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Simplified Removable Ground Test-Bed for Testing Turbofan Engine

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Abstract: A new simplified removable ground test-bed was designed for testing a certain turbofan engine. The facilities are 5.5 m long, 1.5 m wide, 2.2 m high and not more than 4.5 t of its empty weight. There are four rubber wheels that could be towed. There is an independent electrical measurement and control system to test the rotational speed of rotors, the gas pressure of the compressor, the exhaust gas temperature, *etc*. Cooperated with the oil truck and the electric power supply truck, the turbofan engine could be preserved on the ground and started to the idling regime. While running, the parameter of the engine could be recorded, disposed and displayed. In addition, the facilities were successfully applied to the plateau experiment in order to research how the atmosphere pressure affects the start of engines. Some data are given in the paper.

Key words: turbofan engine; simplified type; removable; test-bed; ground test facilities

一种简化可移动式地面试车台. 李文峰, 王永生. 中国航空学报(英文版), 2003, 16(3): 138-141.

摘 要: 针对某型涡扇发动机, 介绍了一种简化可移动式地面试车台。该设备采用牵引四轮结构, 外形尺寸为5.5m×1.5m×2.2m, 自重< 4.5t。具有独立的电气测控系统, 可以测量转子转速、压气机出口压力、排气温度等参数。在油罐车和电源车的配合下, 能够对某涡扇发动机在地面进行开车油封以及发动机起动和慢车等工作, 并且可以实现对发动机状态全过程的多参数记录。该设备成功地应用于某型涡扇发动机高原实验研究, 为研究大气压力降低对发动机起动的影响提供了关键设备, 文中给出了部分试验数据。

关键词: 涡扇发动机; 简化型; 可移动式; 试车台; 地面检测设备
文章编号: 1000-9361(2003)03-0138-04 中图分类号: TP276^{+}.1; V228.4 文献标识码: A

Usually, the position of a test-bed is irremovable, no matter the test-bed is on open air or in rooms. The running box and running support are fixed. The control equipment and testing devices on the ground are also fixed. The investment of this type test-bed is huge, and the test facilities are heavy. If a war takes place, the test-bed will be difficult to be repaired while destroyed. In addition, it is neither economical nor realistic to build a new test-bed on conditions of some temporary demands. So, a new simplified removable ground test-bed is designed for some turbofan engines[1].

1 The Facilities Function

At the beginning, the intention to invent the facilities was that some turbofan engines need to be preserved with hot oil and depreserved. As the flying time of the fighter jet constantly increases, the engines are gradually entering the period of overhaul and breakdown. When the engines are replaced to repair, or when they are deposited on the ground, preservation and depreservation are necessary for engines. However, the device imported from Russia could not do this job on condition of the hot oil and hot engine. The device only could pour the cooling oil into the engine by pressure. By this way, the engine could be deposited not more than three months. So the authors of this paper invented the new ground maintenance facilities and, afterwards, further expanded them to have the following functions: (1) cold starting the turbine starter; (2) preserving the turbine starter; (3) de-

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preserving the turbine starter; (4) cold starting the engine; (5) preserving the engine; (6) depreserving the engine; (7) hot running the engine to the idling regime ($N_2 = 70\% \pm 2\%$); (8) while the engine is working, checking and inspecting the action of some electromagnetic valves and organizations, such as opening and closing, pulling and pushing; (9) checking parameters of the engine, and (10) eliminating the breakdown on the spot in the outfield.

2 The Facilities Constitution

Fig. 1 shows that the facilities are made of four parts. The first part is the bodywork to install and fix the engine and the external case. The second part is the oil and fuel feeding system installed under the bodywork. The third part is an electrical measurement and control system. The fourth part is an independent system to heat and dewater the oil. Fig. 2 shows the facilities appearance with engine.

