Research on Core Module Design of NR Power System Based on Engine Parameters

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Abstract. This paper proposes the concept of constant power interval for turbocharged engines. Based on the analysis of the existing engine and torque converter matching, a new method for engine and torque converter matching is proposed. At the same time, the paper adopts the modular idea, and divides the loader into five modules: engine, hydraulic torque converter, gearbox and drive axle, complete machine and external environment, and establishes mathematical model and MATLAB/Simulink simulation model respectively. The MATLAB/Simulink simulation model of each module is connected to establish the loader powertrain simulation system, and the performance of the loader drive system under the conditions of shovel loading, forward lifting and full load retreat is analysed. It indicates that the loader's power and economy cannot be satisfied at the same time, and the design should be focused. The experimental results show that the system has perfect functions and stable performance, which meets the needs of engine performance development test.

1. Introduction
The powertrain of the loader includes the power unit and all of the transmission components between it and the drive wheels. At present, the common wheel loader power transmission system transmission types are: mechanical, hydraulic mechanical, electric wheel and full hydraulic. The domestic ZL series loaders mainly adopt the hydraulic mechanical transmission type. As shown in Figure 1, the powertrain of the loader is mainly composed of a diesel engine, a torque converter, a power shift transmission, a transmission shaft, and a front and rear drive axle.

Figure 1. Schematic diagram of the powertrain of the loader.
Taking the hydraulic mechanical transmission system of the loader as the research object, on the basis of analyzing the shortcomings of the prototype, the drive system of the loader is improved, and the dynamic performance, economic performance and work of the whole machine are improved by reasonably matching the parameters of the transmission system. Performance. On the basis of reasonable matching of the transmission system parameters, the hydraulic mechanical transmission system of the loader is divided into five modules: engine, torque converter, gearbox, drive axle, complete machine and external environment, respectively, and the dynamic model of each module is established. Based on the MATLAB/Simulink software platform, the loader powertrain simulation system is built, and the performance of the drive system under typical working conditions is analyzed.

2. Loader engine power calculation

2.1. Insertion resistance
The insertion resistance is the reaction force of the pile to the bucket when the loader bucket is inserted into the pile. The insertion resistance is mainly composed of the following resistances: the resistance of the cutting edge before the bucket and the cutting edge of the two side walls; the frictional resistance of the bottom surface of the bucket and the side wall and the material; the frictional resistance of the outer surface of the bucket when in contact with the material. It is known from the experiment that as the depth of the bucket insert pile increases, the insertion force increases by a parabola with an index slightly larger than 1, and the empirical formula of the insertion force is calculated:

\[ P_C = 9.8K_1K_2L_C^{1.25}B_KK_3K_4 \]  

Where: \( P_C \) represents the bucket insertion resistance (N); \( K_1 \) depends on the influence coefficient of the blackness and looseness of the material being excavated; \( K_2 \) represents the influence coefficient (t/m³) of the material type (volume specific gravity), see Table 1; \( L_C \) represents the bucket insertion depth (cm); \( B_K \) represents the bucket width (cm); \( K_3 \) represents the bulk material pile height influence coefficient, see Table 2.

| Bulk material type | Volume ratio (t/m³) | Coefficient \( K_2 \) | Bulk material type | Volume ratio (t/m³) | Coefficient \( K_2 \) |
|-------------------|--------------------|---------------------|-------------------|--------------------|---------------------|
| River sand        | 1.6–1.8            | 0.12                | Mud shale         | 2.65               | 0.1                 |
| Clay              | 1.8–2.0            | 0.1                 | Sand stone        | 2.6                | 0.12                |
| Slag              | 0.8–1.0            | 0.07                | Granite (fine grain) | 2.75             | 0.14                |
| Coal              | 1.2–1.3            | 0.08                | Ore               | 3.6–3.8            | 0.17                |
| Limestone         | 2.6                | 0.1                 | Ore               | 4.2–4.5            | 0.25                |

| Pile height (m) | 0.4 | 0.6 | 0.8 | 1.2 | 1.4 |
|-----------------|-----|-----|-----|-----|-----|
| \( K_3 \)       | 0.55| 0.8 | 1   | 1.1 | 1.15|
2.2. **Shovel resistance**

Shovel resistance refers to the reaction force of the boom to the bucket and the reaction of the pile to the bucket after the bucket is inserted into the pile to a certain depth. After the bucket is inserted into the pile \( L_c \) depth, the bucket is lifted by the boom, and the scooping resistance is determined by the material on the rectangular area determined by the bucket bottom insert pile \( L_c \) and the bucket width \( B_k \).

The shovel resistance is also affected by the blackness, looseness, bulk specific gravity, temperature, humidity, material and the friction between the material and the bucket wall. The maximum shovel resistance occurs when the bucket has just started to lift, and as the boom is raised, the shovel resistance is gradually reduced.

The shovel resistance \( P_a \) at the beginning of the bucket lifting can be determined as follows:

\[
P_a = 9.8 \times 2.2L_c B_k K_f \tag{2}
\]

Where:
- \( C_l \) represents the bucket insertion depth (m);
- \( B_k \) represents the bucket width (m);
- \( K_f \) represents the shear resistance (kg/m²) of the material when the bucket begins to lift.

