Gas engine with world highest generating efficiency —Green gas engine

Since 2007, we have supplied green gas engines as high-efficiency gas engines. They exhibit the world's highest class of power generation efficiency, as development efforts have been devoted to further improving power generation efficiency. The results obtained from these efforts have been utilized in the market, being used at the Kobe Power Center of our Kobe Works and Japan's largest 110 MW class large-scale gas engine power generation plants.

Preface

After the Great East Japan Earthquake of 2011, uncertainty about the supply of utility power has activated the market of in-house power generation facilities including emergency backup facilities, as well as the market of distributed power generations. In particular, clean high-efficiency gas engines are attracting the attention of the market.

Having developed high-efficiency green gas engines (KG series) in 2007 and having added the KG-V series products of improved efficiency in 2010, we continues maintaining the world's highest power generating efficiency. We also have addressed the strengthening of supply chains and production capacity to respond to the needs of the market, establishing a setup for producing 4 units per month.

Supported by high power generation efficiency and high environmental performance, this green gas engine has seen an increase in orders with 28 units delivered to customers in Japan and other countries in 2011.

Given the market situation, we continue focusing its effort on improving performance characteristics of the green gas engine with the aim of further strengthening its market superiority in terms of power generation efficiency.

1 Overview

(1) Product lineup

From the start of development, the green gas engine attained a power generation efficiency of 48.5%, standing at the world's highest level among gas engines of the same class in terms of the power generation efficiency. In this product lineup, 2 types of engine are available by output, a 5,000 kW class 12-cylinder engine (KG-12) and a 7,500 kW class 18-cylinder engine (KG-18).

In 2010, the product lineup was enriched with a more efficient KG-V series, with 4 models made available (Table 1).

Table 1 Green gas engine product lineup

Model		KG-12	KG-18	KG-12-V	KG-18-V
Cylinder diameter (mm)		300		300	
Revolutions (min^{-1})	50 Hz	750		750	
	60 Hz	720		720	
Electric output (kW)	50 Hz	5,200	7,800	5,200	7,800
	60 Hz	5,000	7,500	5,000	7,500
Efficiency at generator terminal (%)		48.5		49	
NOx (ppm) (Converted at 0% O_2)		200		200	
Operating range		30-100% load		30-100% load	

(2) Features

The green gas engine is characterized by the following features.

- Power generation efficiency is 49%, the world's top level performance.
- With an NOx (nitrogen oxides) value being as low as 200 ppm or less, the engine stands at the top level in terms of environmental performance also.
- The engine is capable of maintaining a power generation efficiency of as high as 45% under 50% partial loading.
- The engine can reach the 100%-load state within 10 minutes of startup, and is capable of running in a wide load range of 30 to 100% loading. This allows the engine to be operated in a flexible manner.

2 Approaches to the improvement of the power generation efficiency

We have been continuing development work on the green gas engine, even after its introduction onto the market, to maintain the engine's power generation efficiency at the world's highest level. This chapter presents our approaches to the improvement of the power generation efficiency.

(1) Adoption of a variable turbine nozzle area (VTA) turbocharger

In 2010, the Kobe Power Center was established with a 12-cylinder engine adopted as the power supply facility for our Kobe Works. The Kobe Power Center is used not only to supply power to the Works but also as a setting for improving power generation efficiency. This is where we developed a number of engines with a variety of turbocharger specifications. Different from the conventional practice of controlling the intake pressure via an exhaust bypass valve, the green gas engine adopts a variable turbine nozzle area (VTA) in the turbocharger itself to control engine intake pressure. This has increased power generation efficiency from the 48.5% of the conventional structure to 49.0%. Fig. 1 shows the difference in the turbocharger system between the standard specification (referred to as the KG model) and the high-efficiency one (referred to as the KG-V model). In the conventional KG model, an exhaust bypass valve is provided to release part of the exhaust energy so as to control the intake pressure. In the new KG-V model, on the other hand, the exhaust bypass valve was abolished and a variable nozzle is installed on the turbocharger instead to control engine intake pressure. The adoption of a variable nozzle has allowed the pressure in the exhaust cylinder before the turbocharger to be lowered. Efficiency has also been improved by increasing pumping work in the intake and exhaust strokes.

