Chapter 10

Possibility of improving the dynamic characteristics of an adaptive mechatronic hydraulic drive

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10.1 INTRODUCTION

In recent times, mobile and technological machines for various applications contain a wide range of mechatronic hydraulic drives based on adjustable pumps, proportional hydraulic equipment, and controllers (Finzel & Helduser 2008, Kozlov 2011, Stamm von Baumgarten et al. 2008). In such hydraulic systems, simultaneous operation of several consumers from one pump is provided with the possibility of proportional control over the movement parameters of each of them. The supply of an adjustable pump is adapted with the total consumption by a hydraulic motor. It provides minimization of power losses in the work of mechatronic drives and high hydraulic efficiency. Application of controllers provides parameter adaptation of hydraulic motor motion to the change of external conditions which considerably increases the operational efficiency of mechatronic hydraulic drives.

10.2 ANALYSIS OF THE RESULTS OF INVESTIGATIONS OF MECHATRONIC HYDRAULIC DRIVES

Such mechatronic hydraulic drives are multi-coordinate, have one pump and several hydro-motors, the work of which must be coordinated by additional cross couplings, which are implemented by controllers and additional hydraulic connections. In distinguished works by several authors (Dyakonitsa & Sugachevsky 2014, German-Galkin

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2001, Shumigay et al. 2013), it is noted that the work of multi-coordinate systems with cross couplings deteriorates significantly due to the interaction of various branches of the system. This is manifested in the decrease of stability margins and deterioration of static, dynamic, and energy characteristics of the systems (Kozlov et al. 2019, Mashkov et al. 2014, Ogorodnikov et al. 2018, Titov et al. 2017, Tymchyk et al. 2018).

In a number of papers devoted to the study of automatic regulation systems with transient couplings (Kostarev & Sereda 2018, Kwasco et al. 2014, Pavlov 2018), measures are proposed to ensure sustainable operation and to improve characteristics through the development of special measures. This improvement of work processes is provided through the development of regulators, including digital ones, and the development of methods for their adjustment (Nizhnik & Neluba 2015, Povarchuk 2017, Repnikova et al. 2010).

It is of scientific and practical interest to solve the problem of developing and adjusting a digital adaptive regulator for a mechatronic hydraulic drive of a mobile machine. Such a task should be solved taking into account the peculiarities of working processes in hydraulic drives operating in wide ranges of changes in speed modes of hydraulic motors and loads on them. In addition, the solution of such a task should take into account the simultaneous operation of two hydraulic motors in coordinated speed modes with several simultaneously operating regulators available, with one of them being digital (Dragobetskii et al. 2015, Ogorodnikov et al. 2004, 2018).

10.3 OBJECT AND METHOD OF RESEARCH

Figure 10.1 shows a diagram of mechatronic hydraulic drive developed by the authors. The hydraulic drive comprises an adjustable pump 1 with a regulator 2 and throttles 3 and 4. Two branches of the hydraulic drive are connected in parallel to the pump 1. The first branch feeds the hydraulic actuator 9. The working fluid enters the hydraulic actuator 9 through the adjustable throttle 5 and the hydraulic distributor 7. The second branch feeds the hydraulic cylinder 10. The working fluid enters the hydraulic cylinder 10 through the valve 14, the adjustable throttle 6, and the hydraulic distributor 8. The hydraulic drive also includes a controller 11 which receives signals from sensors 12 and 13 installed at the inlet to the hydraulic actuator 9 and at the inlet to the hydraulic cylinder 10, respectively. Based on signals from sensors 12 and 13, signals are generated that enter the electromagnets of adjustable throttles 5 and 6 through amplifiers 15 and 16. The logic valve 17 determines the largest pressure on the inlet to the hydraulic actuator pc_1 and to the hydraulic cylinder pc_2 and passes it to control the regulator 2 of the pump 1.

The mechatronic hydraulic drive works in the following way. Working fluid moves from pump 1 to hydraulic actuator 9, which provides the main motion of a work tool (for example, a drill head when drilling wells of a shallow depth). The presence of an adjustable throttle 5, a regulator 2, and a logic valve 17 enables the pump 1 to supply a stable value of flow Q_{n1} to the hydraulic actuator 9. The flow Q_{n1}, which determines the rotational speed ω_1 of the hydraulic actuator 9, will be maintained constant, regardless of the magnitude of the load moment m on the shaft of the hydraulic actuator 9. By changing the magnitude of the area f_{x1} of the window of the adjustable throttle 5 by the signal U_1 from the controller, it is possible to implement a program-driven control over the rotational speed of the hydraulic actuator 9, which drives the work tool.

