

THE MECHANOTRONIC CONTROL AND DIAGNOSTIC SYSTEM OF THE HYDROMECHANICAL TRANSMISSION OF THE MOBILE MACHINE

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Introduction

On modern truck and other vehicles has found the hydromechanical transmissions (HMT). Efficient and reliable operating the machines, equipped HMT, can be provided only way to automations of control, as well as using the most making principle, methods and technical facilities of the determination their technical condition, i.e. processes of diagnosing. For this HMT must be provided with by system automaton of control (SAC) [1].

The primary task SAC is concluded in optimum coordination state of working engine and transmission of the truck. Besides, SAC must provide the high factors a quality processes of the operation mechanism HMT, particularly in connecting mode, conditioned by gearshift. The important requirement to control of HMT is a provision unceasing cart to energy to leading wheel of the car in any condition of the motion. For this gearshift must be realized without breakup of the flow to powers. SAM also must protect the engine and transmissions from overloading, reducing before possible minimum dynamic loads at gearshift, and exclude the dangerous modes operating the engine and mechanism of the transmissions.

On department «Automobiles» of Belorussian-Russian University for many years are conducted studies and development electronic control system (ECS) of the hydromechanical transmissions of the mobile machines. Methods of the syntheses algorithm control energy mode machines is designed within research work «Mehanika-31» with hydromechanical transmissions. On base executed on this program of the studies and within the research work of task on «Mechanics 2.35» is designed electronic managerial system of the hydromechanical transmissions of the mobile machines for produced on Belorussian truck plant (PA «Belarusian Autoworks BELAZ») for car-dump truck «BELAZ-7555» cargo-carrying capacity 60 ton design hydromechanical transmissions were designed within the research work of functioning data, which is completely adapted to automations [2, 3].

Currently designed systems of the autocontrol passed the service tests, and is realized preparation to their production. The next, the most important and consequent stage of the work on automations of the hydromechanical transmission of the truck of the dump truck BELAZ-7555 is a creation electronic on-board system of the diagnostic, providing operative determination of the technical condition transmissions of the trucks.

Creation electronic control system and diagnostic of the hydromechanical transmission

The most perspective direction to automations of control of HMT is an using the electronic control systems, made the most latest technical facility and supplied efficient of algorithm [3, 4]. The electronic controller (EBU) of HMT realizes shaping a signal control on gearshift, blocking of hydro-transformer, control state of working engine at gearshift. Besides he controls the process of the cut-in and shutdown frictions, providing execution noted above requirements. Since control frictions HMT is realized by means of hydraulic drive, that carrier of the final signal of control system is a worker liquid. Consequently, controlling signals, formed by electronic block, need the physical nature for reinforcement and change. The decision of this problem is provided by using of electro-hydraulic executive mechanism of control of frictions (clutch's). In composition managerial system except EBU enter

the electro- hydraulic executive mechanisms, providing realization controlling influence on control body of the HMT. Such heterogeneous technical system is accepted name the mechatronic control system (MCS).

Creation MCS HMT for quarry dump truck BELAZ-7555 was realized on os-new technical requirement, designed employee research centre of Belorussian truck plant (PA «Belarusian Autoworks BELAZ») with employee of the department «Automobiles» Belorussian-Russian university. At development of the technical requirement it is used world experience to automations of control of HMT. The most making technical decisions are created company Allison, Caterpillar, Komatsu. The analysis of the modern engineering decisions has allowed to form scientifically motivated complex of the specifications to created MCS HMT for quarry dump truck BELAZ. The realization of these requirements allows to provide the high technical level and competitiveness of the quarry dump trucks.

We shall consider the main technical decisions marketed in created MCS HMT. MCS HMT provides two modes of control: automatic and command. The choice mode control is realized by driver by means of selector (the constituent mode control). Shaping realizes in automatic mode MCS to-cunts on gearshift and blocking of hydro-transformer (HDT) and provides the process of cut-in control and shutdown of the friction muffs. In command mode shaping the commands on gearshift realizes driver by means of selector, but control blocking HDT and process of the cut-in and shutdown friction muffs is realized in automatic mode in accordance with algorithm, mortgaged in MCS.