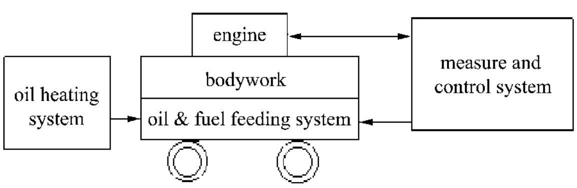

Fig. 1 The facilities constitution

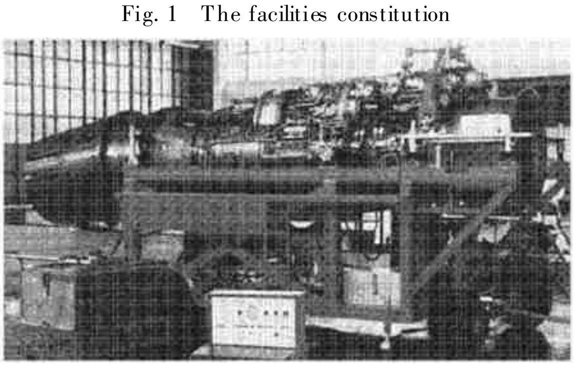

Fig. 2 The facilities appearance with engine

There are four rubber wheels that can be towed under the bodywork bedrock, and there is a handbrake control machine to turn the direction in order to move the facilities conveniently. The dimension of the bodywork cradle accords with the dimension of the engine and turbine starter. While the facilities are working, the four braces are put down and screwed up. The accumulation of the whole frictional force is about 1600kg, so the facilities could support the engine to the idling regime, *i. e.* the bodywork can resolve the problem of thrust force (< 250kg) [2]. The displacement cannot be produced between the bodywork and the ground when the engine runs.

The oil feeding system firstly is parallel to the fuel feeding system; then both of them are connected collusively to the fuel pipe. By a single direction oil or fuel electromagnetic valve, one could make the engine work normally in different regimes, such as preservation, depreservation, idling, *etc.* Besides, a device was also designed to take the waste oil.

The oil heating system is specially designed for the engine to ground seal oil in the outfield. The oil is not only heated to 95±3°C by the heating tube but also lasting 40 minutes to be dewatered. Then the oil is cooled between 50°C and 60°C. There is a filter within the output pipe, whose percolation accuracy is 5μm. The system can operate automatically from heating, mixing, cooling to exporting.

The electrical measurement and control system contains four subsystems. They are the power supply, measurement, starting and regime controlling system. In detail, it consists of the control board, the electrical box and the throttle-by wire. The direct current 27 V and the alternate current 380 V power are guided into the electrical box to supply energy to the whole system. There are the terminal board, the starting box and the voltage regulator within the control board. There are measurement meters, switches, buttons, knobs and signal lights in the surface of the control board. At the same time, the engine, the external case, the electrical box and the control board are jointed by three thick multi-conductor cables. They are shown in Fig. 3.

The parameters that can be measured include starting voltage V_s/V, starting current I_s/A, rotational speed of high-pressure rotor of engine N_2/%, rotational speed of low-pressure rotor of

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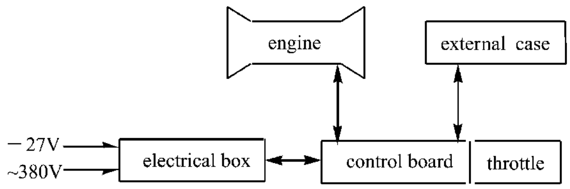

Fig. 3 The electrical measurement and control system

engine N_1/%, rotational speed of starter N_S/(r/min), pressure of vice-oil pipe P_V/kPa, atmosphere pressure P/kPa, compressor pressure of starter P_{2S}/kPa, compressor pressure of engine P_2/kPa, oil pressure P_o/kPa, fuel pressure P_f/kPa, atmosphere temperature T/°C, exhaust gas temperature of engine T_4/°C and exhaust gas temperature of starter T_S/°C.

3 The Data Acquisition System

Designing the data acquisition system is a rather difficult and complex task. The system is required to not only acquire and process the parameters, but also display and output the data in proper ways, such as tables, curves, and so on. In addition, the system will give an alarm display in case of the parameters overflowing in the course of test running.

The signal sources of N_1, N_2 and N_S come from the frequency of the speed voltage generator installed on the engine. The transducers of T_4 and T_S are thermocouples installed on the engine, and the temperature signals are transmitted to the data acquisition system by the temperature compensating lead. The transducers of pressure are used to transform the signals of P_2, P_{2S}, P_V, P_o and P_f.

Both the hardware and software of the data acquisition system adopt a modularization technique and have an opening structure in order to use, maintain and extend conveniently. PLC carries out the task of detecting the rotating speed, pressure signal and temperature signal. There are 16 analog signals inputs, 128 digital signals I/O ports, several counters and timers within CPU. Here, there are A/D conversions with 12-Bits accuracy resolution within analog signals inputs. RS-485 communication mode is used for transmitting data with high reliability, efficiency and anti-jamming. Chinese Windows is the foundation of software. The monitor of Notebook PC is the system's display.

