

# Exploitation aspects of diagnostic hydraulic and pneumatic systems of Multimedia Hybrid Mobile Stages

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**Abstract.** Knowledge of the technical state and construction of the hydraulic and pneumatic control system of Multimedia Hybrid Mobile Stage HMSM allows you to identify hazards and make a risk assessment. The aspects of the algorithmic process of diagnosing pneumatic and hydraulic control systems presented in the work form the basis for the development and implementation of safe solutions in the process of operation. This article describes the methodology for diagnosing HMSM machine hydraulics and industrial pneumatics systems, detailing the factors determining the correctness of maintaining functional fitness. The considerations developed illustrate the complexity of the diagnostic testing design process for condition assessment.

## 1 Introduction

The complexity of today's machine hydraulics systems and the responsibility for the quality of the tasks carried out is now so great that it becomes necessary to provide the user with fast and reliable information about the current technical condition of these systems. Such information can be given by correctly carried out diagnosis of the system [3,6,8].

The solution to obtaining reliable information about the state of the hydraulic system and, above all, about the condition of hydraulic components, determining the quality of work performed and the safety of operation, requires close cooperation between users and manufacturers of hydraulically driven and control machines [2].

Modern hydraulic and pneumatic systems of equipment and work machines should have a high level of diagnostic susceptibility, the choice of methods and means of diagnosis depends primarily on the following factors [6]:

- whether the device (or work machine) is a serial product or a unit product,
- hierarchy of the device in the ongoing technological process,
- the use of the machine, or the working machine (in a continuous process or periodically),
- the required level of reliability,
- the complexity of the structure,
- the cost of the equipment (or work machine),
- level of automation and computerization,
- required level of operation of the hydraulic system.

Compressed air, as a working factor, is increasingly used in the drive and control of many modern technological machines. In many industries, the use of compressed air as a

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carrier of energy supplying machinery and equipment is a necessary and required factor to ensure the correct conditions of the process [5].

The widespread use of pneumatic drives and controls is due to the many advantages of the compressed air working agent. Among the many advantages, the most important are:

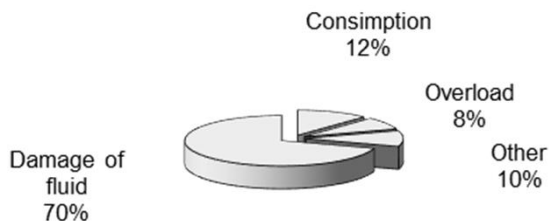
- simple operation of the controls (low forces are needed to control and the controls can be placed in places convenient for the operator),
- the possibility of automation, using typical, standardized components and components,
- prevalence of air,
- compressed air after work can be expelled into the atmosphere, practically without any side effects on the environment,
- long life of the compressed air network and its components – while complying with the conditions given in the technological and motor documentation.
- the possibility of transferring the working agent over long distances, at a low cost,
- a wide range of manufactured forces in the working elements of the equipment: from several daN to several kN,
- an uncomplicated way of securing the pneumatic system against overload.

## **2 Characteristics of hydraulic and pneumatic systems**

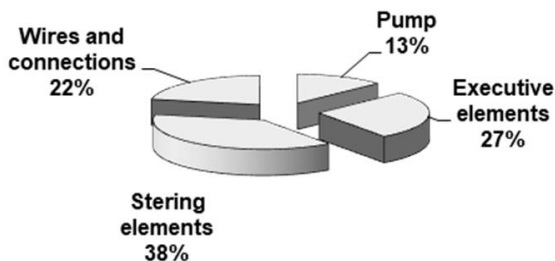
Hydrostatic drive properties

- high kinematic stiffness - hydrostatic drives can be used in devices from which the positioning accuracy of the actuators is applied (due to the very low compressibility of the liquid). Where high positioning accuracy is required, account shall be taken of compressibility and leaks. Kinematic stiffness can be reduced by using elastic elements, e.g. gas cushions.
  - compact construction (small mass of actuators per power unit).
  - self-adjusting force.
  - rapid reaction of the system (favorable ratio of active forces to reactive forces).
  - starting from rest can take place under full load.
  - simplicity of control.
  - easy to carry and distribute energy over long distances.
  - an easy way to store energy.
  - wide range of operating speed achieved.
  - high durability of system components.
  - high level of system reliability.
- defects in hydrostatic systems include:
- efficiency (lower than mechanical drives but higher than electric drive efficiency).
  - sensitivity to temperature changes.
  - high sensitivity to working fluid contaminants.
  - the tendency to leak, increasing with the increase in temperature of the working fluid.

