

Design of Performance Testing Bench System for High-Pressure Gear Pump in Automobile Suspension System

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Abstract: In order to test the relevant performance parameters of the high-pressure gear pump used in automobile suspension systems, a performance testing bench system for high-pressure gear pump was designed. Taking into full consideration the principles of hydraulic system design, the performance parameters of the pump to be tested, and the functions required by the system, the hydraulic circuit design, hardware design, and software design of the system were carried out. Finally, the entire system was subjected to experimental testing, validating its reliability and confirming its compliance with performance requirements.

Keywords: Automobile suspension system; High-pressure gear pump; Testing bench system; System design.

1. Introduction

High-pressure gear pumps are mechanical devices used to transport high-pressure fluids[1]. They consist of one or more gears that mesh together to achieve the intake and discharge of the liquid. They have advantages such as high-pressure capability, good stability, high efficiency, and durability. In the automotive field, high-pressure gear pumps are often used as suspension control pumps in automotive suspension systems, serving as the power source for establishing hydraulic pressure in the accumulator[2]. High-pressure gear pumps often need to provide pressures exceeding 15 MPa, making them crucial in automotive suspension systems.

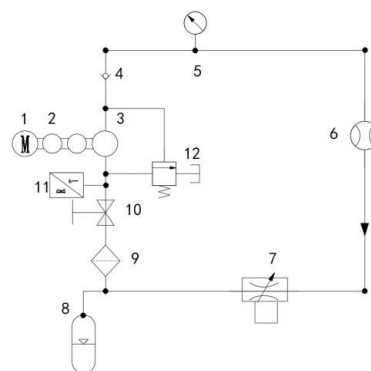
During the development of high-pressure gear pumps, research and development in testing techniques have a significant impact on the design and development of these pumps. Testing techniques play an extremely important role in the fundamental theoretical research and development of gear pumps. Through testing and experimentation, the design methods and levels of the pump can be continuously improved and optimized[3-4]. Difficult problems can also be solved through the analysis of test data. Comprehensive performance testing of high-pressure gear pumps ensures the quality and reliability of the pumps, providing reference and guidance for subsequent applications. Therefore, it is necessary to propose a testing bench system for high-pressure gear pumps to test various performance indicators and provide a theoretical basis for the development and improvement of these pumps[5].

2. Overall Hydraulic System Design for Gear Pump Performance Testing Bench

2.1. Hydraulic System Design for Gear Pump Performance Testing Bench

The function of the hydraulic system circuit largely depends on the combination and connection of hydraulic components. Therefore, when designing the hydraulic system circuit for a gear pump performance testing bench, careful consideration and thoughtful design are required. First, select a suitable gear pump based on the requirements and

performance criteria of the testing bench[6-7]. The type, flow, and pressure capabilities of the gear pump will directly impact the performance of the system circuit. Next, choose appropriate hydraulic valves to control and regulate the flow and pressure of the system. For example, directional control valves can be used to change the hydraulic flow direction, while proportional control valves can be used to precisely adjust flow and pressure. This allows for precise control of the system[8]. Additionally, it is crucial to arrange the oil lines and pipe connections in a rational manner. Ensure that the hydraulic oil can flow smoothly while reducing pressure loss and leakage. Use proper hoses and fittings to ensure the reliability and safety of the system. Furthermore, consider the working environment, safety requirements, and maintainability of the system. Design accordingly to ensure the stable and reliable operation of the hydraulic system circuit. This will enable an accurate evaluation of the gear pump's performance parameters. In conclusion, through careful design of the hydraulic system circuit, the hydraulic system of the gear pump performance testing bench can operate more smoothly and efficiently. This will ensure the stability and reliability of the system, allowing for an accurate assessment of the gear pump's performance parameters. The hydraulic system schematic is shown in Figure 1.



