

Diagnostic system of wheeled tractors detecting four defect's categories

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Abstract: - In a classical approach to damage diagnosis, the technical condition of an analyzed machine is identified based on the measured symptoms, such as performance, thermal state or vibration parameters. In wheeled tractor the fundamental importance has monitoring and diagnostics during exploitation concerning technical inspection and fault element localizations. The main functions of a diagnostic system are: monitoring tractor components which affect operation, safety, performance parameters and exhaust gas emissions; registering information about component damage; registering performance parameters at the moment of damage. The diagnostic device detects and identifies the following types of defects: functional defects (u_f) which affect performance, exhaust defects (u_e) which increase toxic emissions and fuel consumption, defects that jeopardize driving safety (u_s), defects that affect engine performance (u_d). The key component of diagnostic device is on-board computer with touch screen, connected by USB/DeviceNet converter (master module) via the USB port. The CAN bus connects the interface module with one (three) slave modules collecting data from sensors installed in various locations of wheeled tractor. Slave devices acts as data concentrator units. In the paper hardware structure, developed software, basic algorithms of diagnostic system and some realized tests of a wheeled tractor are presented.

Key-Words: - wheeled tractor, diagnostic system, data acquisition, diagnostic procedures, measurement points, hardware, software

1 Introduction

Tractor diagnostic's is not a new problem, and leading manufacture of tractors and self-propelled machines have been analyzing it for many years. In most cases, however, diagnostic measurements are reduced to periodic inspections in service stations usually one time in the year.

Development of modern constructions of wheeled tractors, introduction of electric and electronic devices of new generation for control of assemblies' work requires also on-board system [4], working on-line for monitoring of failures development [9]: functional, emission, jeopardise driving safety and impairing wheeled tractor's dynamics [7]. It is especially important for mapping of real exploitation loads by proposed mechatronic system of tractor state monitoring in defined exploitation situations and diagnostic information availability in each moment.

As regards the effects of wheeled tractor defects, they can be classified as:

- functional defects (u_f), resulting in impaired performance (power, torque, towing force, operating speed, fuel consumption);

- emission defects (u_e) which increase toxic emissions (and noise) as well as fuel consumption due to a malfunction of the fuel supply system, layout of the diesel engine and the power transmission system;
- defects that jeopardise driving safety of a tractor (u_s) affecting the following systems: brakes, suspension, steering and lights;
- defects impairing wheeled tractor's dynamics (u_d) which affect driving parameters, such as: decreased acceleration, unequal power levels, significant loss of power and moment of force, etc.

The development of a model of the diagnostic system for the differentiated categories of a wheeled tractor's defects with regards to its functionality, exhaust gas emissions, safety and dynamics under changeable operating conditions required the identification of various types of diagnostic symptoms capturing a particular class of faults during simulation and experimental tests for the assumed type of model. The set of diagnostic parameters will be assigned to the types of wheeled tractor's faults.

In the paper a structure of distributed CAN network system [10, 11] of the diagnostic system,

developed software, chosen diagnostic algorithms and some realized tests of a wheeled tractor are presented.

2 Structure of diagnostic system of wheeled tractors

Two diagnostic systems are designed and built:

- research, universal computer diagnostic system of wheeled tractor – MSDC-1, an open diagnostic system which enable measurements up to 50 diagnostic signals, their on-line analysis and calculations concerning dynamic and kinematic of tractor movements at different loads, operating in CAN network with DeviceNet protocol;
- exemplary diagnostic system – MSDC-2, which enable measurements up to 20 diagnostic parameters and their evaluation based on accepted diagnostic procedures and proper software, operating in CAN network with CANopen protocol [3].

Main purposes of the systems development were: identification of diagnostic signals assigned to defined defect categories of wheeled tractor and development of diagnosing methods.

2.1 Measurement points of a wheeled tractor

The first version of diagnostic system [1] for wheeled tractors has the following location of sensors and enables acquisition of the following measurements (Fig. 1):

We distinguish a set of temperature measurement sensors with resistance dependence (RTD) for lower temperatures and thermocouples for highest ones:

- T_{ch} – coolant temperature;
- T_{ols} – engine oil temperature;
- T_{kw1} – exhaust gas temperature in cylinder 1;
- T_{kw2} – exhaust gas temperature in cylinder 2;
- T_{kw3} – exhaust gas temperature in cylinder 3;
- T_{kw4} – exhaust gas temperature in cylinder 4;
- T_{sp} – gearbox temperature;
- T_{pg} – final drive temperature;
- T_r – reduction gear temperature.