3. **NR power system design based on engine parameters**

A total of 82 sensors are installed in each engine system. In order to facilitate the wiring of the sensor, the sensor signal test module is placed in the test room, and the test module uploads the sensor data to the host computer for processing. Considering that the system needs to communicate with the Xiangyi measurement and control system through the CAN bus, the communication between the test module and the host computer also adopts the CAN bus mode, which simplifies the structure of the system and fully utilizes the advantages of the CAN bus to improve the system. Reliability [1]. According to the type and quantity of signals collected in the experiment, and considering the need to reserve the acquisition channel, the signal test module includes 5 signal test sub-nodes, each of which can collect 24 signals, and the integrated test module can simultaneously collect 24 Road PT100 thermal resistance, 24 K series thermocouples and 72 voltage / current signals, a total of 120 signals. The upper computer communicates with each sub-node in turn through the CAN card to obtain the data collected by the sub-nodes, and further processed by the host computer software. The host computer is equipped with a network card to communicate with the HORIBA exhaust gas analyzer through the LAN bus to obtain data on various emissions. The leakage meter for the test, the supercharger speed measuring module and the smoke meter all have the analog signal output function, and the output signals of each device are connected to the test sub-node for collection and processing. The structure of the whole test system is as shown in the figure. 2 is shown [2].

![Figure 2. Schematic diagram of the test system.](image-url)
3.1. Signal Conditioning Circuit Hardware Design

The test system needs to receive different types of signals such as thermal resistance, thermocouple, voltage and current. For this reason, the signal conditioning circuit is designed to process various types of signals and convert them into standard voltage signals. The signal conditioning circuit is designed as follows. The distance between the test system and some PT100 sensors is far, and the longest signal line is about 5 meters. In order to reduce the influence of lead resistance on the test results, the circuit design uses a three-wire design method [3]. The constant voltage source chip MC1413 is selected to supply power to the bridge arm of the bridge; according to the temperature range that the thermal resistance sensor needs to test, the resistance of the three bridge arms is selected; the output signal of the bridge is amplified by the differential operational amplifier circuit, and the operation is adopted. The chip is LM258. Figure 3 is the principle and layout of the thermal resistance signal conditioning circuit.

![Figure 3. Thermal resistance signal conditioning circuit.](image3)

3.2. Current and voltage signals

The pressure transmitter and flow meter output signals selected in the test are 4 to 20 mA current signals, and the signals output by the equipment such as the air leakage meter are voltage signals. The current signal is directly converted into a voltage signal of 1~5V by using a 250-ohm precision resistor [4]; the amplitude of the voltage signal output by some devices is relatively high. Therefore, a voltage dividing circuit is designed to step down the signal. The voltage signal obtained by the above circuit processing is processed by a voltage follower designed by the LM258. Plate layout of 8 current/voltage signal conditioning circuits.

![Figure 4. Thermocouple conditioning circuit.](image4)
4. Upper position function design
The host computer requires the following functions: It can preprocess the data of the test module and other acquired devices, and display and store the processed results; realize the calibration of each acquisition channel; and can realize the over-limit alarm of some important parameters; Access other test equipment through the CAN bus and LAN bus to obtain relevant parameters.

4.1. Display and storage of data
The sampling frequency can be set by the upper computer software. The upper computer sequentially calls each sub-node through the CAN card according to the set sampling frequency, and requests to collect and upload data. When the upper computer receives the data of each sub-node, it uses the interrupt mode supported by the CAN card. After the data is successfully received, the data of each channel is processed by the sliding filter processing method. The number of points used in the sliding filtering can affect the fluctuation amount and response speed of the data [5], and the sliding filter points are reasonably selected according to actual needs.

The amount of data to be tested and displayed during the test is large. In order to facilitate the operation of the tester, the test results of the same system are displayed together. In order to facilitate comparison, the data of each measuring point is arranged according to certain rules. Each system generally includes two columns of data, generally the temperature is displayed on the left side and the pressure of the same measuring point is displayed on the right side. The background color of the monitoring interface and the font color of the test data are adjustable to meet the visual requirements of different operators. Figure 5 is the distribution diagram of each system of the upper computer monitoring interface.

![Generator host computer monitoring interface.](image-url)
4.2. System calibration

The number of sensors used in the test is numerous, and the types of output signals are various. In order to ensure the accuracy of the test results, it is necessary to periodically calibrate each test channel and corresponding sensor. In order to simplify the calibration workload, a batch calibration method is adopted, and the same type of sensor is simultaneously calibrated. If the PT100 thermal resistance needs to be calibrated, all the thermal resistors are placed in the temperature-adjustable heating device, and the heating device is stabilized to different temperatures [6]. After setting through the calibration interface, the upper computer software collects data, and according to each the amount of change in the channel data automatically determines the currently calibrated channel; the calibration coefficient of the channel is automatically calculated based on the calibration data, and the coefficients are saved. In the same way, other types of sensors can be calibrated. This calibration method can quickly calibrate multiple acquisition channels and sensors at the same time, and has high operability [7].

5. Conclusion

The paper designs a comprehensive test system for engine steady-state parameters. The system can test and analyze the operating state, engine dynamics, and economy and emission performance of the main components of the engine. The paper designs the signal conditioning circuit for the common sensors of the engine. The thermal resistance, K series thermocouple, voltage and current signals are processed. The performance test and analysis of various engines are completed by the developed system. The test results show that the system has a friendly operation interface and good robustness. Suitable for performance development testing of engines.

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