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Testing The Hybrid Hydraulic Drive Aircraft Tractor Via LXI Bus Technique

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***Abstract*—Based on the analysis of the structure and the power transmission system of aircraft towing tractor, a new project applying hydraulic drive hybrid power is put forward considering the requirements of towing aircraft and working process without towbar. As the testing and controlling signals of the system are multi channel and distributed, the testing program is designed via LXI bus. The experimental data indicate both the pressure change of accumulators and the capacity change of the hydraulic pump/motor are ideal. All the data are in good agreement with expectation. The research may highlight the design for a new generation aircraft towing tractor.**

***Index Terms*—LXI, Aircraft towing tractor, Hydraulic drive, Hybrid power, pump/motor**

I. INTRODUCTION

For energy and environment concerns, the future vehicles should be eco-friendly with high performance and high technology[1,2]. The wheel hydraulic driving style based on quadrate hydraulic adjustment and equipped with hydraulic accumulator may collect the wasted energy while breaking and stockpile the energy into the accumulator, thus the power efficiency can be increased[3]. The theoretical basis for applying this technology to aircraft tractor is mature enough.

The transfer rate of the Ethernet can reach 100MBPS and the kilomaga Ethernet has also become widespread. As the LXI bus works on general computer network, replacing the CAN bus inside the aircraft tractor with LXI bus can improve the transfer rate enormously.

Because the data can be transferred via Ethernet without impedance matching, building a testing system is more convenient and flexible[4]. LXI bus transmits the data serially with high speed. The mature standards of computer network cable and connectors are abided. On this basis the instrument web pages and virtual control panels are added. All these features makes it convenient to observe the state of the testing and controlling terminal, get the data and transfer the testing and controlling instructions. C type LXI equipments can meet the requirements of such parts as rotating sensors, accelerating/braking displacement sensors, etc.

In this essay, the scheme that is applicable to towbarless aircraft tractor with hybrid hydraulic drive has been put forward, and the testing system based on LXI bus technology has been designed to meet the demand of data collecting and signal processing for the system performance testing.

II. THE SCHEME ANALYSIS BASED LXI BUS

The hybrid hydraulic power system of the aircraft tractor is controlled via electrohydraulic servo. In the process of the controlling, the testing system obtains all real-time parameters, transfer the data to DSP, and then analyze and process them.

The numbers and types of different sensors are listed in Table 1.Hybrid power system adopting DSP controller, its program flow chart as shown in fig 1.

TABLE I. THE NUMBERS AND TYPES OF DIFFERENT SENSORS

Sensor Type	Num.	Measured Parameter
Metal strain Pressure transducer	6	The pressure of the pipeline
Revolution transmitter	4	Rotating speed of wheels
Magneto strictive sensor	5	Hydro cylinder displacement
Inductance sensor	2	Accelerating/braking pedal shift angel
Revolution transmitter	1	Engine revs
Torque sensor	4	Hydraulic bump/motor torque

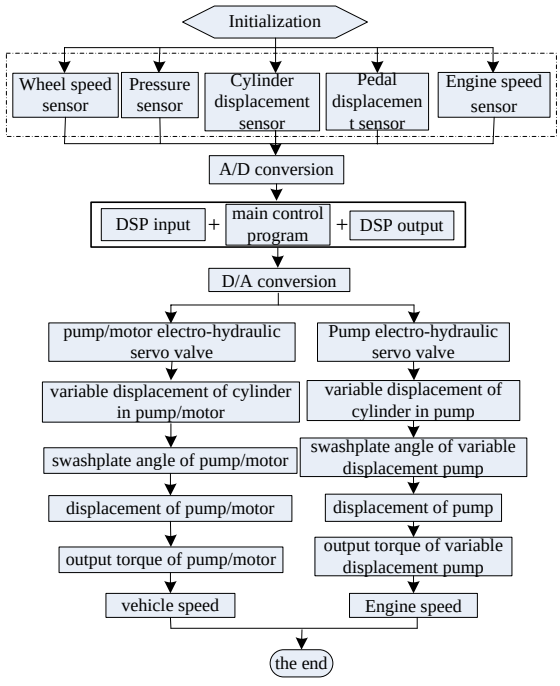

Figure 1. DSP control process of hybrid power system

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While the tractor is working, the velocity should be stable and the acceleration should be continuous. To control all the variable hydro cylinders accurately, the real-time measurement of the characteristic parameters (such as pressure and temperature) of the transitory hydraulic fluid, as well as the input data of the driver, is required. The mass time-varying data must be processed simultaneously and the optimal control signals must be transferred to the actuators as quickly as possible. Thus, each part of the hybrid power system should be on-line monitored. The instruments for analyzing the real-time data from the sensors are complex, so the testing bus demands higher performance.