A set of sensors for pressure measurements:

- p_{ol} – oil pressure;
- p_{ks} – suction manifold pressure.

A set of sensors for angle speed of wheel and shaft measurements:

- n_s – crankshaft speed;
- n_{zl} – left rear wheel speed;
- n_{zp} – right rear wheel speed;

- n_{kl} – left front wheel speed;
- n_{kp} – right front wheel speed.

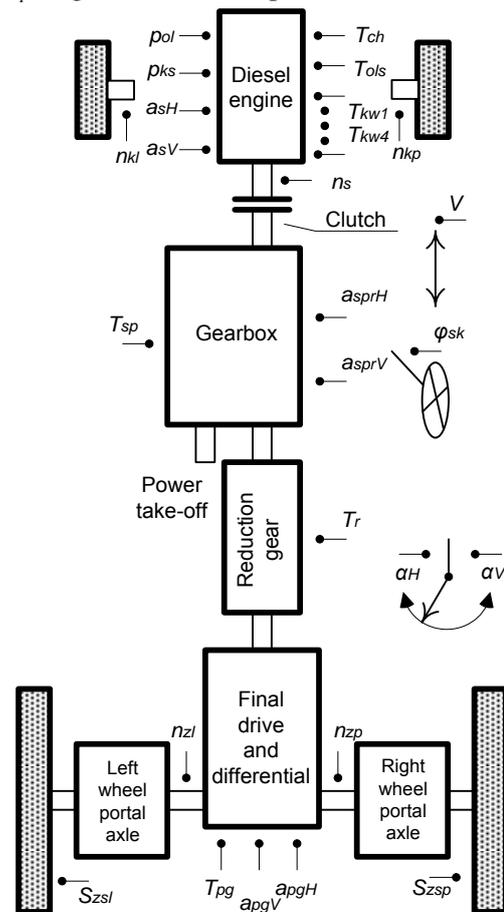


Fig. 1. Measurement points of a wheeled tractor

A set of acceleration sensors for vibration measurements:

- a_{sH} – engine vibration level (in H axe);
- a_{sV} – engine vibration level (in V axe);
- a_{sprH} – vibration levels in gearbox and reduction gear (in H axe);
- a_{sprV} – vibration levels in gearbox and reduction gear (in V axe);
- a_{pgH} – vibration level in final drive (in H axe);
- a_{pgV} – vibration level in final drive (in V axe).

A set of sensors for location measurements:

- S_{zsl} – distance between brake shoes in the left rear wheel;
- S_{zsp} – distance between brake shoes in the right rear wheel.

A set of remaining sensors:

- ϕ_{sk} – steering angle;
- α_H – vehicle tilt angle (in H axe);
- α_V – vehicle tilt angle (in V axe);
- V – vehicle speed according to GPS receiver.

2.2 Hardware structure of the diagnostic system MSDC1

Hardware structure of the diagnostic system MSDC1 (Fig. 2) contains [1]:

- Fujitsu FUTRO S100 on-board computer in shock and vibration-proof housing, with passive cooling and a 16 GB Compact Flash memory card;
- NVOX LCD 10" VGA/FVAT touch screen;
- USB/DeviceNet converter module I-7565-DNM, ICP DAS production [5];
- slave device working in CAN network with DeviceNet protocol, CAN-8424, ICP DAS production [6].

The following software was used: Windows XP-2000, driver of the USB/DeviceNet interface module and a developed diagnostic program. The installed memory card supports the operation of the diagnostic system.

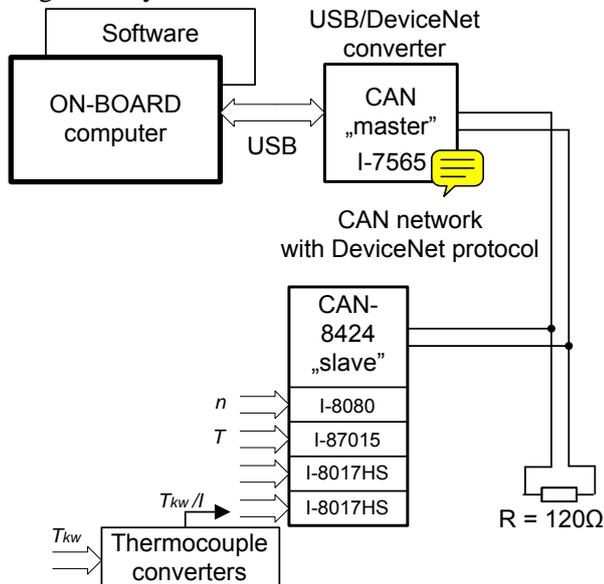


Fig. 2. Structure of a diagnostic system MSDC1 for wheeled tractors

The computer is connected with the I-7565 USB/DeviceNet master device via the USB port. The CAN bus connects the interface module with slave device collecting data from sensors installed in various locations of a wheeled tractor. Slave device acts as data concentrator unit. The device is equipped with 4 input cards which correspond to the range and type of the measured signals.