Shaping controlling commands in automatic mode is realized on base of information, characterizing state of working engine and mechanism of the transmissions, as well as with provision for control other mechanism and system of the machine. Herewith information is used about angular velocity of the rotation of the gross of the engine and gross HMT (the gross of the turbine HDT, output and intermediate gross gearbox), about position of the treadles of the accelerator, level of the loading and speedup of the machine, condition control body of the brake system, the overturning mechanism and etc.

In process of the gearshift MSC on channel CAN (the protocol J1939) realizes auto control of the engine, regardless of positions of the treadles of the accelerator, installed by driver. This provides the reduction of the dynamic loads at gearshifts, reduction to velocities of the moving the machine at dangerous situation: ascent of the cargo platform or cut-in brake on move of the machine, malfunction in control system of the frictions and others.

Account big amount factor, characterizing state of working mechanism and systems of the machine and controlling influence of the driver, allows to provide shaping the optimum features of the gearshift and blocking HDT. The algorithm of control of the frictions marketed in MSC, provides the high quality of the connecting processes at gearshifts and smoothness of the moving the machine, preventing overloading of the transmission and creating comfort of the condition of the working the driver. This is reached by coordinated control included and switched off friction muffs and using of proportional control pressure worker to liquids in hydraulic cylinder of the clutch's of HMT.

Coordinated control of the frictions HMT provides the unceasing transmission to energy of the engine to leading wheel of the vehicle, but proportional valves allow to execute high-quality control a pressure worker to liquids with feedback on relative value of the slide friction disk included friction muffs. Created MSC disposes the system of the diagnostic, providing processing signal about fault its component and friction muffs of the HMT. MSC provides protection from wrong action of the driver, excludes simultaneous cut-in two gear shifts, gives information on block of indication (the display) about emergency state of working main mechanism and dangerous situations, provides keeping to this information and possibility of the conclusion it on computer for analysis and decision making on about reconstruction of capacity to work of the system (drawing 1). Information on state of working HMT and condition control body by machine is removed on block of indication in the manner of pictographs, deskside which corresponds to the standard ISO 2575-2005 «Symbols for control body, indicator and attention devices».

The block to indication disposes the possibility of the change parameter algorithm of the process of the gearshift and algorithm of control friction disk HMT.

The building of the principle scheme MSC HMT was realized with provision for requirements stated in technical requirements on development of the pilot model electronic-hydraulic system of the auto-control and diagnostic HMT of the quarry dump trucks by cargo-carrying capacity 45-60 tons. Were taken in attention constructive particularities of HMT these machines, their kinematics and hydraulic schemes.



Figure 1: A display MSC HMT company Rexroth Bosch Group:
a – general type; *b* – indication on display one of cut HMT

The principle scheme MSC HMT, formed with provision for enumerated premises, is submitted for figure 2 [5–7].

The main component of the system are: selector 1 (the constituent mode control HMT), kit of the sensors, electronic controller 2 (EBU), block proportional valves devices 3 (the block PVD), block to indication 4, diagnostic connector 5, breaker of the power supply EBU 6 and connecting wires 7. The selector hereinafter interpretation shall name «board of control HMT».

EBU 2 with electronic controller by engine 8 and block to indication 4 are united in united network by means of CAN buses 9. Exchange by information with engine is produced on protocol SAN (J1939).

The board of control HMT 1 serves for choice of the number of the shift of the transmission HMT in command mode. In automatic mode of control board is used for choice of the mode of the motion (propulsion *D*, motion by back move *R* and neutral *N*). The board of control has four discrete outputs, on which in determined combinations take seats the signals of the positive pole of the voltage power source. The output signals of the board of control are processed in EBU and are used when shaping controlling influence in PVD MSC 3.

The sensors serves for reception of information on values of parameter, characterizing condition HMT, engine, control body by dump truck, its mechanism and systems. In composition MSC enter the following sensors: sensors of the frequency of the rotation of the turbine 10, intermediate 11 and output 12 grosses HMT; the sensor of the cut-in worker the brake system 13; the sensor of the cut-in stop brake 14; the switch mode control HMT 15; the switch band limits of the switchable transmissions 16; the sensor of the position of the cargo platform 17; the sensor of the pressure in output hydraulic line HDT 18; the sensor of the temperature worker to liquids on output HDT 19; the sensor of the pressure in system of lubricant HMT 20; the sensor main pressures HDT 21; the sensor contamination of the filter fine peelings worker liquid 22; the sensors of the pressure in channel of the cut-in of the clutch's of HMT 23.

