

THE CONCEPT OF THE BUS FLUID POWER SYSTEM OF THE MINING MACHINE

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Summary. The paper presents the old hydraulic structure of a drilling vehicle and some reasons of its failures. It describes a new fluid power system called bus fluid power system. Also, it presents a new bus control system.

Key words: hydraulic structure, control system, fluid power system

INTRODUCTION

Mining machines perform complex tasks, work intensely in a difficult underground environment and are exposed to considerable loads. The basic kind of drive used in mining machines is the fluid power (hydrostatic) drive. It is supposed to meet higher design and performance requirements than typical heavy-duty machines.

The fluid power system is expected to:

- have a simple and compact design,
- guarantee operational reliability and damage resistance,
- be easy to repair and service in the mine,
- be energy-saving,
- co-operate with a simple and user-friendly control and diagnostic system,
- be cheap.

Fluid power systems used currently in mining machines meet the requirements to a limited extent. An exemplary analysis of the design and operation principle of a typical mining machine's operation unit, that is the unit of a self-propelled drilling car (Fig. 1), enables to formulate several remarks. First of all, the structure of the system is complex. It consists of two subsystems: the subsystem of the extension arm and the subsystem of the drill. The extension arm subsystem features 7 circuits that supply the actuators of the individual elements of the extension arm.

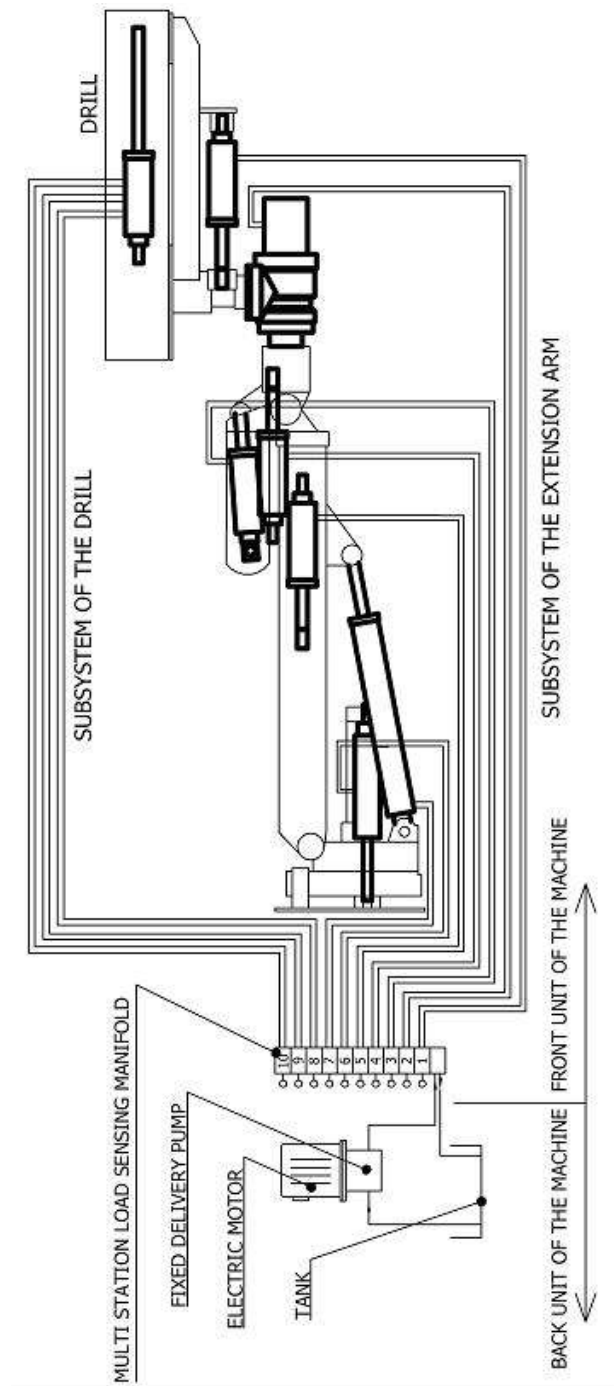
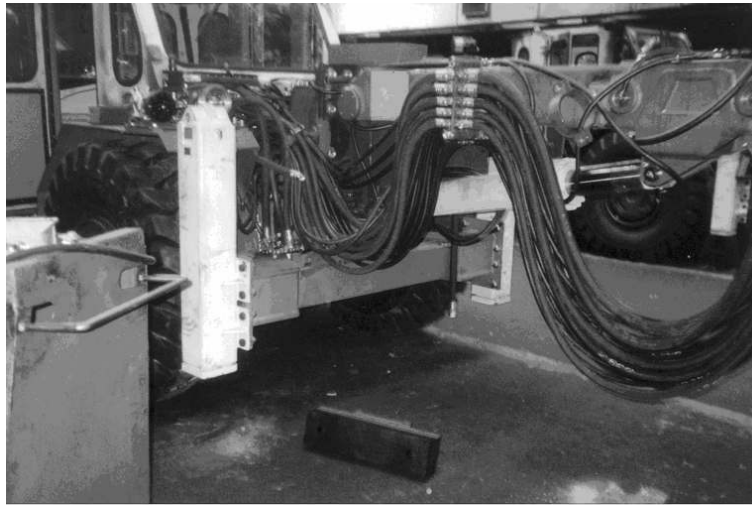