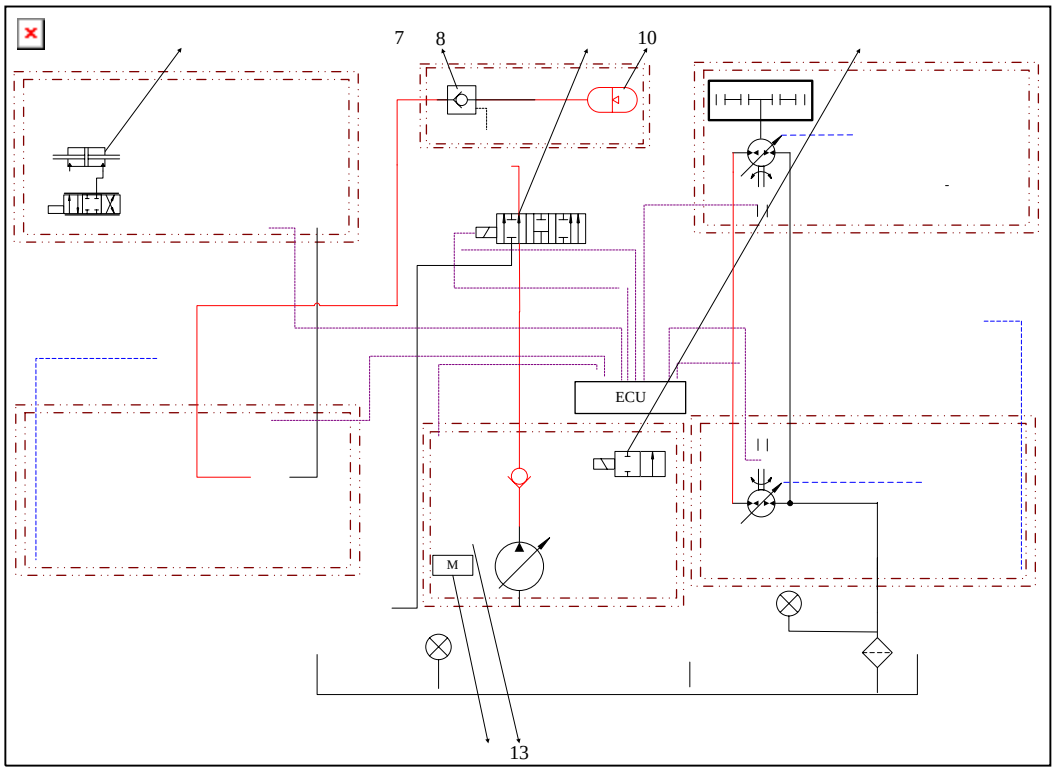
The high transfer rate makes it possible that self-governed ECU can be installed on the hydraulic motors, the electro hydraulic servo valves, the variable hydro cylinders without causing influence over real-time testing. Then, the complex entire hybrid hydraulic power system can be divided into several self-governed subsystem and the logic complexity of the system control is reduced, which simplifies the work of the system software designing.

The performance of LXI bus is much better than CAN bus. The highest transferring rate of CAN bus is 1Mb/s (at this speed the transmission distance is limited to 40 meters), while the transferring rate of LXI bus via kilomega Ethernet can reach 1000Mb/s, and the transmission distance is increased to 100 meters (which can be extended by the repeater).

The POE net interfaces are used in every part of the testing system, which simplifies the design of electric connection. As the RJ45 connector and common net cable are applied in the testing system, the common PC can be plugged into the testing system directly to observe the data and configure/analyze the parameters. Thus, the cost of the whole system is greatly lowered.

III. THE HYBRID HYDRAULIC POWER SYSTEM DESIGN

The working principle of the hybrid hydraulic driving system is shown in fig 2.



1-variable hydro cylinder 2- electro hydraulic servo valve 3-wheel 4-wheel redactor 5-gimbal 6-double-duty element 7-revolution transmitter 8-kydraulic one-way servo valve 9,11-electromagnetic directional valve 10-accumulator 12-engine 13-pedal 14- constant pressure pump 15-oneway valve 16-donkey pump 17-relief valve

Figure 2. Schematic Diagram of the Hydraulic Drive Hybrid Tractor

The aircraft tractor are composed of the engine, the constant pressure pump, the hydro accumulator, the hydro pump/motor, the wheel redactor, the feedback elements and the control system, etc[5]. When the aircraft tractor is traveling along a route, the constant pressure pump driven by engine and the hydro accumulator supply hydraulic liquid for the towing system and the wheels are driven by the pumps/motors through the wheel reducers. When the aircraft tractor is braking, hydro pumps/motors working as pumps are pulled by the inertia and at the same time transfer the energy to the system. Then the energy is stored into the hydro accumulator via high pressure hydraulic liquid. When the aircraft tractor starts again, the energy stored in the accumulator is output into the pumps/motors working as motors via high pressure hydraulic liquid and drive the engine. The inertia power is recycled.