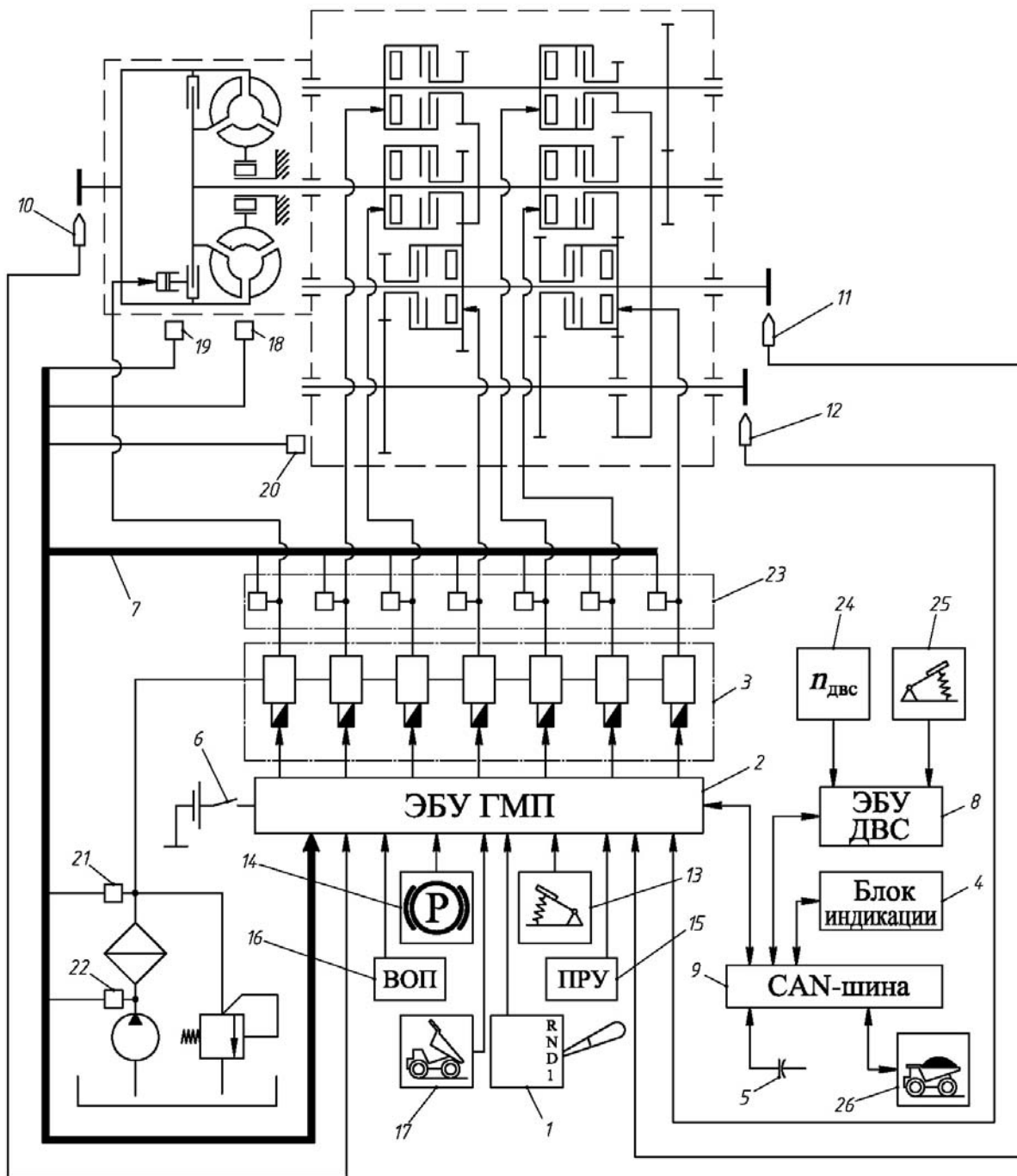


Figure 2: A principle scheme MSC HMT

Necessary for functioning_ MSC HMT information on frequency of the rotation 24 crankshafts of the engine and position to treadles of the presenting fuel 25 enters in EBU HMT 2 from EBU engine 8 on CAN bus 9 on protocol J1939. Also information gets through CAN bus EBU HMT 2 about value of the loading the dump truck from EBU systems of the checking the loading 26.