Fig. 1. The diagram of the fluid power operation system of the mining drilling machine

The drill subsystem consists of 3 circuits. All the 10 circuits are connected to the 10-station load sensing manifold, and the manifold, at the same time, is connected to the fixed delivery pump. The pump is located at the back unit of the machine, whereas the manifold is placed at the front unit in the cockpit of the operator. The natural consequence of this structure is a large number of hoses that connect the pump, the manifold and the actuators. Especially difficult and complicated is the connection of the actuators with the load sensing manifold, because it requires 20 up to 10m long hoses that run along the extension arm (Fig. 2a).

a)



b)

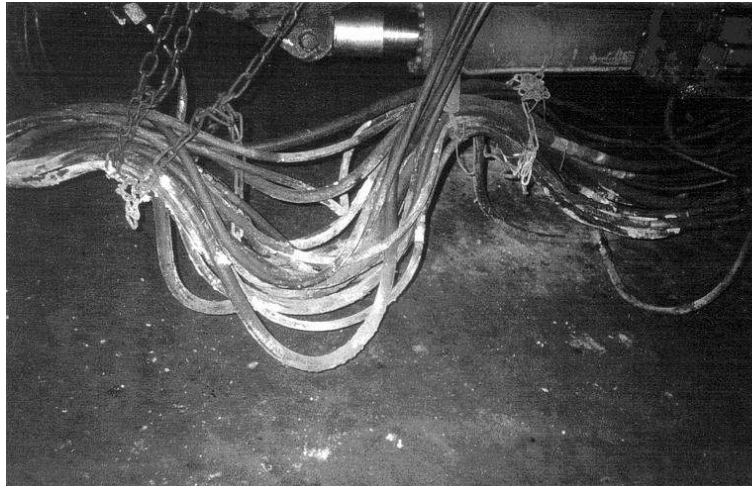


Fig. 2. The view of the hoses in the fluid power operation system of the mining machine:
a) during mounting, b) during operation

During the operation of the machine in the mining conditions, the hoses are folded, twisted, rub against each other and against the surface of the heading, and are exposed to the impact of stone chips. The result of the influence is that the group of lines is often tangled and the connection to the extension arm is only a makeshift (Fig. 2b). Such circumstances make a perfect environment for failure of the lines, which results in the out-of-control outflow of oil from the system, and repairing or servicing of the system in the underground conditions is difficult, labour-consuming and expensive.

Controlling the actuators of the individual elements of the extension arm is performed by means of the 10-station load sensing manifold co-operating with the fixed delivery pump. The analyses presented in [Stryczek 1997] show that it involves considerable power losses, which proves the system energy-consuming. The control process itself is also relatively troublesome, because the operator must attend 10 levers. Practically no diagnostic system is connected with the hydraulic system. The cost of the construction of the fluid power system, and above all the costs of operation, repairs and servicing are considerable.

In these circumstances, the concept of a new hydrostatic system has been designed. The so called „bus fluid power system” is believed to perform well where the old system fails.