Motor; 2-Speed sensor; 3-Pump under test; 4-Check valve; 5-Pressure sensor; 6-Pressure transducer; 7-Flow control valve; 8-Accumulator; 9-Filter; 10-Manual shut-off valve; 11-Temperature transducer; 12-Unloading valve

Figure 1. Hydraulic System Schematic

The speed sensor is used to measure the rotational speed of the motor. When the manual shut-off valve is in the open position, the tested gear pump draws hydraulic fluid from the reservoir. Subsequently, the fluid passes through a one-way valve, a flow meter, and a pressure transducer to monitor the flow rate and outlet pressure of the pump. The flow control valve is employed to regulate the flow within the circuit, and the filter removes impurities from the liquid. The temperature transducer is utilized to monitor the temperature of the incoming hydraulic fluid. Additionally, the relief valve is connected to the reservoir to prevent potential explosions or damage caused by excessively high internal pressure within the hydraulic system. In the event that the pressure exceeds the predetermined safety threshold, the relief valve automatically opens to release excess pressure into the

reservoir, thereby reducing the system pressure to maintain it within a safe range.

2.2. Design of Gear Pump Performance Testing Rig System

The gear pump testing bench system mainly consists of two major components: the hardware system and the software system[9]. The hardware components include the motor power supply, oil tank, temperature control heating rod, turbine flow meter, flow control valve, pressure transducer, safety relief valve, temperature transducer, and industrial control computer. Figure 2 illustrates the schematic diagram of the hardware system Architecture of the apparatus.

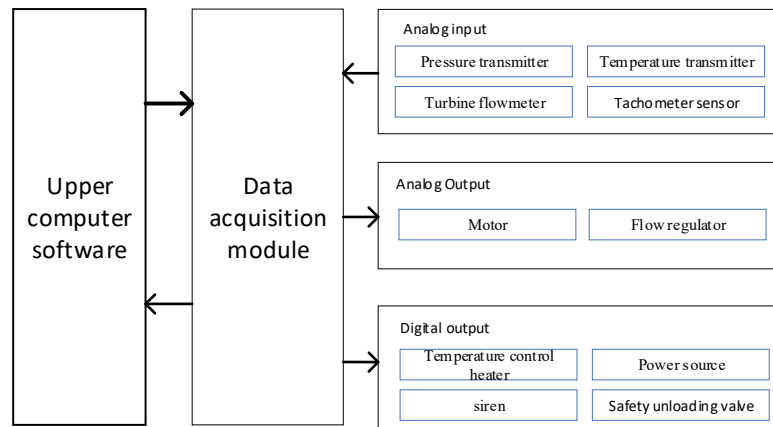


Figure 2. Schematic Diagram of System Architecture

The data acquisition module, along with the industrial control computer, forms the hardware foundation platform for measurement and data acquisition display[10]. The data acquisition module communicates with the relevant hardware through analog and digital signals. The sensors in the testing bench transmit analog electrical signals representing physical quantities to the data acquisition module, which stores the data in registers of the data collector. The industrial control computer retrieves the relevant analog values by querying the

registers and converts them into actual physical quantities. This enables the monitoring of sensor signals, data acquisition, and sending of control instructions. The industrial control computer controls the data acquisition module to output analog and digital signals, thereby controlling the on/off status of the motor, flow control valve, temperature control heating rod, power supply, alarm lights, and safety relief valve. The main sensor models are shown in Table 1.

Table 1. Main Sensor Models

Numble	Name	Model	Quantity	Feature
1	Pressure transmitter	CYB4301	1	Inlet pressure measurement
2	Turbine flowmeter	LWGYC-30	1	Measured flow
3	Temperature transmitter	SBWZ-2280	1	Measuring liquid temperature
4	Tachometer sensor	ZJ2000-II	1	Measuring motor speed

The core components of the hardware system are the industrial control host and the data acquisition module. The data acquisition module uses the ETH-MODBUS-IOR-A data acquisition module, which is based on Ethernet and Modbus protocol. This data acquisition module is commonly used in industrial automation systems to communicate with other devices via Ethernet and to collect and transmit data using the Modbus protocol. It offers high-speed communication, strong stability, and easy installation and maintenance, making it a suitable choice for communicating, transmitting, and storing data between the data acquisition module and the industrial control computer. Data Acquisition Module is shown in Figure 3.