For measurement of the frequency of the rotation in designed MSC HMT used sensors of the frequency DSM-10 companies Rexroth Bosch Group (Germany). They have a big range of the measurement of the frequency (1 - 5000 Hz), pinpoint accuracy of the measurement and small size. The measurement of the pressure in hydraulic lines of MSC is produced by means of sensor of the pressure Suco 0605-51104-0-003 (Germany). They also have pinpoint accuracy of the measurement, small size and sufficient range of the measurement of the pressure – from 0 before 3 MPa.

As EBU HMT is used programmed controller of series RC8/8-22, made Germanys Company «Rexroth Bosch Group», specializing on supply high-tech component car using. He on all amounts meets the requirements European standard to reliability product auto-mobile electronics. The controllers of series RC capable to function in condition of the high temperature, striking and vibratory loads, have locked body and high degree to electromagnetic compatibility.

The main part of the EBU HMT is 16-class microcontroller of the type C167CS, in composition which enters the processor, generator with clock rate 40 MHz, operative remembering device by volume 256 Kbytes, flash-memory by volume 512 Kbytes, electrically erasable reprogrammable constant remembering device by capacity 16 Kbytes, modules of the entering-conclusion, providing interfacing with sensor and executive device control system, two CAN controllers, intended for connection EBU to CAN bus, the source of the constant voltage for power supply the sensors.

EBU has a modules of the entering analog, frequency and discrete signal with sensors of MSC HMT, as well as modules of the conclusion signal control proportional electro-magnet and device with discrete action. All modules of the entering are protected from excess of the electric voltages and electric hindrances in on-board network of the dump truck. Provided possibility of the checking input signal sensor is provided for the reason finding breakaway wire or short circuits.

The modules of control proportional electromagnet are greatly adapted to use proportional valves, produced Rexroth Bosch Group, and provide pinpoint accuracy features of the regulation of the pressure. There is possibility of the finding refusal, caused by breakaway of the cables and short circuits output on proportional electromagnets.

Programming EBU HMT is realized by means of software BODAS-design, delivered Rexroth Bosch Group.

The block PVD is intended for fluent cut-in or shutdown of the frictions HMT in combination and the sequence, assigned EBU HMT. In composition of the block there is seven PVD alike design, each of which realizes individual control corresponding to clutch HMT.

A proportional valves device 3 converts the electric signal of control, formed EBU HMT, in flow worker to liquids in channel of the cut-in of the friction of HMT with pressure, proportional value of the signal of control. PVD comprises of itself 3- linear hydro-distributor of the type with double (pilot) by control and feedback on pressure in channel of clutch, as well as sensor of the pressure. As pilot is used small-dimensioned proportional reduction valve FTDRE 2 K32/18AG24C4V-8, made by company «Rexroth Bosch Group». Amperage worked out by electronic block, is converted by pilot valve in hydraulic signal of the small power, acting on valve of the hydro-distributor-oscillator, having possibility of the work by greater expenses to liquids. As a result on leaving the distributor is formed flow worker to liquids with pressure, proportional amperage, acting on electromagnet of the proportional valve.

Development to designs, stand and service tests of electronic control system and diagnostic of the hydromechanical transmission

When making MSC HMT is designed new electronic hydraulic executive system of the gearshift, providing high-quality control of the clutch's. In the course of performing the design work serial HMT of the dump truck BELAZ cargo-carrying capacity 45–60 tons were subject to fundamental modernization.

For governing of the frictions of the HMT of the dump truck BELAZ cargo-carrying capacity 45–60 tons are designed design of the electronic system of proportional control of the clutches. She comprises of itself source of the presenting worker to liquids under pressure 1 (hydraulic pump with safety valves), executive hydraulic cylinder of the frictions, implementing compression of the package friction disks under its cut-in, executive mechanism of control of the frictions, kit sensor and electronic controller 5 (EBU).