The I/O device supports acquisition of data from analogue inputs and digital inputs. The device is equipped in the following modules:

- module 1 – I-8080 of ICP DAS production [13], pulse input module, which supports the acquisition of data from 4 (8) two-state signals,

up/down pulse counting and frequency measurement. The module is used to measure the angle speed of shafts with the involvement of pick-up sensors;

- module 2 – I-87015W of ICP DAS production [12], analogue input module of RTD sensors which supports the acquisition of data from 7 analogue inputs of resistance sensors of various type and temperature range; Pt100 sensors with $0^{\circ}\text{C} \div +200^{\circ}\text{C}$ temperature range were used;
- module 3 – I-8017HW of ICP DAS production [13], which supports acquisition of data from 8 differential analogue inputs;
- module 4 – I-8017HW, which supports acquisition of data from 16 single-ended analogue inputs;
- module 5 – converters of thermocouple's voltage range to 4 – 20 mA output current.

I-8017HW modules can have 8 differential or 16 single-ended analogue inputs with 14-bit resolution. Available input range is: $\pm 1,25\text{ V}$, $\pm 2,5\text{ V}$, $\pm 5\text{ V}$, $\pm 10\text{ V}$ and $\pm 20\text{ mA}$. The proper input range for the diagnostic system was set via programming.

3 Software of the diagnostic system of wheeled tractors

The following diagnostic procedures were deployed at the current phase of development [1]:

- on-line diagnostics – cyclic operation of the data acquisition program with data readout from sensors at intervals of $T = 1\text{ s}$ (default value), diagnosis, error code generation;
- vibration tests – acquisition of data files from acceleration sensors, the use of fast Fourier transform and dedicated diagnostic procedures;



Fig. 3. The diagnostic program main window

- engine performance tests – acquisition of data files from shaft speed sensors, determination of

speed and acceleration characteristics under given operating conditions based on the knowledge of engine performance diagnostics;

The main window of the diagnostic program is presented in Fig. 3.

The key „Device initialization” allows to review the CAN network and to start connections with existing nodes. The information concerning available “slave” devices and their MAC ID addresses are saved in EPROM memory of “master” device.

3.1 Configuration of CAN-8424 devices

In the first stage of configuring the data acquisition system based on CAN-8424 network devices, hardware parameters are defined and the transmitted measurement data is organized with the use of the SlaveUtility (ICP DAS) application. The user defines the types of modules installed in successive punch-down blocks of the CAN device, the functions of each input and, optionally, the sensitivity ranges of module inputs. Data inputs (connected sensors) and the readout sequence can be defined in the Assembly Object layer of the CAN network. One data frame can contain up to 8 bytes, and up to 16 frames can be described. Data selected by the user is saved in an Electronic Data Sheet (EDS) file which is used to configure the CAN-8424 module. A text file is additionally generated for the user.

Read data contains measured parameters – 2 bytes per measurement. The configuration subprogram assigns the name of the measuring element to the measurement, it converts bytes to numeric values in MKS units and assigns the name of the measuring element to the calculated variable. An unnamed field implies that a given measurement was omitted.

The designed subsystem also features a data configuration option based on connected data frames of different device modules for 16 to 48 byte transmissions (Fig. 4). The above option relies on the Application Object layer of the CAN network.

The user enters the following data in the configuration subprogram:

- MAC address of a data acquisition device,
- names of measured values,
- used units,
- data scaling coefficient,
- number of procedure for measured value calculation.

Byte 1:2	Byte 3:4	Byte 5:6	Byte 7:8	Byte 9:10	Byte 11:12	Byte 13:14	Byte 15:16
Description 1	Description 2	Description 3	Description 4	Description 5	Description 6	Description 7	Description 8
Tkw1	Tkw2	Tkw3	Tkw4	Pks	Pol	allH	allV
Unit							
°C	°C	°C	°C	Bar	Bar	V	V
Coef. 1	Coef. 2	Coef. 3	Coef. 4	Coef. 5	Coef. 6	Coef. 7	Coef. 8
1	1	1	1	1	1	1	1
Procedure							
1	1	1	1	31	30	40	40

Fig. 4. Screen of measured data configuration in option „Application Object”

Subject to module type, successive inputs and the assigned bytes are displayed on the screen. When a name is assigned to an input, a given measurement is taken into account, and its physical value is computed.

