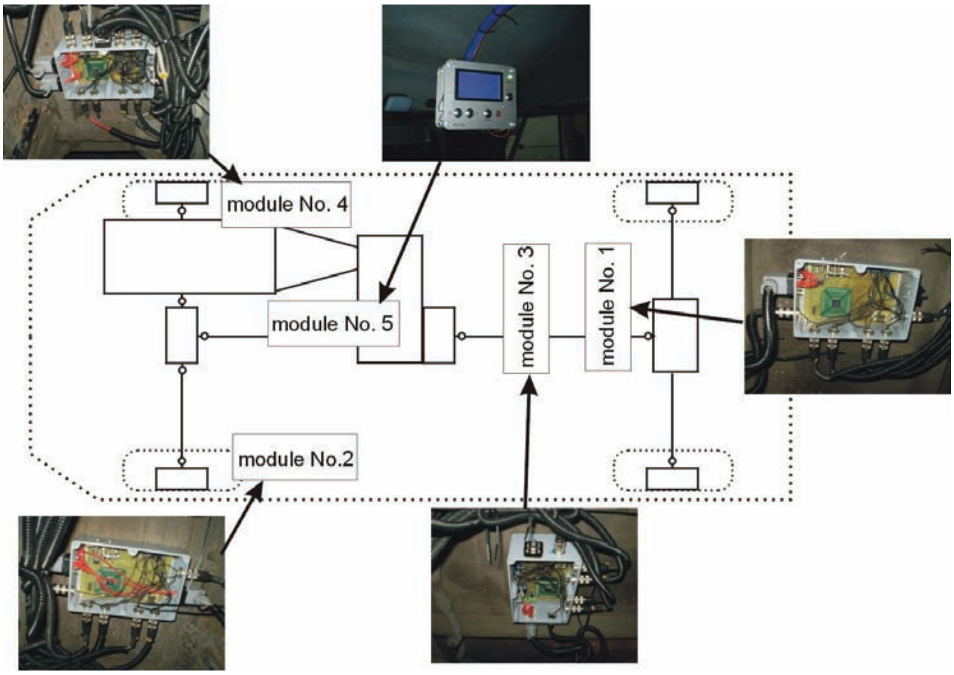

Fig. 3. Location of actuating modules in the Tarpan Honker vehicle

Receiver-transmitter actuating modules (modules 1, 2, 3 and 4) have been placed in aluminum boxes and mounted under the chassis. Receiver-transmitter module No. 5 was placed in the driver's cab above the internal rearview mirror. The modules were linked by a network of data transmission and feed buses. The modules were also connected to measuring sensors with multipin plugs and connectors. Most measuring sensors were installed separately, and they did not constitute built-in vehicle equipment. The implemented system is independent of the vehicle's internal circuits, therefore, if damaged or not activated, it does not affect the vehicle's mission performance. Modules 1 to 4 are twin modules that differ only in the number and type of measuring sensor inputs and the type of software implemented in the memory of the control processor. Those modules collect and process data from measuring sensors, and they transmit processed data (in the form of data packets) to module No. 5 which generally manages and visualizes the data registered and processed by modules 1 to 4. The above does not apply only to decisions concerning the power transmission system, which require simultaneous data from several actuating modules. Module No. 5 "questions" the other modules, and based on the gathered information, it independently processes and visualizes the obtained data. In the designed system, the questioning speed of module No. 5 and the transmitters has been set by default at 1 Hz. Every module has a diagnostic connection for entering data into processor memory and for module self-testing. A diagnostic tester has been developed for self-diagnosing individual modules. The operating algorithm of module No. 5 features mechanisms for diagnosing each module, but the tester can be used to diagnose any module without activating the entire system. This solution is very useful for identifying sensor damage or connection socket damage.

The diagnostic information system has a hierarchical programming structure that has been implemented in a structured programming language (BASCOM). The sequence and type of information (screens) displayed on the control panel of the ALS system have been designed subjectively to produce a clear and intuitive user interface. The hierarchy of information displayed on the LCD screen of the control panel is presented in Figure 4. A general view of the control panel is shown in Figure 5.