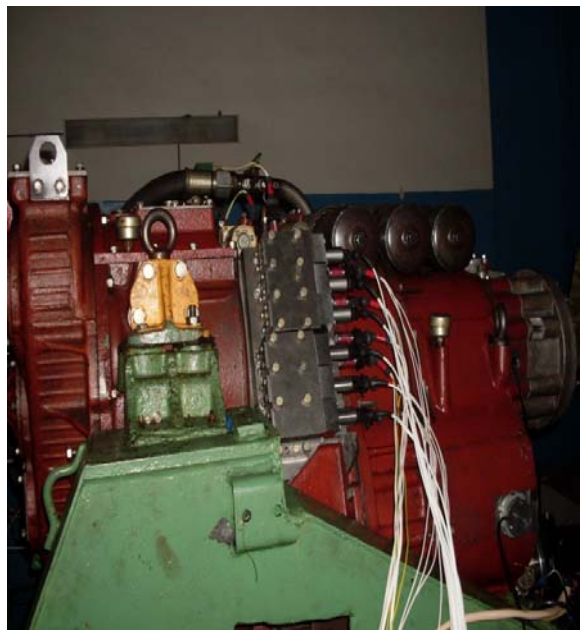
As EBU is used 16-bit microcontroller of the company Rexroth Bosch Group. The microcontroller processes the signals with sensors and on base of the given algorithm of control forms the signal of control on electromagnetic valve in mode of the width-pulse inflexion. Current control in winding of the electromagnet of the valve microcontroller realizes by means of PID-regulator. As signal to feedback is used amperage on winding of the electromagnet of the valve.

The designed system was practiced in plant condition on stand, then she passed sought-after test on dump truck BELAZ.

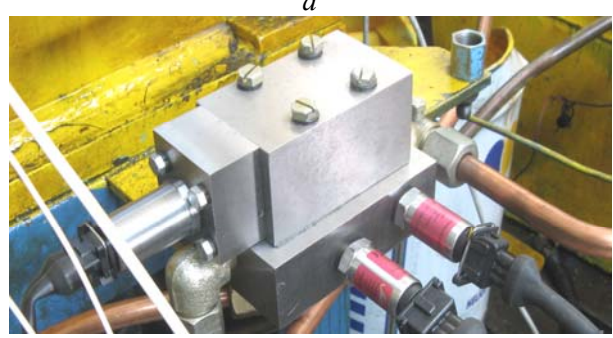
The photography of the stand is brought on figure 3, *a, b*. On her are seen mechanisms of control of the frictions HMT with proportional electro-magnet valves. The general type made executive mechanism (actuator) of control of the clutches of HMT, installed on test-beds, is submitted for drawing 3, *c*; but installation executive mechanism is shown on drawing 3, *d* on gearbox of the dump truck BELAZ.



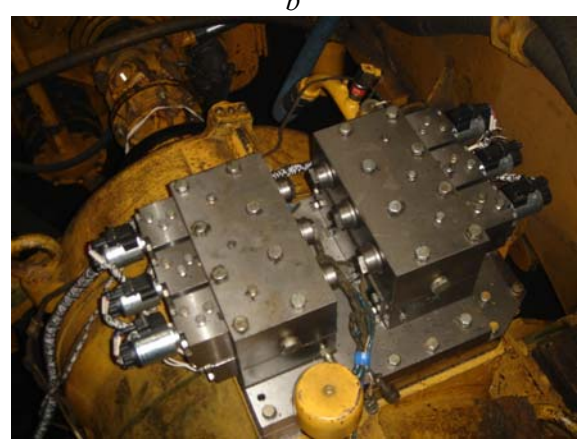
a



b



c



d

Figure 3: General type of stand for undertaking the test HMT

Called on test have shown that created the system (real object of the MSC HMT) is runnable and efficient. In the course of test electronic block processed on mortgaged algorithm information, entering from sensor, and formed the commands of control electro-hydraulic executive mechanism (actuator). PVD MSC executed control an HMT frictions in combination and the sequence, assigned by electronic block, providing cut-in necessary step in gearbox. On all speed state of working HMT and at

miscellaneous temperature worker to liquids pressure in channel of the cut-in experienced of HMT frictions changes pro rata signal of control, formed by electronic block of HMT.

The designed algorithms of control of HMT frictions allow with sufficient accuracy to define the moment of the filling hydraulic cylinder of the clutch and in time go to stage of the regulation of the pressure that enables to reduce the dynamic loads in transmission at gearshift.

At present design system is introduced in production on a PA «Belarusian Autoworks BELAZ», and prepares technical documentation for its production in series.

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