Approximately 70 % of the hydraulic failure of the working machines was caused by participation contamination of working fluids. Other causes of failure are: premature wear of components (pumps, valves, splitters, wires), fatigue of the material antisystem leakage – Figure 1.



**Fig. 1.** Breakdown of hydraulic damage to work machines due to cause of damage.



**Fig. 2.** The damage to the hydraulic components of self-propelled work machines.

The biggest disadvantage of pneumatic systems is the operating factor, which is most often the air in particular is its compressibility (about  $2 \cdot 10^3$  times the compressibility of the liquid, e.g. hydraulic oils) [1].

This defect is primarily a problem in controls and actuators, as it makes it difficult to maintain the smoothness of movement of mechanisms throughout the range of forces played.

Other disadvantages of pneumatic control are:

- the presence of unavoidable compressed air leaks (leaks cause problems with the positioning of the actuators and make it difficult to link the movements of individual machine and equipment units, which in turn prevents the automatic control system from functioning properly),
- changes in the speed of movement of the actuators as a result of changes in external load.

Pneumatic systems distinguish between three basic groups of components that combine functionally compressed air, which is a working fluid for the system:

- components in which the parameters of the working fluid and mechanical parameters (compressors and pneumatic motors) change simultaneously,
- elements in which there is only a change in the physical parameters of the working fluid (dryers, filters),
- components in which mechanical parameters change to change fluid operating parameters (valves and splitters).

### 3 Diagnostic signals

The processes carried out in the hydraulic and pneumatic components can be divided into working and accompanying systems. The parameters of the processes characterizing the technical condition of hydraulic and pneumatics components can be divided into [4,7]:

- hydrodynamics,
- mechanical
- chemical
- electric

- pneumatic
- pause.

Worker processes refer to parameters whose change in value affects the operation of hydraulic and pneumatic components, but this is not always a simple function of the technical condition of the components.

The values of the parameters describing the associated processes depend on the level of impact values forcing these processes and the characteristics of the location of the signal measurement for diagnostic purposes and are therefore a function of the technical condition of the system components. In the process of diagnosing any technical objects, external and internal factors may be interference N, measurable and non-measurable, controllable and non-controllable.

Diagnosing the installation of the working agent in practice amounts to monitoring the technical condition of the transmission network by reviewing the network for possible leaks caused by e.g. corrosion, seal damage at the piping sites (if any) or pipeline cracks due to stress..

Power supply equipment – compressors including drive, central units and local refrigerant treatment units – are also diagnosed.

## **4 Contaminants in hydraulic and pneumatic systems**

### **4.1 Particulate pollution**

The average concentration of dust in urban non-industrialized areas reaches up to 7 mg/m<sup>3</sup> of air, in industrialized areas the concentration of dust is about 1.5 times higher, in rural areas, depending on climatic conditions, the concentration of dust can reach up to 15 mg/m<sup>3</sup> of air.

Please note that at a pressure higher than atmospheric pressure, the concentration of impurities is proportionally higher.

When choosing the size and place of installation of the suction filter, the requirements specified by the compressor manufacturers must be strictly observed.

Impurities, in the form of particulate matter, are sucked not only from the air, they are also generated inside the compressed air network as a result of wear processes. Most pollutants are generated in pipelines. These are most often products of corrosion caused by the presence of water (in the form of liquid or steam) [3].

Another type of contamination is the oil from the compressor lubrication system (this problem occurs primarily in compressed air-powered networks in reciprocating compressors with a significant degree of wear). Air pollutants also interact by forming mixtures (solid particles with water or oil) or emulsions (water with oil).

### **4.2 Solids**

There is no clear definition of particulate matter because the lower limit of particle hardness below which particulate matter and particles with clearly rheological properties would not be classified as impurities is not specified.

At high airflow rates in pipelines, particulate matter, larger than 5 mm in the air, has very high kinetic energy. By hitting the metal surface of pipelines or parts of controls and work pieces, they cause wear called erosive wear.