3.2 Conversion of measurement data

Measurement modules have different data representations in bytes. The following information should be taken into account during conversion:

- number of data bytes – 2, 4 and 6 bytes are used,
- number of bits in two bytes of data – 14 and 16 bits are used,
- maximum range of data in 2 bytes, e.g. 7FFFh, 1FFFh,
- minimum range of data, e.g. 0000h, for a negative range – 2000h,
- maximum and minimum physical ranges of a sensor which correspond to data ranges in bytes,
- effective measuring range of 4 ÷ 20 mA, for the applied range of ±20 mA,
- conversion of physical units.

Eleven computing procedures have been developed for the conversion of measurement data. The procedure is selected based on the name of the measuring device.

The measured parameters of a wheeled tractor can be viewed during the online diagnostic process (Fig. 5). Computed parameter values which are not available during direct measurement (another window) can also be previewed.

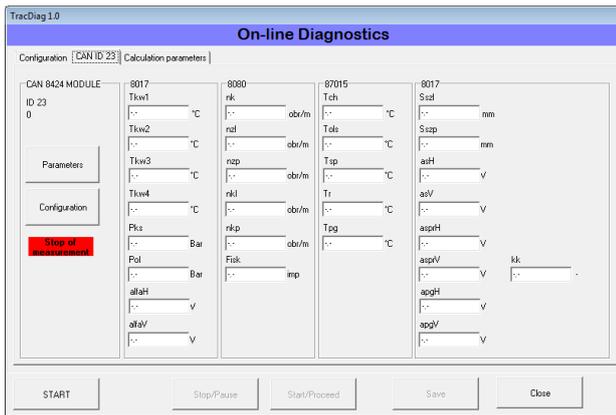


Fig. 5. Screen of measured parameters of wheeled tractor

3.3 Setting boundary values of parameters

Diagnostic knowledge is connected with relations between defects (faults) and specific diagnostic symptoms. Intervals of permissible parameters value are setting in the window of boundary values of parameters (Fig. 6). According to introduced boundary values diagnostic procedures indicate appearing defect detected by the parameters value change.

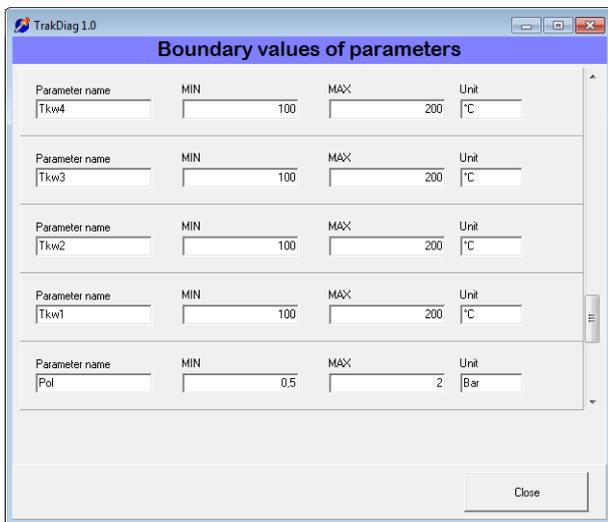


Fig. 6. Screen of window for setting boundary values of parameters

3.4 Selected program algorithms

A real-time clock controls data readout in the online diagnostic process. The data readout procedure is called at time intervals T . Bytes written in a table are converted into physical values that are assigned to variables named after the measuring sensor. Physical values of performance variables which are not available during direct measurements are computed based on registered data and the

parameters stored in memory. Registered and computed values are used in the diagnostic process, and they may be displayed on the screen. Cause-and-effect relationships between a fault and its symptoms are identified as defects and are communicated by the respective error codes.

Real-time control

In the Windows environment, real-time control is problematic due to difficulties with stability and sampling frequency. The available tools in popular programming languages do not support stable and precise time control. The *WinApi* library offers the only solution to the problem.

A separate time control option with the highest priority (*tpHighest*) has been introduced to guarantee the accuracy of time intervals between successive measurements. The accuracy of intervals between measurement samples was maximized with the use of the *timeBeginPeriod* function which increases the precision and resolution of the Windows timer (this function is used in real-time applications and multimedia systems). The value of the expected stable timer resolution in milliseconds is the function parameter. The function is called directly before the use of other counting functions and measurements that require a stable real-time clock.

Accurate time measurements are performed with the involvement of the *QueryPerformanceCounter* function which returns the number of the clock cycle performed by the processor as a parameter and the *QueryPerformanceFrequency* which indicates the frequency of clock cycles.