The distribution of the main parts taken into consideration, the electric apparatus elements of the sensors and the actuators are designed as modules, including the engine module, the main pump module, the driving information module, the wheel module and the energy storing module. Each module is tested independently and the parameters are optimized, which are adjusted in stimulating system. Then the types of the main components are chosen and the parameters are set. between the modules of data and the relationship of the signal transmission as shown in Figure 3.

TABLE II. THE PARAMETERS OF THE MAIN COMPONENTS

Item	parameter
Pressure of the net	30MPa
Hydraulic bump/motor	(Rexroth) A4VSO125
Wheel reductor	(Fairfield) W20D1-53.1
Main variable pump	(Rexroth) A20VO260
Engine	Cummins ISBE185 32
Accumulator	(Tobul) BR60-10-60

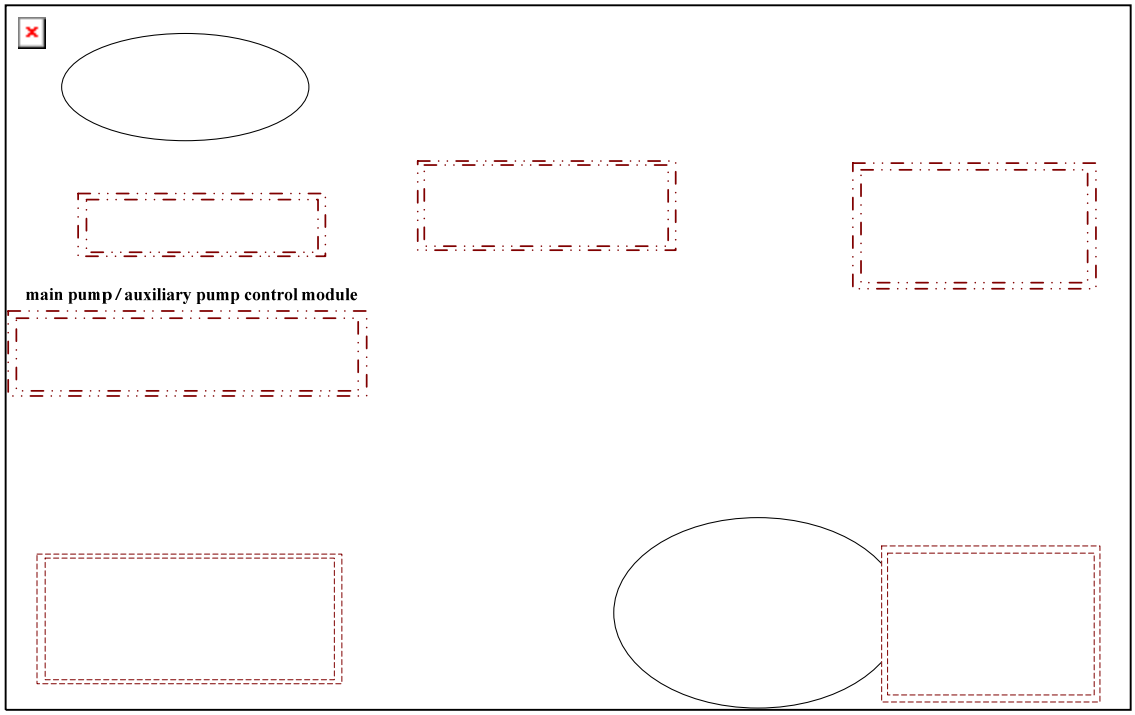


Figure 3. between the modules of data and the relationship of the signal transmission

The service objects are homemade huge aircrafts. The calculation is carried out according to MH/T 6017-1999 national standard. The structure parameters of the main components are listed in Table 2, which are obtained after optimal calculation and type choosing[6].

IV. THE CONTROLLING STRATEGIES OF HYBRID HYDRAULIC POWER SYSTEM

A. *Working State of Start*

In this stage the bus and the main parts working on the bus should be initialized. The clock should be synchronized. The virtual panel of the testing terminal and the instrument webpage server begin to provide service. The relevant hydraulic and mechanical parts perform the following work flow:

The power system starts. The capacity is set to zero (ready state) when the system pressure is raised to 30MPa by the constant pressure pump.