Particulate matter of less than 5 μm in combination with water and oil creates a hard-to-remove sediment.

Some contaminants may have catalytic properties and their chemical properties may cause chemical corrosion of surfaces in direct contact with them.

The particulate diameter of the particulate matter can be measured using the following devices:

- cascading filter (can be used at high pressures and high temperatures). You can use a cascading filter to determine the dimensional distribution of particles.
- particle counter – the microscope scans the surface of the membrane filter, the pores of which have precisely defined diameters.

Determining the dimensional distribution of particles requires the use of a set of membrane filters, in which each filter has a different filtering accuracy.

Two types of concentrations of impurities are distinguished:

- gravimetric concentration,
- granulometric concentration.

The gravimetric concentration (mass concentration) expressed in g of pollutants per 1 m<sup>3</sup> of air is commonly used to quantification of pollutants in the air. To determine the amount of particulate matter in compressed air, gravimetric concentrations are practically used, which determines the number of particles with the highest permissible linear dimension expressed in  $\mu\text{m}$  [8,9].

Gravimetric concentrations can be determined by:

- particle counters,
- photometers of diffused light,
- gravimetric methods which can be used at high pressures.

Particle counters and diffuse light photometers can only be used at atmospheric pressure. In industrial practice, the determination of gravimetric composition is used only in exceptional cases, as measurement methods are complex and require the use of specialized apparatus.

### **4.3 Water**

Steam, in a certain amount, is always in the atmospheric air. As a result of compression and the resulting temperature rise, the water does not condense. In a cooler (inter still or final) where the air is cooled, in a compressed air distribution pipeline or pneumatic tools where the air is expansional, the water vapor condenses and the air is saturated with steam.

Moisture corrodes piping, metal surfaces of controls and work elements, increases flow resistance through filter elements, and can cause freezing in winter conditions. It also reduces the quality of the final product when sandblasting, drying surfaces or painting.

The concentration of water vapors can be measured by [8,10]:

- psychrometer,
- hygrometric:
  - electronic,
  - electrical.
- piezoelectric hygrometric isopycnic.

The technological conditions of many industrial processes require a continuous supply of compressed air with strict parameters. Process air contains a certain amount of humidity that can cause damage to pneumatic controls or actuators uncontrollably, reduce their reliability, reduce the quality of the industrial process, the efficiency of the device and increase the costs of the industrial process. In industrial practice, measurements of water concentrations are not used. The use of the abovementioned measuring instruments requires high qualifications and therefore the measurement of water concentration is carried out by compressor manufacturers, dryers and test units. In practice, the humidity of compressed air is controlled indirectly by controlling the condition of the installed dryers (dew pressure point)

#### **4.4 Oil (mineral or synthetic)**

Oil (mineral or synthetic) is used in compressors with lubricated compression chamber. Lubrication-free (dry) compressors may contain traces of oil sucked in with inlet air. In compressed air, oil can occur in the form of:

- liquid,
- aerosol (dispersed liquid, in the form of fine particles suspended in the air),
- vapors.

What part of the oil lubricating the compression chamber will remain in the compressed air depends on the compressor type, its technical condition, the type of oil and the quality of the filters.

### **5 Diagnostic algorithm of HMSM hydraulic system**

The methodology for diagnosing HMSM machine hydraulics systems depends on a number of factors, e.g.:

- type of system controls – hydraulic or electro-hydraulic,
- installed in the diagnosed system of sensors and measuring devices,
- the possibility (measuring points) of mounting sensors and measuring transducers (without dismantling the system),
- preparing space for diagnostic sockets (outputs of terminals of installed measuring transducers),
- type and efficiency of the diagnostic equipment.

Analogue diagnostic instruments cannot load ordinal data, compare measured diagnostic parameter values with limit values, and update databases. Digital technology, on the other hand, allows this.

The specificity of diagnosing hydraulic systems is that if a hydraulic system malfunction (e.g. malfunction in the operation of the work machine's work pieces) is found, it is necessary to check the condition of the components of the system. Checking the components (drive, control or working) when they need to be removed from the machine is not a diagnosis. It requires a separate test bench to check the technical condition of the component, i.e. to compare the actual characteristics with the theoretical ones.