A waitable timer object for synchronizing timing tasks has been used to control the passage of time and the arrival of a specified due time. When the "time synchronization object" has been created, the user can control the expiry of successive time intervals. Time intervals can be set in accordance with Windows instructions with a minimum step of 100 ns.

Data readout procedure

The MAC address of the device and the number of lines (successive Instance ID numbers, beginning from 0x64) are specified in the Assembly Object layer of the configuration subprogram in the data acquisition system. Data can be cyclically read from the loop with the use of explicit messages.

The data readout procedure is called cyclically at intervals T which are specified in the configuration subprogram. Two bytes of data are combined to form words, and they are entered into the table. Identical indicators are found in the table specifying the names of measurement sensors in the configuration subprogram.

Data conversion procedure

The table specifying the names of measurement sensors is reviewed. Elements without names are omitted. The procedure assigned to a named element is called. The table index also indicates the source of measurement data which is sent to the procedure. The computed physical value of a parameter is assigned to the variable named after the sensor.

Procedure of computing physical values which are not available during direct measurements

Not all physical parameters are measured directly, and they may have to be computed independently. The most important values are: N_e – effective engine power and M_e – effective torque. Parameters were computed mechanically based on formulas (1) ÷ (7):

$$V = \frac{\prod n_k r_d}{30} \text{ [m/s]}, \tag{1}$$

$$a = \frac{\Delta V}{\Delta t} \text{ [m/s}^2\text{]}, \tag{2}$$

$$F = ma \text{ [N]}, \tag{3}$$

$$N_e = FV \text{ [kW]}, \tag{4}$$

$$M_e = \frac{Fr_d}{i\eta} \text{ [Nm]}, \tag{5}$$

where: V – velocity read from a GPS receiver,

n_k – average velocity of drive wheels,

a – acceleration,

F – inertial force,

η – total efficiency of the power transmission system,

$$i = \frac{\prod r_d n_s}{30V},$$

m – tractor mass,

r_d – rolling radius,

n_s – rotational speed of engine shaft,

i – overall gear ratio.

The percentage relative slip ratio of rear axis wheels S_{ot} is determined based on the following formula:

$$S_{ot} = \left(\frac{n_{kl} + n_{kp}}{n_{dl} + n_{dp}} - 1 \right) 100 \% . \tag{6}$$

The below equation is used to calculate slip based on GPS data:

$$s = \frac{V - \omega R}{V}, \tag{7}$$

where: $\omega = 2\pi n_s / 60$ – angular velocity of drive wheels,

ωR – circumferential speed of the drive wheel tire.

4 Diagnostic procedures of wheeled tractor

We define meaning of a fault as an event of negative influence on efficiency of machine functionality, which with determination of kind, place, occurrence’s time, size and character of variance in time should be detected. A tractor’s fault (S_N) in our case results from one of four defects categories (u_f, u_s, u_e, u_d) and can be presented in the form of the following relation [7, 8]:

$$S_N \Leftarrow (u_f \cup u_s \cup u_e \cup u_d) \neq 0. \tag{8}$$

Diagnostic knowledge is composed of facts, relations and procedures. In a mathematical approach, the diagnostic process involves the search of relations R between defects (faults) and specific diagnostic symptoms. There exist cause and effect relationships between malfunction $f_i \subset F$ of tractor components and symptoms s_j represented by set S . This relationship can take on one of the following forms:

$R: \{s_j\} \Rightarrow f_i$ – one-to-one relationship (a set of symptoms identifies a given state);

$R: \{s_j\} \Rightarrow \{f_{i>1}\}$ – one-to-many relationship.

The development of diagnostic relations based on different methods and information sources will foster the growth of reliable declarative knowledge which comprises facts and state-symptom diagnostic relations, as well as procedural knowledge which underlies diagnostic inference.

If we assume that knowledge is an organized data set, the acquisition of (diagnostic) knowledge is a process of gathering diagnostic information (data set) and developing models that support the most effective use of that information (ordering a data set).

Diagnostic information about a tractor’s status can be presented in the following form:

$$f_i \Rightarrow U_i; U_i = \{u_{n,i}\}, \tag{9}$$

where: U_i – set of parameters characteristic of the i^{th} fault (defect),

$u_{n,i}$ – n^{th} parameter characteristic of the i^{th} fault (defect).

Relations R_{XF} can be described by the Cartesian product of sets F and X :

$$R_{XF} \subset X \times F, \tag{10}$$

where: X - set of process variables;

F - machine’s state space.