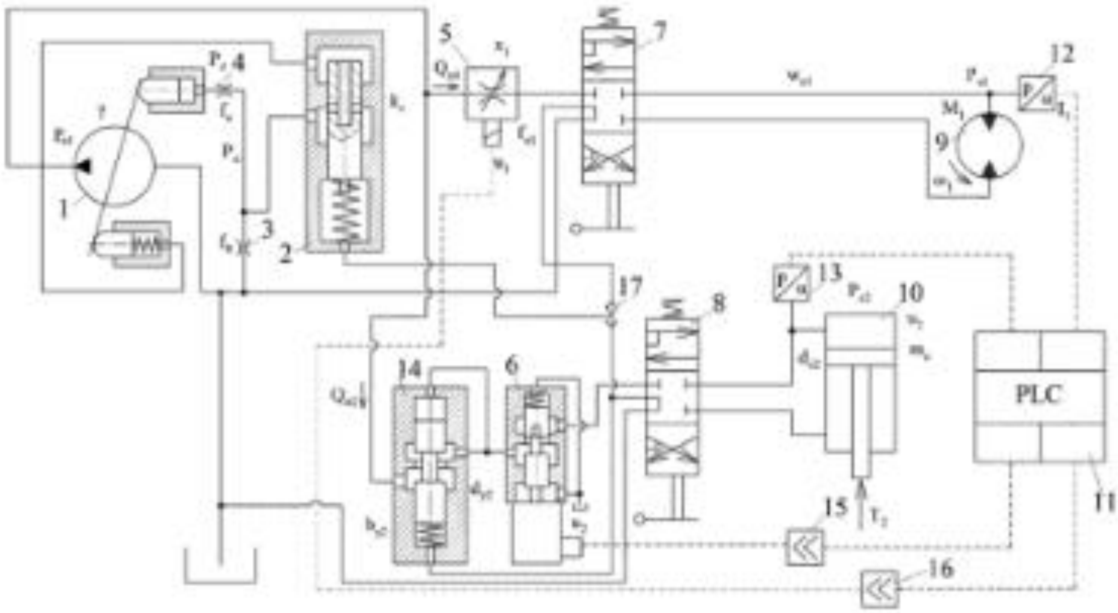

Figure 10.1 Diagram of mechatronic hydraulic drive.

The working fluid from the pump 1 is also fed to the hydraulic cylinder 10, which provides the tool feed. The presence of the valve 14, the adjustable throttle 6, and the hydraulic distributor 8 enables the value of flow Q_{n2} to be maintained and supply to the cylinder 10 to remain constant, regardless of the load size T_2 on the hydraulic cylinder 10 at the pressure ratio $pc_1 > pc_2$. This will ensure a constant feed rate of the work tool $s = \upsilon_2$. The ratio of the feed rate s and the rotational speed of the work tool ω_1 will be determined by adjusting the areas of the working windows f_{x1} and f_{x2} of the adjustable throttles 5 and 6. This ratio may change in the process of operation of the hydraulic drive when changing the external conditions of the hydraulic drive operation (changing the resistance during drilling or changing the depth of the work tool immersion). The change in the ratio of the feed rate s and the rotational speed of the work tool ω_1 is provided by the controller 11 on the basis of an algorithm determined by the developer and the pressure signals pc_1 and pc_2, which arrive at the controller during the process of performing a working operation. In this way, the controller 11 will act as an adaptive regulator, which brings the operation of the mechatronic hydraulic drive into accordance with the change in the external conditions of its operation.

The mechatronic hydraulic drive ensures the movement of an actuation mechanism. Dynamic processes will be determined by the interaction of the hydraulic drive, the actuation mechanism, and external stimuli. In Figure 10.2, the structural diagram of the adaptive mechatronic hydraulic drive is presented.

One of the branches of the hydraulic drive provides the basic movement of the drill tool with the help of a hydraulic actuator, and the transmission function of the basic movement mechanism is described by the function:

$$\frac{1}{m_c s + b_c}.$$