Figure 3. Data Acquisition Module

2.3. Design of Gear pump performance test bench software system

The software system, to a certain extent, determines the functionality and convenience of operation of the testing system. In order to control the gear pump test bench and ensure its normal operation, based on task analysis, it is required to perform various performance tests on the gear pump, including gear pump performance test, high-temperature test, low-speed performance test, overspeed performance test, overload performance test, durability performance test, and accumulator test. The overall structure of each test is consistent and can be roughly divided into four functional modules: basic component operation module, data acquisition module, data display module, and data archiving module. Software function module diagram is shown in Figure 4.

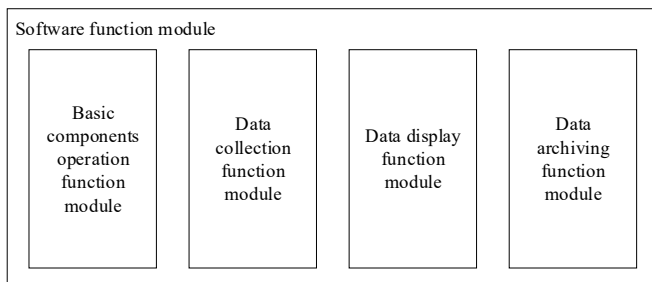


Figure 4. Software function module diagram

1) Basic components operation function module: The main function of the module is to adjust the opening of temperature control heating rod, flow control valve, motor and other components, switch equipment and other operations. The specific business process is to send packets to the data acquisition module through the TCP network port[11], and then send the relevant analog or switch quantity to the corresponding device through the data acquisition module to achieve the function of operating the device.

2) Data collection function module: The main function of this module is to collect data from pressure transmitters, turbine flowmeters, temperature sensors and other related sensors. The specific business process is to send messages to the data acquisition module through TCP network ports to collect relevant analog quantities in the registers of the data acquisition module[12].

3) Data display function module: This module mainly displays the data collected in the data collection function module on the client page.

4) Data archiving function module: This module is mainly to save the data collected in the data collection function module, and save the data in the relevant documents for the convenience of subsequent review and summary of the experimental law.

Among them, the core functions are control components and data collection functions. To realize these two functions, communication with the data collection module is required. Through the data collection module, electrical signals are sent out to control related components or collect related data returned by the data collection module. The data acquisition module realizes TCP network port communication through the Scket library in python. In the software, the data acquisition module sends, receives and parses packets through TCP protocol to complete data collection, storage and control of components.

3. Gear Pump Performance Test Bench Experiment Verification

In order to verify whether the design of the test bench meets the design requirements, a certain type of high pressure gear pump is selected for loading and performance testing. When the speed of the selected high pressure gear pump is 3700rpm, the pressure of the oil pump is 15Mpa, the displacement is 1.2L/min, and the unloading pressure of the unloading valve is set to 2Mpa. Open the stop valve to open the hydraulic circuit, wait for a period of time, increase the speed of the gear pump to 3700rpm, the flow rate at this time should be 1.2L/min, wait for stability after the signal collection. After 30 seconds of continuous acquisition, the test bench system was closed and the obtained data was summarized, as shown in the figure below. The speed of the collected pump is basically stable at 3700r/min, and the fluctuation range is 10r/min; the pressure of the collected pump is also basically stable at about 2Mpa, and the fluctuation range is about 0.05Mpa; the collected flow rate is basically stable at 1.2L/min, and the fluctuation range is 0.05L/min. Speed-Time Graph is shown in Figure 5, Pressure-Time Graph is shown in Figure 6. Flowrate-Time Graph is shown in Figure 7.