THE CONCEPT OF THE BUS FLUID POWER SYSTEM

The following assumptions stem the new 'bus' fluid power system:

- the system needs to have a simple structure that can be obtained through integrating the hydraulic elements into units and simplifying the configuration of the connections,
- the system should be energy-saving and damage resistant,
- the hydrostatic system should co-operate with the electronic control system
- the hydrostatic system should co-operate with the diagnostic system.

Assuming the above, a diagram of the new fluid power system has been worked out and the operation principles of the system have been explained (Fig.3). Parallel-series connection scheme has been applied in the system. It involves three lines (P- delivery, T- tank, L - leakage) that run in series along the extension arm and stand for the hydraulic bus that enables the flow in the entire system. A variable delivery pump (G) with a pressure control (PC) is connected to the line P, which provides constant pressure ($p = \text{const}$) in the line. The bus is divided into sections connected to each other by means of manifolds (Kr). From the manifolds (Kr) to the actuators (S) lead parallel lines (P, T, L). It is possible to make line connections from the manifold (Kr) to one or more actuators. For the construction of the whole structure of connections both hoses (e) and pipes (s) can be used. The actuators (S) are grouped with the manifolds (Kz) on which valves (Z) and electrically controlled slip-in directional control valves (R) are mounted. Thus, the old central control option with the multi station load sensing manifold has been replaced with the new 'spread out' control option in the form of valves and slip-in directional control valves located at the actuators.

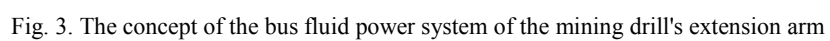


Fig. 3. The concept of the bus fluid power system of the mining drill's extension arm

Change of the connection scheme and use of different hydraulic elements should result in lowering the level of energy consumption by the system. A very important factor for the performance of the new system is the application of the variable delivery pump with the pressure control. As it was stated in [Stryczek 1997], the pressure control automatically adjusts the delivery of the pump to variable demand of the actuators, thus maintaining constant pressure in the delivery line. In consequence, the delivery surplus that in the structure with the fixed delivery pump (Fig. 1) was generated and then directed uselessly to the tank, making a structural volumetric loss, is not generated in the new design. The bus system illustrated in Fig. 3 should be also more reliable and damage resistant even if it was only for the smaller number and length of hoses running along the extension arm.

The fluid power system is assisted by the electronic control system CAN-BUS (Fig. 3). The system features an electrical bus that goes parallel to the hydraulic lines. It consists of two lines. One of them is designed for sending control signals, whereas the other for supplying the valves (Z) and the directional control valve (R) at manifolds (Kz). The electrical bus combines the following elements and units of the control system: the control board, PLC, and IN/OUT modules.

PLC is the mastermind of the system. A special program that is fed into the PLC determines the operational functions that the hydrostatic system is expected to follow. Signals are sent from the PLC by means of the electrical bus to the adequate module IN/OUT and further to the directional control valves (R) that control the actuator (S). In order to change functions performed by the system it is enough to reprogram the PLC.

The diagnostic system can co-operate with CAN-BUS control system. The idea of the co-operation is that sensors (S) monitoring the values of the hydrostatic system parameters such as pressure, flow, oil temperature (Fig. 3.) are connected to the electrical bus. Signals from the sensors are sent to the PLC where they are analyzed, and then, according to the program, a decision on the readjustment of the system elements is made. After that, the PLC sends a signal through the bus to modules IN/OUT, and these, to the actuators. Because both the hydraulic and the electric lines go along the extension arm of the mining drill in the form of the bus, the entire hydrostatic system has been labeled as the „bus fluid power system”.

ASSEMBLY DIAGRAM OF THE BUS FLUID POWER SYSTEM

Using the conceptual diagram of the system (Fig. 3), the assembly diagram of the bus fluid power system has been prepared (Fig. 4). The pump unit has been moved from the back to the front of the machine in the neighborhood of the extension arm. Along the extension arm the fluid power bus has been installed and marked with a full line. It involves several 3-line groups (P, T, L) connected to each other in series by means of manifolds (Kr). Hoses have been used in those areas of the extension arm where the manifolds change their mutual position, and pipes in the areas where the positions do not change. The groups of parallel lines (p, t, l) lead from the manifolds (Kr) to connect the bus with the actuators (S). Pipe sections have been installed in the parts of the system particularly exposed to the influence of external factors. Comparison of the bus connection scheme (Fig. 4) with the old one (Fig. 1, 2) shows a significant simplification and ordering of the system. It is easy to identify and monitor. The elements of the system can be easily dismantled and replaced.