The engine in which a VTA-type turbocharger is adopted has been undergoing demonstration tests at the Kobe Power Center since 2010, and it has been confirmed to exhibit stable performance throughout the year.

(2) Adoption of a new lubricant

Recent performance improvements in gas-engine-use lubricants have made it possible to ensure viscosity of low viscosity lubricants in engines at high temperature.

The adoption of a low viscosity lubricant allows the mechanical loss of an engine to be reduced, promising an increase in power generation efficiency. To verify the compatibility of low viscosity lubricants with gas engines, we replaced a conventional high viscosity lubricant with a low viscosity lubricant at its Kobe Power Center and conducted verifications. Oiled with low viscosity lubricants, engines were run over 1,000 hours to verify the power generation efficiency and the reliability of mechanical sliding parts such as bearings.

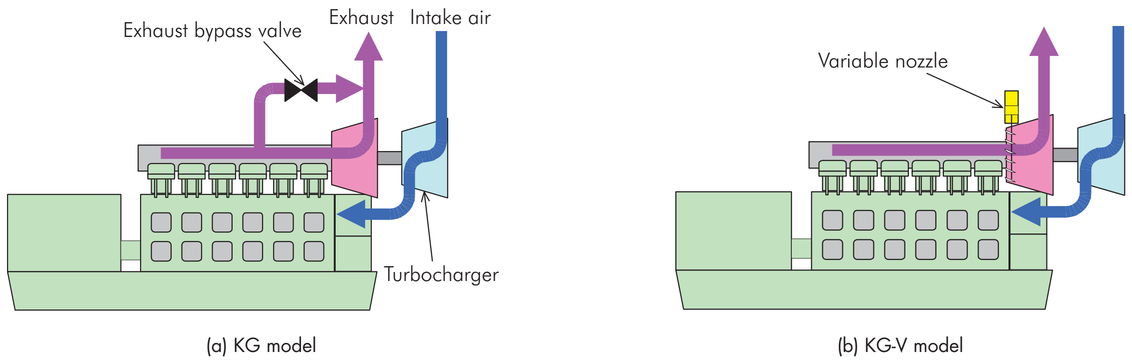

Fig. 1 Turbocharger system

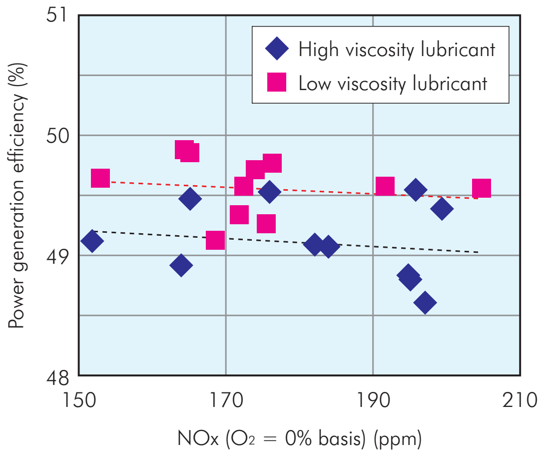

Fig. 2 Improvement in efficiency through use of different lubricant

The power generation efficiency increased by about 0.5 points over cases where conventional high viscosity lubricant was used. And, the overhaul after the test showed no problems with the reliability of bearings and other similar parts. Fig. 2 shows the results of the efficiency improvements from the change of lubricant. Currently, low viscosity lubricants are offered as options for conventional models.

(3) Changing intake air temperature

In the past, gas engines were used mainly for cogeneration, and, accordingly, facilities were planned so that heat performance supply was compatible with electricity supply performance. However, recent changes in the market needs have resulted in an increase in inquiries for projects focusing on power generation performance only. In response to such interest from the market, we started developing engines with more emphasis placed on power generation efficiency than on the utilization of heat.

For the purpose of heat utilization, in the past, cooling water from the engine was set at a high temperature so that the heat recovery rate in the form of hot water was increased. Since it was not necessary this time to raise the temperature of the extracted cooling water, performance was improved as a result of re-examining the cooling system and, thereby, lowering the intake air temperature.