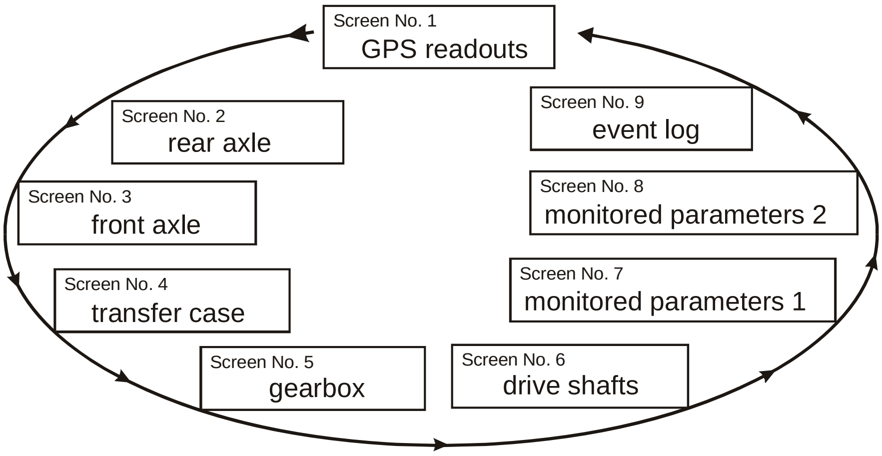

Fig. 4. Hierarchical structure of ALS screens

Owing to the vehicle's functional characteristics (all-terrain vehicle), an LCD touch screen was abandoned during preliminary tests. When the vehicle is driven in uneven terrain, screen buttons are difficult to control, and they are almost impossible to operate at low temperatures.

A general view of the front and the rear side of the ALS v 1.0 control panel with an indication of the key control and service buttons is presented in Figure 5.

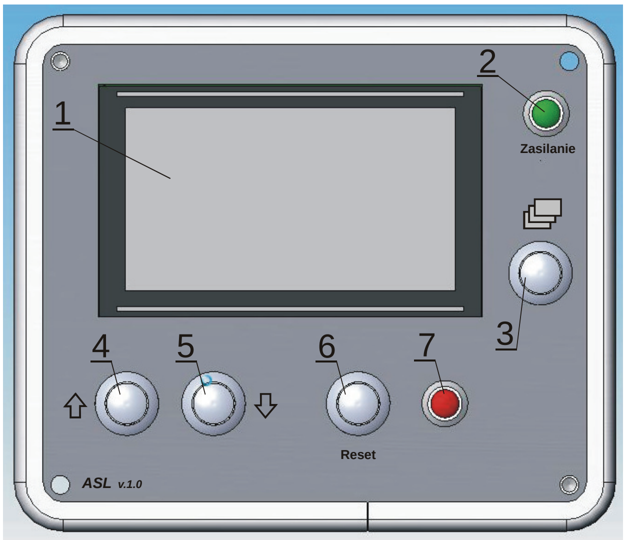

Fig. 5. General view of the ALS v 1.0 control panel: 1 – LCD display; 2 – power-on diode indicator (green); 3 – panel key for switching between system screens; 4 – panel key for scrolling the screen up; 5 – panel key for scrolling the screen down; 6 – Reset key; 7 – fault diode indicator (red)

5. Conclusions

A structural analysis of the diagnostic information model of the Tarpan Honker military vehicle leads to the following conclusions:

1) The information model reporting on the status and faults of power transmission system components will not identify limit state values. Limit state values will be identified after the vehicle has been tested with an implemented diagnostic system;
2) An RS-485 type communication and data transmission system with linear (serial) half-duplex technology was designed for the proposed monitoring and diagnostic system. The developed data transmission topology (number of transmitters and receivers) accounts for the vehicle's unique structure, operating requirements, system functionalities and structural feasibility;
3) The proposed transmission system supports quick data transfer between modules (devices) monitoring selected systems and mechanisms. The system minimizes the number of sensors and signal cables through the multiple use of measuring sensor signals. The proposed system is an open structure which supports data transfer between control devices supplied by different manufacturers;
4) The modules are linked by a network of data transmission and feed buses. The modules are also connected to measuring sensors with multipin plugs and connectors. Most measuring sensors were installed separately, and they did not constitute built-in vehicle equipment;
5) Every module has a diagnostic connection for entering data into processor memory and for module self-testing. A diagnostic tester has been developed for self-diagnosing individual modules;
6) Every screen on the ALS panel features cohesive display areas for each of the nine screens. The LCD screen contains the following display areas: screen header identifying a given system or component, screen footer displaying information on the current status of the monitored system, main screen with a graphic interpretation of the monitored systems, fault grading values and current fault status;
7) The screen interface and the control panel were optimized to maximize the information content of the displayed data. Efforts were made to reduce to the minimum the number of panel keys required to operate the system, and visual and audio signals were deployed;
8) Owing to the vehicle's functional characteristics (all-terrain vehicle), an LCD touch screen was abandoned during preliminary tests. When the vehicle is driven in uneven terrain, screen buttons are difficult to control, and they are almost impossible to operate at low temperatures;
9) The implemented system is independent of the vehicle's internal circuits, therefore, if damaged or not activated, it does not affect the mission performance.

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