The essence of diagnosing process in this case is to mapp the space of process variable values X as a function of the machine’s state space F .

Engine parameters evaluation

Diagnostic parameter: T_{ch} – coolant temperature.

Coolant temperature is measured by a cooling system sensor installed in the area of the coolant pump. $T_{ch} > T_{ch\max}$ indicates:

- engine overheating due to overload;
- coolant pump failure;
- low coolant level;
- thermostat failure;
- radiator failure;
- cooling system airlock.

Diagnostic parameter: T_{ols} – engine oil temperature.

Engine oil temperature is measured directly by a sensor installed in the lubrication system. $T_{ols} > T_{ols\max}$ indicates:

- engine overheating due to overload;
- excessive engine speed under given operating conditions or inadequate setting of the power transmission system;
- low engine oil level;
- engine seizure.

Diagnostic parameter: T_{kw1} – exhaust gas temperature in cylinder 1, T_{kw2} – exhaust gas temperature in cylinder 2, T_{kw3} – exhaust gas temperature in cylinder 3, T_{kw4} – exhaust gas temperature in cylinder 4.

Exhaust gas temperature is measured by sensors installed in the exhaust manifold by every cylinder.

If $T_{kwi} > 1,15 \cdot T_{kwav}$ or $T_{kwi} < 0,85 \cdot T_{kwav}$,

where $T_{kwav} = \frac{1}{j} \sum_{i=1}^j T_{kwi}$, then symptoms indicates

injector system failure or abnormal pressure in the i^{th} cylinder.

Diagnostic parameter: p_{ol} – oil pressure.

Oil pressure is measured directly by the pressure sensor. $p_{ol} > p_{ol\max}$ is indicative of:

- oil pump failure.
- $p_{ol} < p_{ol\min}$ indicates:
- oil pump failure,
 - low oil level,
 - oil leak,
 - inadequate oil parameters,
 - significant fuel or coolant leak into engine oil,
 - main bearing failure,
 - oil filter blockage,

Diagnostic parameter: p_{ks} – suction manifold pressure.

Pressure is measured directly by a sensor in the engine's suction manifold. $p_{ks} < p_{ks\min}$ indicates:

- air filter blockage,
- blockage of the air supply conduit.

Diagnostic parameters: n_s – crankshaft speed, N_e – effective engine power, M_e – effective torque.

Diagnostic parameter: $|a_s|$ – engine vibration level.

Engine vibration levels are measured directly by a biaxial vibration sensor. $|a_s| > a_{s\max}$ is indicative of engine failure.

Gearbox parameters evaluation

Diagnostic parameter: $|a_{spr}|$ – vibration levels in gearbox and reduction gear.

Vibration levels are measured directly by a biaxial vibration sensor installed on gearbox housing. $|a_{spr}| > a_{spr\max}$ is indicative of gearbox or reduction gear failure.

Diagnostic parameter: T_{sp} – gearbox temperature.

Gearbox temperature is measured directly by a sensor installed on gearbox housing. $T_{sp} > T_{sp\max}$ indicates gearbox failure or low gearbox oil level.

Reduction gear parameters evaluation

Diagnostic parameter: $|a_{spr}|$ – vibration levels in gearbox and reduction gear.

Vibration levels are measured directly by a biaxial vibration sensor installed on gearbox housing. $|a_{spr}| > a_{spr\max}$ is indicative of gearbox or reduction gear failure.

Diagnostic parameter: T_r – reduction gear temperature.

Reduction gear temperature is measured directly by a sensor installed on gearbox housing. $T_r > T_{r\max}$ indicates reduction gear failure or low oil level in reduction gear.

Final drive and differential parameters evaluation

Diagnostic parameter: $|a_{pg}|$ – vibration level in final drive.

Vibration levels are measured directly by a biaxial vibration sensor installed in the final drive. $|a_{pg}| > a_{pg\max}$ is indicative of final drive failure.

Diagnostic parameter: T_{pg} – final drive temperature.

Final drive temperature is measured directly by a sensor installed on final drive housing. $T_{pg} > T_{pg\max}$ is indicative of final drive failure or low oil level in the final drive.

Left hub reduction gear parameters evaluation

Diagnostic parameter: n_{cl} – left wheel speed.

Wheel speed is measured directly by a speed sensor. When the differential is locked and the

clutch is disengaged, $n_d < \frac{n_s}{i}$ is indicative of power transmission failure.

Right hub reduction gear parameters evaluation

Diagnostic parameter: n_{zp} – right wheel speed.

