

Experimental Study on the Three-phase Sequential Turbocharging System with Two Unequal Size Turbochargers

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ABSTRACT

To improve the vehicle diesel engine performance at part-load operation, experiments on sequential turbocharging system used in a vehicle diesel engine are investigated in this paper. The brake specific fuel consumption and smoke emission of diesel engine are measured in four schemes: with the based turbocharger, with a small turbocharger, with a big turbocharger, with both small and big turbochargers. Then, a new turbocharging method named three-phase sequential turbocharging system with two unequal size turbochargers is presented by analyzing and comparing the experimental results. The experiment on a vehicle diesel engine with three-phase sequential turbocharging system shows that the brake specific fuel consumption and the smoke emission are reduced observably in complete engine speeds range, especially in the low speed operation. Finally, the transient performances of three-phase sequentially turbocharged vehicle diesel engine are analyzed by experiments. The transient experimental results show that in the transient accelerating operation the smoke emission of the diesel engine with the three-phase sequential turbocharging system is lower than that with conventional turbocharging system.

INTRODUCTION

During the last several decades, turbocharging has contributed greatly to the development of the heavy-duty diesel engines. Emission control regulations are increasingly strict and the claim of economizing energy sources is advocated more and more, which result in the critical challenges facing the vehicle engine. So the new

type turbocharging systems become one of the necessarily technical instrumentalities to vehicle diesel engine [1-6]. The sequential turbocharging (STC) system can be matched to the diesel engine well in the wide engine speed range, especially to the heavy-duty diesel which running a wide speed range [7]. The transient response and low operation performances of the sequentially turbocharged diesel engine are better than the conventional diesel engine [8]. Sequential turbocharging system has been a quite successful technology applied to vessel diesel engine and armored vehicle power [9-11]. With unceasing improvement of the boost pressure ratio of vehicle diesel engine, the sequential turbocharging technology will be widely applied in vehicle diesel engine [12].

In this paper, the experiments are described to find out the effects of a three-phase STC system with two unequal size turbochargers on the brake specific fuel consumption (BSFC) and the smoke emission of a vehicle diesel engine in steady operation. Then, the diesel engine's transient smoke emission performances are studied during the engine's rapid acceleration.

SEQUENTIAL TURBOCHARGING SYSTEM TEST BED AND FACILITIES

ENGINE DATA AND TEST APPARATUS - A six-cylinder, four-stroke, water-cooled and turbocharged vehicle diesel engine is used in the sequential turbocharging experiment. And the test engine specification is listed in Table 1. Some turbochargers used in the test are as follows. The based turbocharger is TBP4 from Honeywell, the big turbocharger is T04E from Honeywell and the small one is RHP5H from

IHI. The order of the turbochargers' equivalent circulation area from large to small is TBP4, T04E and RHF5H.

Table 1. Specifications of the test diesel engine

Type	In-line, 4-stroke, turbocharged, inter-cooled
Number of cylinder	6
Bore × Stroke (mm)	114×135
Connecting rod length (mm)	216
Displacement (L)	8.26
Rated speed (r/min)	2200
Rated power (kW)	184
Compression ratio	17.7

The main test apparatus are as follows: GWD300 dynamometer from Power Link, FCM04 transient fuel consumption measuring apparatus from Yike, Turbocharger speed measurement device from MICRO-EPSILON, AVL 439 opacimeter from AVL and DIGAS4000 exhaust analyzing apparatus from AVL.