The efficiency of a gas engine is improved by advancing the ignition timing, because this results in an increase in pressure during combustion. However, advancing the ignition timing too early results in the frequent occurrence of knocking, which hinders engine operation. In the current development work, lowering the intake air temperature made it possible to ensure a margin for knocking as it hindered any increase in efficiency. As a result, this allowed the ignition timing to be advanced, which translated as an improvement in power generation efficiency. Operation on actual engines confirmed an improvement in power generation efficiency of about 0.2 points.

By combining the efficiency improvement measures described in items (1) to (3) above, the green gas engine achieves a power generation efficiency of 49.8%

Figure 3 shows the progress in the improvement of power generation efficiency of green gas engines.

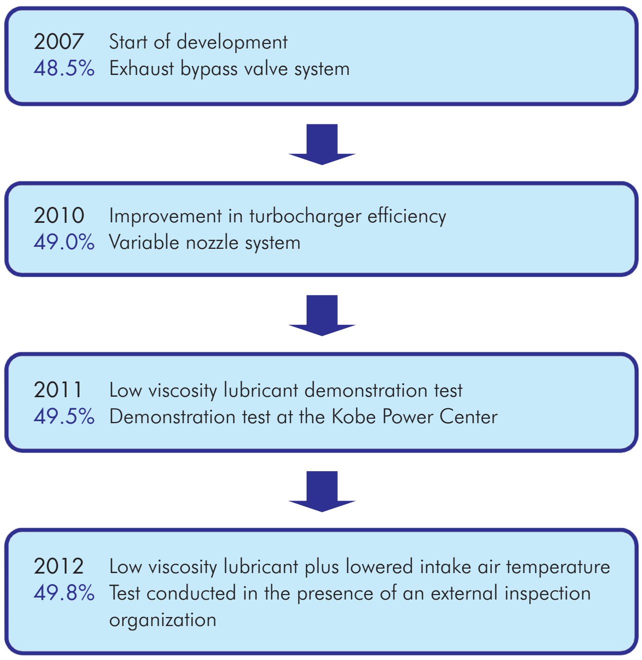

Fig. 3 Progress in improvement of power generation efficiency

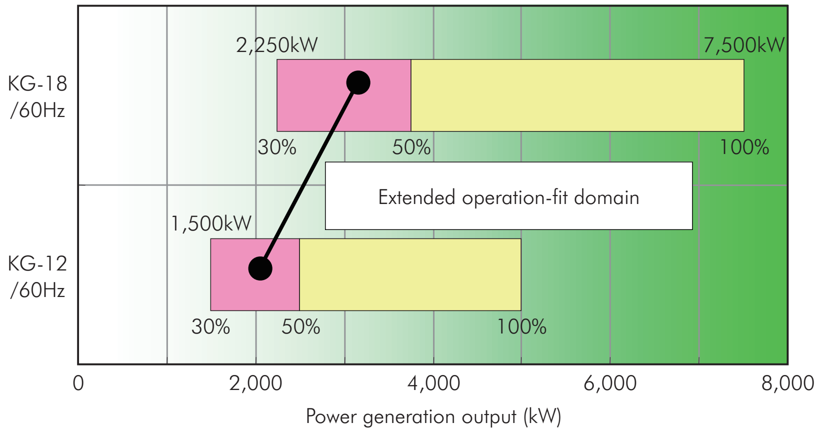

Fig. 4 Operation-fit domain for green gas engines

3 Improvement in operability

For many gas engines, the lower limit load at which they can be operated at a continuous rate is about 50%, and for this reason, gas engines have been generally viewed as having a smaller operability range in spite of their higher power generation efficiency. We have been making an effort to widen the operability of green gas engines with the aim of making them easy-to-handle power generating sets not only in terms of power generation efficiency but also practical operation. At the Kobe Power Center, green gas engines were operated under low loading for a long time to verify the range of engine operation.

Generally, long-hour low-load operation of a gas engine causes combustion residue in the combustion chamber, which in turn becomes a major factor of knocking and thereby impairs the reliability of operation. The long-hour low-load operation test of green gas engines at the Kobe Power Center, on the other hand, demonstrated the scarcity of combustion residue in the combustion chamber, verifying the excellence of combustion performance of green gas engines.