Wheel speed is measured directly by a speed sensor. When the differential is locked and the clutch is disengaged, $n_p < \frac{n_s}{i}$ is indicative of power transmission failure.

Steering system parameters evaluation

Diagnostic parameter: φ_{sk} – steering angle.

The steering system's response to a given wheel angle is determined.

Braking system parameters evaluation

Diagnostic parameter: S_{szl} – distance between brake shoes in the left wheel, S_{szp} – distance between brake shoes in the right wheel.

The distance between brake shoes is measured directly by distance sensors. $S_{szl} \leq S_{szl\ min}$ or $S_{szp} \leq S_{szp\ min}$ is indicative of break shoe failure.

Location parameters evaluation

Diagnostic parameter: α – vehicle tilt angle measurement. The tilt angle is measured directly by an inclinometer.

Front axle wheels parameters evaluation

Diagnostic parameter: n_{kp} – right wheel speed, n_{kl} – left wheel speed, s_{wkn} – relative slip of drive wheels (indirect measurement).

For rotational speed of rear right n_{zp} and left n_{zl} wheels we evaluate s_{ot} – relative slip of rear wheels [%] (indirect measurement);

if $n_{kl} + n_{kp} < n_{zl} + n_{zp}$ then

$$s_{ot} = \left(\frac{n_{kl} + n_{kp}}{n_{zl} + n_{zp}} - 1 \right) \cdot 100 \%,$$

if $n_{kl} + n_{kp} \geq n_{zl} + n_{zp}$ then $s_{ot} = 0 \%$.

Determination of slip based on GPS data:

$$\omega = \frac{2\pi \cdot n_s}{60} - \text{angular velocity,}$$

V – vehicle speed given by GPS receiver,

ωR – wheel circumferential speed,

$$s = \frac{V - \omega \cdot R}{V},$$

$s > 0$ – braking slip,

$s < 0$ – acceleration slip,

$s = 0$ – slip-free driving,

$s = 1$ – wheel lock.

5 Exemplary tests of a wheeled tractor

Tests were carried out using diagnostic system MSDC-1. The system was installed on Ursus MF 255 tractor.

During test trial runs are realized in variable condition of loads and different ranges of engine crankshaft speeds. Some of the exemplary diagrams achieved from the diagnostic system, showing measured parameters during realized tests are presented below.

In figure 7 a diagram of an exemplary test of the cranshaft engine speed is presented. The speed of cranshaft during the test is constantly changing.

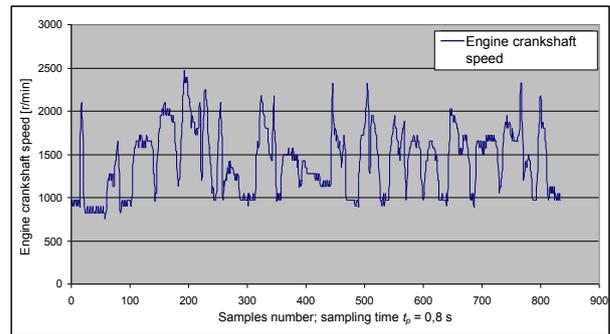


Fig. 7. Time diagram of engine crankshaft speed

In figures 8 and 9 time diagrams of calculated linear velocity of the front and the rear wheels and time diagram of slip changes are presented.

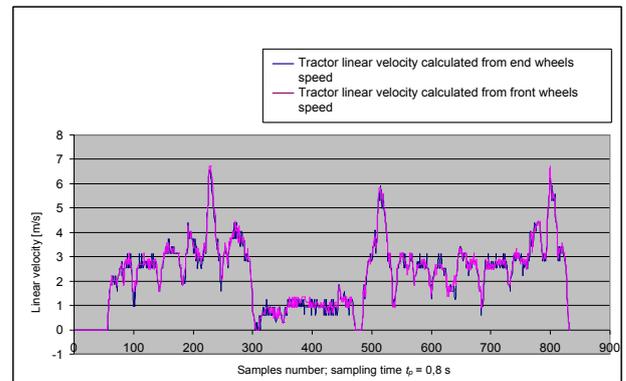


Fig. 8. Time diagrams of calculated linear velocity of front and rear wheels

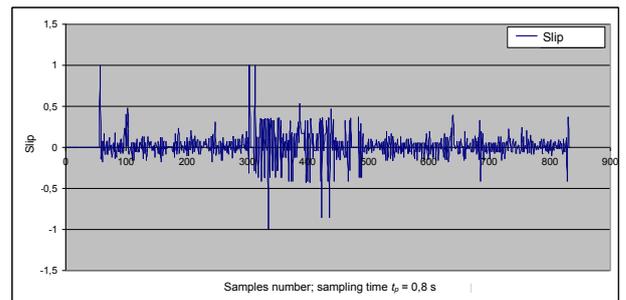


Fig. 9. Time diagram of calculated slip changes

Diagnostic tests of the wheeled tractor in a good functional state (without distinguished classes of defects) were carried out; diagnostic parameters were evaluated and then measurements of diagnostic parameters of the wheeled tractor with defected injector of third cylinder are carried out. The following changes of parameter are achieved:

- a drop of exhaust gases temperature of the third cylinder,
- increasing of the engine vibration level,
- a drop of power and the engine torque in compare to parameters achieved in diagnostic tests of the wheeled tractor in good state.

In Fig. 10 time diagrams of exhaust gases temperature of particular cylinders are presented. The values of exhaust gases temperature of the first and second cylinder measured in output manifold are greater then the values of third cylinder with defected injector.

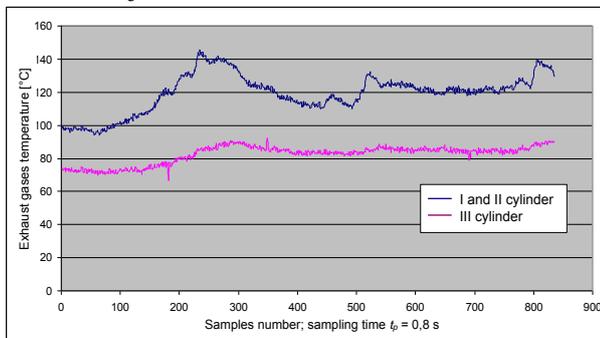


Fig. 10. Time diagram of exhaust gases temperature of particular cylinders

In Fig. 11 a diagram of vibration level changes registered during the tractor engine test is presented. The vibration level changes for the tractor with defected injector of third cylinder. As results from comparing the plots of the engine in a good functional state and according to defect of the injector end in the third cylinder, the vibration level increased circa ten times.

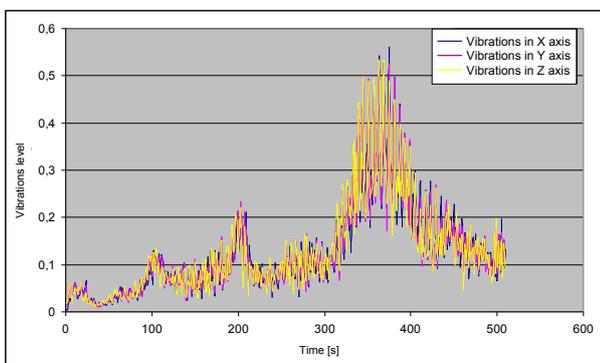


Fig. 11. Vibration levels change for the tractor's engine with defected end of injector

As results from realized tests of the wheeled tractor, essential defects of tractor causes changes of different diagnostic parameters, what confirms the accepted assumptions.

6 Conclusion

The analysis of the on-board systems of wheeled tractors shows, that the systems are directed for monitoring current parameters of tractor operations and control of some assemblies during agriculture process. There is a total lack of diagnostic procedures of a tractor technical status resulting from monitoring parameters of its operations. In case of emission defects only engine's operation parameters are monitored, they can show exceed of the exhaust gases smokiness norm, but exhaust gases are not anyway investigated. Inference concerning eventual emission defect is supported only on developed algorithms, mainly considering exceeding of the exhaust gases emission the defined threshold norms. It causes quite great delay in defect signalization and the fault detection process is not sensitive on the faults resulting from wearing of wheeled tractor parts.

The developed diagnostic system of wheeled tractor oriented on identification of four defect categories is an original solution. Standard diagnostics of wheeled tractors EOBD concerns only basic engine operation parameters [4], it means functional defects but cumulative defects are not taken into account.

Development of the diagnostic system for wheeled tractors was realized based on:

- developed analytical model of defined defect classes influence on tractor's fuel consumption,
- developed simulation model of fuel consumption depending on exploitation loads, operation conditions and simulated faults [2],
- model of diagnostic relations and inference algorithms,
- information model of the diagnostic system.

The presented investigation structure of mechatronic diagnostic system is a base for board version of wheeled tractor diagnostic systems development. Except described system with DeviceNet protocol also an option based on CANopen protocol is tested.

The developed diagnostic models and monitoring systems are original and innovative. Authors consider four categories of wheeled tractor defects, analyses progressing destruction of wheeled tractor during exploitation, by simultaneous measurements of vibrations, temperature state, operation

productivity and performance in different exploitation situations.

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