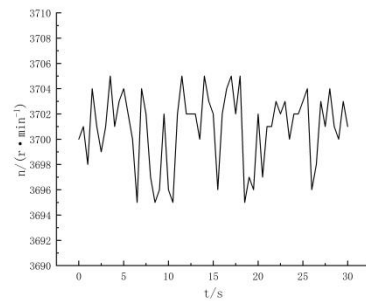


Figure 5. Speed-Time Graph

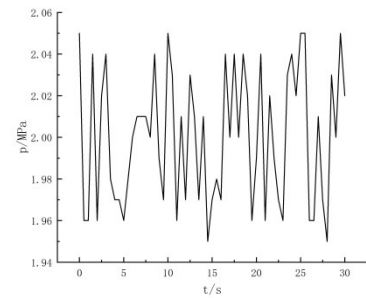


Figure 6. Pressure-Time Graph

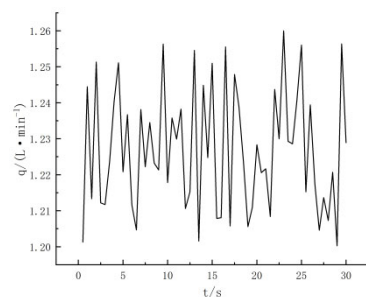


Figure 7. Flowrate-Time Graph

4. Summary

To conduct experimental testing on the relevant performance parameters of a certain model of high-pressure gear pump in the automotive suspension system, a performance test bench system for the high-pressure gear pump in the automotive suspension system was designed. This system enables experimental testing of the performance parameters of the high-pressure gear pump and allows for the control of these parameters through software. It also facilitates the recording of performance parameters during the experimental process. The testing capabilities and accuracy of this test bench have met the expected results, and the rationality of the design concept and methods of this test system has been validated through experiments.

References

- [1] Xing Li, Qingwei Dong, Geqiang Li et al. Research on Radial Force Compensation Method of High Speed and High Pressure Circular Arc Gear Pump. *Modern Manufacturing Engineering*,2022(05):72-78.
- [2] Longjun Luo, Xiaofeng He, Xun Liu et al. Design of Experimental Device for Sealing Performance of Hydraulic Pump Plunger. *China Mechanical Engineering*.
- [3] Wei Dai, Putian Zhang, Fusen Ren. Design and Application of High temperature Test Bench for Mechanical Seal. *Petrochemical Equipment*,2023,52(06):48-52.
- [4] Xiupeng Wang, Xiaobo Gao, Wenting Liu et al. Sealing test of valve. *Chemical Engineering and Equipment*, 2023, (10).
- [5] Huade Song, Yuhua Li, Bo Peng et al. Design Optimization and Experimental Study of Large Thermal Circulation Pump. *Machine Tool & Hydraulics*, 2019,51(20).
- [6] Weiwei Wu. Design of Multi-stage Pressure Source Hydraulic Pump Valve Compound Intelligent Control System. *Information Recording Materials*, 2023, 24(03).
- [7] Jian Chen. Design of Integrated System for Hydraulic Loading Test. *Hydraulics Pneumatics & Seals*,2023,43(03).
- [8] Guoliang Cui, Weiwei Liang. EH3500ACII Mining Truck Hydraulic System Optimization Design. *Open Pit Mining Technology*, 2023, 38(01).
- [9] Bo Hong. Design of Data Acquisition System based on single chip Microcomputer. *Information and Computer (Theory Edition)*, 2023, 35(08).
- [10] Qingchun Yang. Design of Upper Computer Software for Car Body Static Strength Test Bench. *Manufacturing and Upgrading Today*, 2022, (06).
- [11] Xin Zhang. Design and Implementation of Multimedia Technical Support System based on TCP/IP. *Information Recording Materials*,2023,24(07).
- [12] Qing Miao. Demand Analysis of multi-mode Data Acquisition and Communication Technology. *Industrial Control Computer*, 2019, 36(10).