Therefore, it is important to take into account the issue of diagnosis in the earliest stages of machine work, i.e. worth cutting and constructing. Subsequent interference with the structure of the subsystems of facilities necessitates additional, sometimes very high, costs and does not always guarantee the correct use of the diagnostic system (or subsystem). Hydraulic actuators in work machines are coupled to different mechanical components, so not every failure of the machine subsystem being diagnosed is related to the hydraulic system that is part of the subsystem. The diagnostic subsystem of hydraulic systems should therefore be regarded as part of the diagnostic system of the machine.

It distinguishes the diagnosis of the working fluid, treating all activities related to controlling its parameters as an integral part of the diagnosis, which is due to the fact that about 80% of hydraulic failures are caused by liquid contamination [10].

The existing traditional division of diagnostic methods into organon - organless methods instrumentals to the existing naves, which can be seen in a large group of machine operators on the side. However, due to the complexity of machine hydraulics systems, the increasing role of instrumental agnostics can be observed in the development of machine hydraulics.

The most common method of diagnosing hydraulic systems is a simple observation method, in which the human senses – of sight, hearing, touch and sense of sense of mind are used. This method requires a lot of experience and is not very expensive. Typical diagnostic parameters that can be known by simple observation method are [9]:

**1. Visual inspection:**

- indications of control and measuring instruments (thermometer, working fluid level indicator, pressure gauge, filter cartridge contamination indicator, tachometer, ammeter, etc.) installed in a hydraulic roof,
- vibrations (vibrations, strong disposable shocks, repeated shocks),
- external leaks,
- hydraulic oil.

**2. Auditory inspection:**

- external mechanical noises,
- internal mechanical noises,
- noise caused by the flow of liquids.

**3. Touch control:**

- temperature
- vibrations (vibrations caused by over-control),
- leaks.

In some cases, some sizes can only be determined by direct measurements. This applies primarily to the size of the plan, such as:

- coaxially of the pump and the drive motor,
- position of the axles of the actuators (hydraulic cylinders, motor sand rotary cylinders, etc.).

In the case of indirect methods for determining the state characteristics of hydraulic systems (the most commonly used methods), depending on the type of carrier and information of the system state, the following shall be used:

- operating process parameters such as oil pressure, hydraulic oil flow rate, operating motion duration, e.g. actuator background injection, engine torque, aromatherapy,
- accompanying process parameters: temperature, differential pressure (e.g. when testing hydraulic filters), wear products (seals, controls), hydraulic oil aging products, concentration of contaminants (oil purity class), vibration of pumps and motors, etc.,
- other parameters, e.g. acoustic emission (occurring during cavitation).

**6 Diagnostic algorithm of HMSM pneumatic system**

The methodology for diagnosing pneumatic installations and equipment depends on a number of factors, e.g.:

- installed in the diagnosed installation of sensors and measuring transducers,
- the possibility (measuring points) of mounting sensors and measuring transducers (without dismantling the system),
- preparation of places for diagnostic sockets (outputs of terminals of installed measuring transducers),
- capabilities of your diagnostic equipment.

Analogue diagnostic instruments cannot load ordinal data, compare measured diagnostic parameter values with limit values, and update databases. Digital technology, on the other hand, allows this.

The specificity of diagnosing pneumatic installations and equipment is that if a malfunction is detected (e.g. malfunctions in the operation of the actuators), it is necessary to check the condition of the components of the installation. Checking the components (drive, control or working) when they need to be removed is not a diagnosis. It requires a specialized test bench to check the technical condition of the component, i.e. to compare the actual and theoretical characteristics.

Therefore, it is important to take into account the issue of diagnoses already during the design phase of the installation. Subsequent interference with the pneumatic they carry



necessity system structure necessitates additional, sometimes very high, costs and does not always guarantee the correct use of the diagnostic system (or subsystem). Pneumatic actuators are coupled to different mechanical components, so not every failure of the pneumatic actuator is related to compressed air supply [11].

The existing traditional division of diagnostic methods into methods of organoleptic (organelles), no instrumentals instrumental methods is due to the existing naves, which can be seen in a large number of users of compressed air installations [12,13,14].