The accumulator releases the energy (the energy stored during last brake, suppose the pressure is less than 40MPa). At the same time the capacity of the wheel motor increased from near to zero (around 1/5) until the driving force meets the requirement of start.

The pressure hydraulic liquid is provided by the constant pressure pump driven by the engine to the hydraulic pump/motor vehicle.

B *Working state during even pace and acceleration*

After the tractor starts, the main components and the electric apparatus elements transmit the real-time data through LXI bus and respond simultaneously to the instructions from ECU. These data and instructions are sent to the analysis terminal synchronically through LXI bus, where they are stored and analyzed. The main parts perform the following work flow:

(1) The torque requirement is calculated according to the signals of accelerating pedal and the wheels' rotating speed. The present output power is calculated according to the speed, based on which the relevant optimal economical rotating speed and torque. Then the capacity of the constant pressure pump is modulated by the variable controller (variable cylinder controlled by electrohydraulic servo).

(2) The hydraulic pump/motor is controlled by the electrohydraulic servo and variable cylinder. The capacity

is changed through the change of the swashplate angle. The output torque is modulated. Then the speed and acceleration can be controlled.

(3) The tractor without load is driven by two wheels while the towering mode is driven by four wheels. This is controlled by the driver.

(4) The absorption and output of the inertial energy is realized by controlling the valve of the high pressure accumulator through ECU.

Ⅴ. THE ANALYSIS OF PARAMETER FEATURES DURING WORKING STATE

In the process of testing the tractor working, the data test of the engine, the constant pressure pump, the hydraulic accumulator and the hydraulic pump/motor should be highly synchronized. The system is stimulated by software and synchronized with IEEE1588. The local time of the main elements is synchronized through tagging the time of the data package[7]. The accuracy can be evaluated with ms and meets the requirements of the system, which make it possible to collect synchronically the temporary pressure of the pipeline, the working liquid flow, the speed and the mechanical parameters.

The required electric power for data collection and operating elements is comparatively. LXI elements are provided power through POE, which makes it convenient to plug in and remove the parts. Some simulating models can be replaced by real elements and the simulating and real models may work at the same time.

The constant pressure pumps, the variable cylinders, the pressure sensors, the electrohydraulic servo valves and the rotating sensors are plugged in the system bus conveniently and flexibly as independent modules through RJ45 connector. The simulating parts can be added or removed as needed according to the different working states of the tractor, which is beneficial for the operation of simulation and may save the resources for optimizing the parameters and simulating the ultimate parameters.

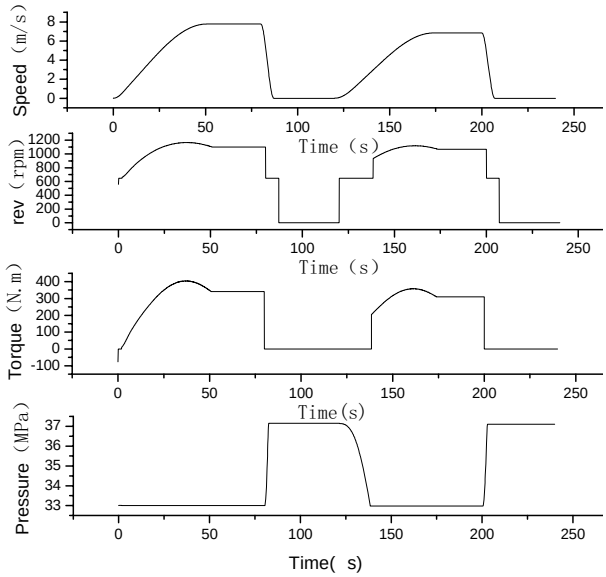


Figure 4. The working permanents of the system varies

The parameters of the hybrid hydraulic drive system during working state are analyzed with MATLAB/Simulink. The state parameters of the hydraulic pump/motor and accumulator pressure in accordance with the tractor speed are illustrated in Figure 4.

The working parameters of each part have been optimized and the ultimate parameters have been stimulated by full stimulation or partial stimulation according to the different working states of the system. The obtained data indicate both the pressure change of accumulators and the capacity change of the hydraulic pump/motor are ideal. All the data are in good agreement with expectation.

Ⅵ. CONCLUSION

The testing system based on LXI has been designed based on the analysis of LXI technology and towbarless hybrid hydraulic driving aircraft tractor with wheel reducer. The working performance of the whole tractor and the change of the working parameters have been tested. The parameters have been optimized through computer simulation. The scheme can be realized as expected.

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