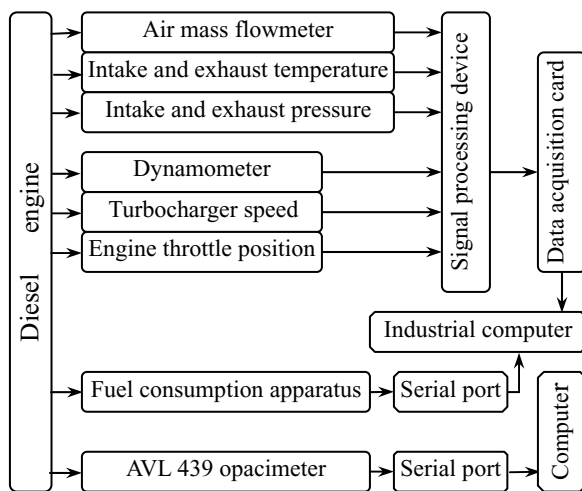


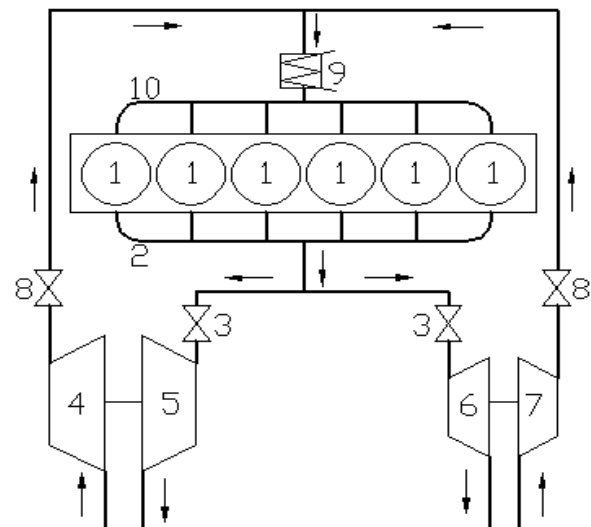
Figure 1. Measure system of experiment

The measure system, schematized in Figure 1, is composed of the measuring module on diesel engine parameters, the measuring module on turbocharging system parameters and the emission measuring module. In this test system, a computer sends dictates to the step-motor to control the engine throttle according to a computer program and records the transient data of every parameter. The turbocharging system parameters including intake and exhaust pressure, intake and exhaust temperature and turbocharger speeds are acquired by Art-PCI2006 data acquisitions card. And the diesel engine performance parameters including fuel consumption and power are obtained by serial port with measuring and controlling program. Smoke emission values are measured by AVL439 opacimeter and the data are sent to computer by serial port. The measurement accuracies for each experimental parameter are shown in Table 2.

Table 2. Experimental instruments accuracy

Measured parameter	Instrument types	Accuracy
Fuel consumption	Fuel mass flow meter (YIKE FCM04)	±0.5%
Smoke emission	AVL439 opacimeter	±0.1%
Turbocharger speed	Turbospeed135 (MICRO-EPSILON)	±0.2%
In-cylinder pressure	Piezoelectric pressure transducer (Kistler 6125A)	±1%

EXPERIMENT SCHEME - In the experiment, the operating points are planned according to the speeds and loads of the diesel engine in the turbochargers allowed running range. In the first instance, the diesel engine performance parameters and exhaust data are measured when the diesel engine is respectively matched with the big turbocharger, the small turbocharger, both big and small turbochargers synchronously, and the based turbocharger. Then, the test results are analyzed and compared. Finally, the test of three-phase sequential turbocharging system with two unequal size turbochargers is carried out. The structure sketch of the three-phase sequential turbocharging system is shown in Figure 2.



1-Diesel engine; 2- Exhaust manifolds; 3-Exhaust switch valve
4- Big compressor;5-Big turbine; 6-Small turbine;7- Small compressor
8-Intake switch valve; 9-Intercooler; 10- Intake manifolds

Figure 2. Three-phase sequential turbocharging system

In this system, the big and the small turbocharger are in parallel, two intake switch valves are respectively set after two compressors and two exhaust switch valves before turbines. When the engine works at low speeds, the switch valves before the big turbine and after the big compressor are closed, so, only the small turbocharger works. Then, at the medium engine speeds operation, the switch valves before the small turbine and after the small compressor are closed, but the other two switch valves are opened, then