The most common method of diagnosis is a simple observation method, in which the human senses – of vision, hearing, touch are used. This method requires a lot of experience and is not very expensive. Typical diagnostic parameters that can be known by simple observation method are [9]:

### **1. Visual inspection:**

- indications of control and measuring instruments - thermometer, pressure gauge, filter cartridge contamination indicator in compressed air treatment units, tachometer, ammeter (compressor),
- vibrations (vibrations, strong disposable shocks, repeated shocks),
- moisture appearing on the actuators.

### **2. Auditory inspection:**

- noise caused by leaks in the pneumatic system.

### **3. Touch control:**

- temperature
- vibrations (vibrations caused by oversteer).

## **7 Summary**

In the case of HMSM, of the total quantity of cleaning of hydraulic oil with solid particles, 70 % due to pollution entering the systems from the environment, about 20 % is organic pollutants (sludge and water), 10 % are products of consumption of components of the nod.

Pollution resulting from the process of use and as a result of improper exploitation plays a dominant role. These impurities consist of quartz particles, high hardness metal oxides, exceeding the toughness of enough elements of metal hydraulic systems and pneumatic systems..

Depending on the conditions of use, the type of materials used in the manufacture of the system components and the intensity of tribological processes, the intensity of the aging process of seal materials, the impurities generated inside the hydraulic system (solid particles) may have ferromagnetic, diamagnetic or paramagnetic properties.

Particulate matter, depending on the dimensions, causes various consequences that are detrimental to the components of the hydraulic system and pneumatic system. Particles larger than 15  $\mu\text{m}$  cause kinematic pairs to become blurred  $\mu$

Particles measuring 5÷15  $\mu\text{m}$  cause accelerated wear of the cooperating surfaces, as a result of which the clearances increase, internal leaks increase, the positioning accuracy of the slider decreases, internal friction in the working fluid increases (resulting in an increase in temperature), the lubricating properties of the liquid deteriorate, which can lead to blurring  $\div\mu$ .

Particles up to 5  $\mu\text{m}$  in size erode the control edges of kinematic pairs, which consequently reduces the precision of the control. The quantitative expression of impurities in specific dimensional groups in the working fluid determines the purity class of the liquid. It should be borne in mind that around 70 % of hydraulic failures are caused by particularly aerators.

In complex hydraulic and pneumatic systems, HMSM can present from several to tens of different operating pressure values at different points in the system. The pressure limits



depend on the application of hydraulic and pneumatic equipment components, in particular overflow and overload valves. pressure adjustment tolerances reach up to 50 %of the adjustable value, most often 5÷7 %.

The temperature or heating dynamics of hydraulic oil is an important parameter for assessing the current state of hydraulic components. The oil temperature increases if the efficiency of the total diagnostic component decreases.

In uncomplicated hydraulic systems, after the temperature measures of the working agent is made directly in the set of the unique. In the case of extensive hydraulic systems, temperature measurement is carried out at several selected points in the hydraulic system. The increase in the temperature of hydraulic oil indicates an intensification of the wear process of the working elements(especially pumps and motors). In winter, we are dealing with over-cooling of the working factor. In this case, the temperature sensor coupled to the rudder system will present the hydraulic pump from starting, protecting frothed fault.

Hydraulic systems always contain a number of components with internal leaks. As a result of leaks, other losses covered by the volumetric damage (volume efficiency decreases, e.g. pumps) and the energy losses increase, mand the speed of working movements increases. Large leaks prevent the hydraulic systema of the machine from working properly.

The use of vibration and acoustic signals should introduce diagnostic measures that have not been used so far in the diagnostics of machine hydraulic system components. Vibroacoustic signals are characterized by high information capacity and speed of transmission.

In the case of indirect methods for determining the condition features of the compressed air system components (the most frequently used methods), depending on the type of information carrier about the state of the system, the following are used:

- parameters of working processes, such as: air pressure, air flow rate, duration of the working movement, e.g. extending the actuator piston rod, torque of the rotary engine, compressor rotation
- parameters of accompanying processes: temperature, pressure difference (e.g. when testing filters), wear products (compressors, seals, control and actuators), vibrations,
- other parameters, e.g. acoustic emission. In the case of manual diagnostic methods, the sequence and quality of the checks performed depends on the knowledge, skills and diagnostic equipment of users of the compressed air network.

The paper provides the most important guidelines for the construction of dedicated systems for assessing the technical condition of HMSM hydraulic and pneumatic systems

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