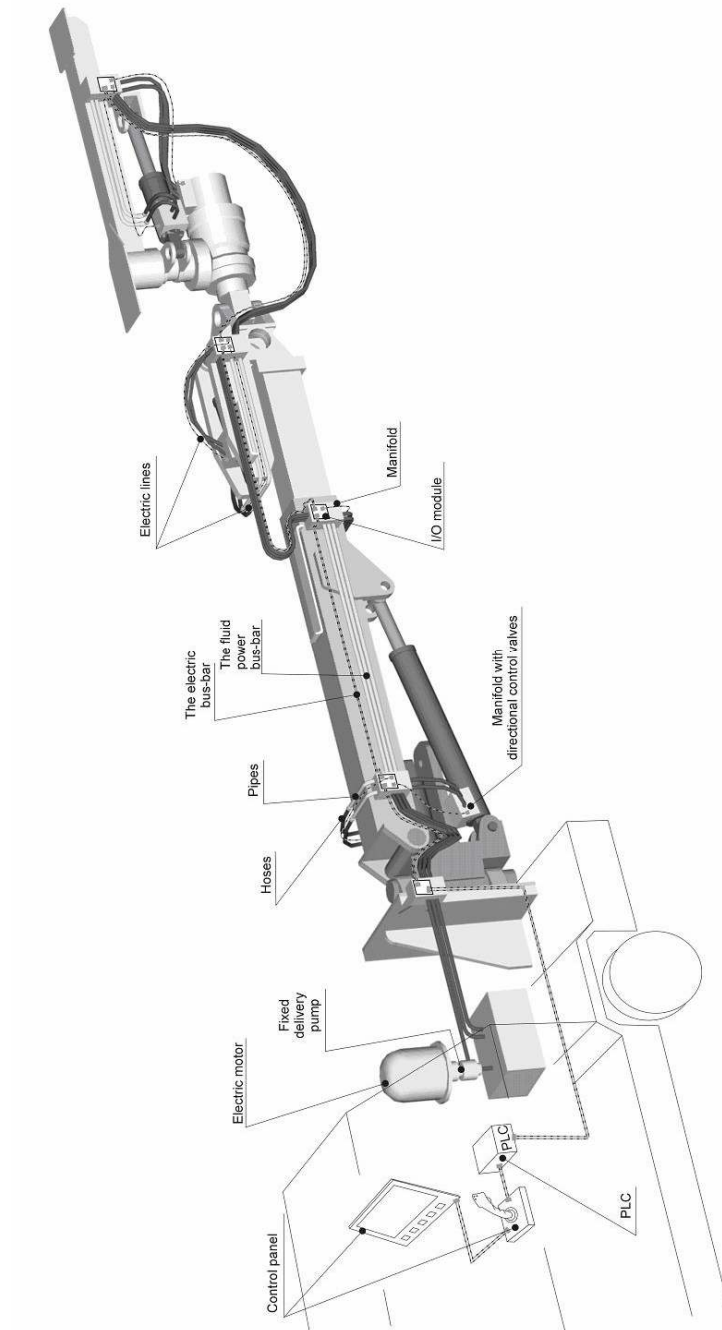


Fig. 4. Assembly diagram of the bus fluid power system

The figure illustrates also an electronic bus, marked with the dashed line. The group of conductors goes from the PLC along the extension arm connecting modules IN/OUT installed in by the manifolds (Kr). The parallel conductors connect modules IN/OUT with the diagnostic sensors in the fluid power system. The arrangement of the conductors and elements of the electronic control corresponds to the arrangement of the hydraulic lines and elements. Thanks to this, it is clear, easy to identify and monitor, as well as easy and quick to repair.

CONCLUSION

The concept of a new bus fluid power system of the mining machine has been presented. The extraordinary feature of the system is the application of the series-parallel connection scheme (P, T, L – p, t, l) as well as of the variable delivery pump with the pressure control ($p = \text{const}$). CAN-BUS electronic control system has been used to control the fluid power system.

The presented system has a simple and well ordered structure. It might be expected to be less energy-consuming, more reliable, damage resistant, easier to operate and control as well as to repair and service.

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