4 The Facilities Characteristic

Because of the integration adjuster only taking the effect in maximum operating regime and the afterburning condition[3], the authors improved the circuit. In other words, one can start, seal, unseal, and operate the engine without the integration adjuster. Several control signals, such as N_2 > 15%, N_2 > 35% and N_2 > 53%, are, now instead, input through manpower by altering the switch or being joined automatically. Some abnormal indication signals such as starting aborts because of over temperature signal of exhaust gas temperature of the starter are, instead, performed by the electronic thermometer. What the authors did could make the equipment more economical and practical.

When the engine dummy runs, it needs to inject oil or fuel, but it does not need retrofire. In the past, people unfixed the starting ignition coil in the outfield. Right now, a special switch is designed on the control board. So the operation is simplified.

Both test meters and electrical equipment are so small and high accurate that the whole electrical measurement and control system looks small. All the controls and manifestations of the system are designed on the control board. It is convenient to operate. And again, the facilities can automatically collect, process and analyze the real time data. It also can alarm emergency.

Because the engine has only three states - preservation, depreservation and idle, the throttle also has three positions- shutdown, idling and afterburning. So throttle-by-wire is easy to operate. The throttle step-by-step controls the motor to move.

In addition, the measurement and control system separated from the bodywork can reduce the noisy influence which comes from the running engine.

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The facilities are 5.5 m long, 1.5 m wide, 2.2 m high and not more than 4.5 t of empty weight. There are four rubber wheels for towing. It is convenient to move.

Running the engine, the facilities must cooperate with the oil truck and the electric power supply truck.

5 The Facilities Application

The facilities were successfully applied to the plateau experiment. Along with the elevation of airports rising, the atmosphere pressure drops, the atmosphere density reduces, and then the rate of airflow entering the engine in a high-altitude airfield is shorter obviously than in the plain. In order to research how the atmosphere pressure affects the starting of engines and explore the adjusting rule in the course of engine starting, the test-bed is necessary for engines in different areas. It is the new simplified removable ground test-bed that supplies the most important equipment. Some data are given in the paper. Fig. 4 shows several real time parameter curves of some turbofan engines running in some airports of Tibet (3540m). Fig. 5 shows several real time parameter curves of some turbofan engines running in some airports of Geermu (2800m). The figures obviously show that the starting performance of the starter and engine got worse in plateau areas than in plains.

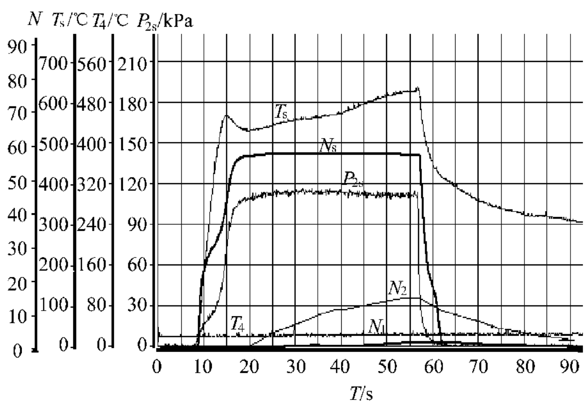

Fig. 4 Several real time parameters curves of some turbofan engine running in Tibet (3540m)

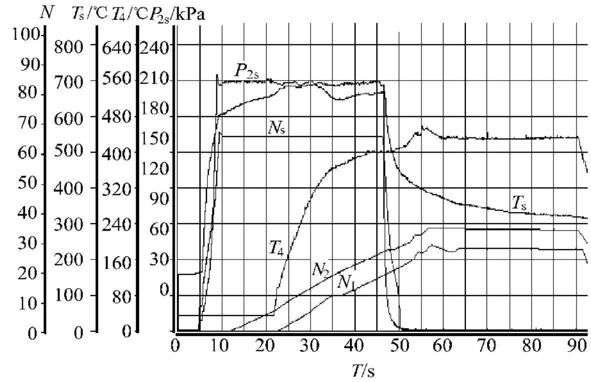

Fig. 5 Several real time parameters curves of some turbofan engine running in Geermu (2800m)

6 Conclusions

The facilities realized some turbofan engines to seal oil on the ground, and realized the engine to start and idle on the ground. On condition that the atmosphere pressure is 60% that of the plain and the temperature difference in a day > 20℃, it has good performance. Now the facilities have served in the Air Force of China.

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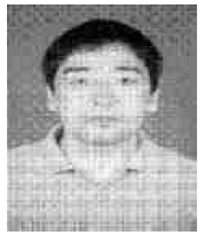

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