The long-hour operation, furthermore, confirmed that the operational lower limit for green gas engines can be set at 30%, a lower setting than that of conventional gas engines. Fig. 4 shows the range of power generation output in which engines are allowed to operate at a continuous rate in 60 Hz areas. The operation test also confirmed that the power generation efficiency at low load does not decrease much (Fig. 5).

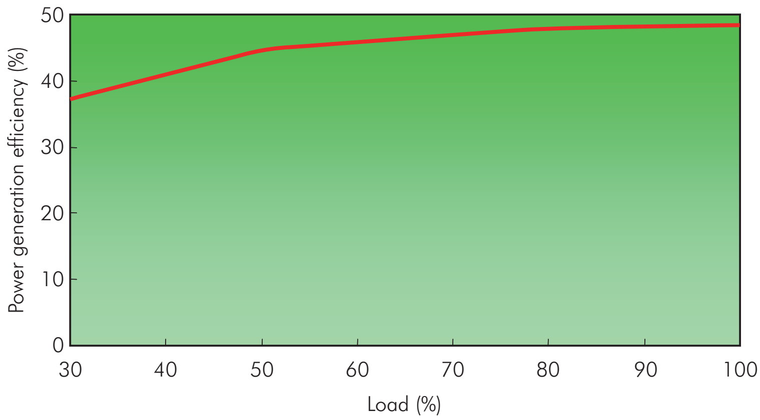

Fig. 5 Power generation efficiency under partial load

4 Effort in strengthening the production system

Concurrently with the improvement of performance of green gas engines, we have been making an effort, since 2011, to strengthen the production system in response to the ever-increasing needs of the market. In particular, production facilities were reinforced as represented by the introduction of large machine tools such as planomillers, and simultaneously, assembly lines and factory test-run facilities were improved (Fig. 6). As a result, the production capacity reached 4 units per month in 2012.

Figure 7 shows the entire view of the test-run site for green gas engines. This testing facility is equipped with a 10,000 kW dry loading unit, allowing a variety of load tests to be conducted with an engine and a generator combined.

Table displacement (m)	13.0
Maximum carrying mass of the table (t)	200
Gate width (m)	5.5
Gate height (m)	6.1

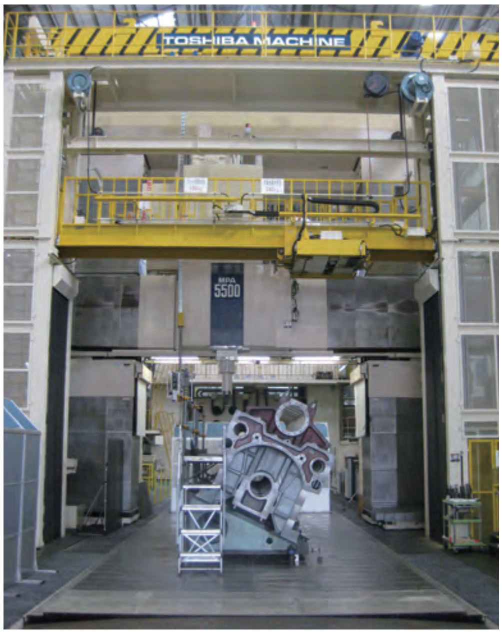

Fig. 6 Large-scale planomiller

Fig. 7 Factory test facility

Concluding remarks

Green gas engines were developed on the basis of Kawasaki's more than 100 years of history with reciprocating engines and its state-of-the-art control technology cultivated through the development and manufacture of various equipment and plants.

We received an order from Nihon Techno Co., Ltd. for a 110 MW class power station, Sodegaura Green Power, which is ranked one of the largest gas engine power stations in Japan (Fig. 8). Adopting a VTA turbocharger, whose performance was demonstrated by the efficiency improvement this time, and the first low viscosity lubricant in the industry, this power station is operated at a power generation efficiency of 49.5%.

We hope to contribute to building an affluent society by providing high efficiency, less environment-loading green gas engines.

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Fig. 8 110 MW class power station delivered to Nihon Techno Co., Ltd.