

Development of Air-cooled, 4-stroke V-twin Cylinder General Purpose Engine GX690/GXV690

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ABSTRACT

Honda has developed GX690/GXV690, a small, high-performance, air-cooled, 4-stroke V-twin cylinder general purpose engine with an outstanding environmental performance.

In this new model, the enhanced shapes of combustion chamber and port, upgraded cooling capability around the combustion chamber, and variable ignition timing effectively suppress knocking, while increasing the compression ratio to 9.3 from 8.3 of previous GX670/GXV670, which results in 8% increase in output. Without using any catalysts, this engine with 10% of increased fuel efficiency has cleared the EPA exhaust emissions regulations. Both the decreased size of air cleaner, which was resulted from enhanced filter, and the adoption of oil filter base, which also had an oil cooler function, eliminating previous oil cooler, allowed us to reduce the total height and width of the engine, as well as the volume by 18%. The modified shape of cooling fan and fan cover, configuration of muffler, and other parts are effective to decrease the measured and perceived noises that occurred in the previous engine in operation.

As new features, we have also added an hour meter and oil alert indicator to enhance the usability of engine. Furthermore, we advanced battery charging performance to offer a diverse use in working machines.

1. Introduction

V-twin cylinder gasoline engines are the mainstream in 10-20 kW general purpose engines that are employed as the power sources for business working machines, such as generators, construction equipments, and ride-on lawnmowers.

Honda launched the GX series of V-twin cylinder engines with GX610/620 in 1993, adding GX670 to it in 1999. Since 2000, other engine makers have commenced offering their V-twin cylinder engine line-ups with higher output than that of Honda's GX engines. As a result, high-output gasoline engines have come to be employed in a various type of business working machines; at the same time, the demand for more fuel-efficient and smaller engines is strong, due to the users' increasing environmental awareness and limited space available for fitting an engine in a working machine.

In order to cope with this background, the new GX690/GXV690 air-cooled, 4-stroke V-twin cylinder general purpose engine has been developed. In this paper, we will introduce our developmental efforts to give more power to the previous GX670/GXV670 engines by achieving higher fuel efficiency, lower hazardous exhaust emissions, and reduced engine size.

2. Development Goals

When we developed the new engine, we set three main goals to achieve sufficient output to meet the work load that was demanded for business working machines, higher fuel efficiency, and reduced engine size, while decreasing hazardous exhaust emissions and noises, and enhancing equipments, as elaborated below:

(1) Output

- 5% more output (16 kW or more) than the previous engine (Fig. 1)

(2) Fuel efficiency and exhaust emissions

- 10% more efficient fuel consumption than that of the

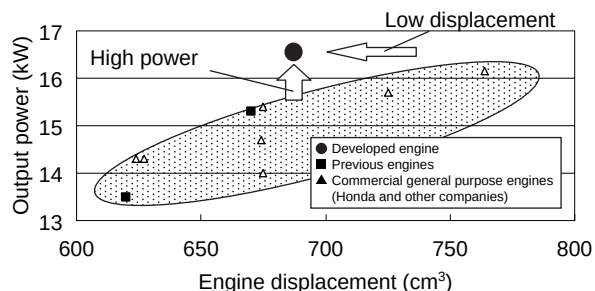


Fig. 1 Positioning of developed engine

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Table 1 Engine specifications

Item	Previous engine (GX670)	Developed engine (GX690)
Engine type	4-stroke, V-90° twin-cylinder	4-stroke, V-90° twin-cylinder
Displacement (cm ³)	670	688
Bore × Stroke (mm)	77 × 72	78 × 72
Compression ratio	8.3 : 1	9.3 : 1
Valve train	2-valve OHV	2-valve OHV
Valve inclination angle (deg)	0	29
Valve diameter (mm)	Inlet: ϕ 35, Exhaust: ϕ 31	Inlet: ϕ 30, Exhaust: ϕ 26
Combustion chamber shape	Wedge type	Hemispherical type
Lubrication system	Forced feed system	Forced feed system
Ignition system	Transistorized magneto (fixed)	CDI (advanced)
Dimension (L × W × H) (mm)	412 × 471 × 457	405 × 410 × 438
Volume (cm ³)	88680	72730

previous model in the EPA mode for general purpose engines⁽¹⁾

- Compliance with the exhaust emissions regulations (EPA Phase 3 Small Nonroad Spark Ignition Engine Class 2)

(3) Engine size

- 3% reduction in total height and 10% reduction in total width from those of the previous model

(4) Noises

- Equivalent to or lower than those of the previous model
- Enhanced noise feeling

(5) More equipment with advanced usability

- Addition of hour meter and oil alert indicator
- Enhancement of charge output

3. Basic Performance of the Engine

Table 1 shows the main specification of the developed GX690 engine, a V-90° twin OHV engine in a uniblock cylinder structure that consists of cylinder heads and cylinder block⁽²⁾.

A horizontal-type engine in which the output shaft faces in a horizontal direction and a vertical-type engine in which the output shaft faces in a vertical direction were developed simultaneously with the aim of sharing parts between both types. Figures 2(a) and 2(b) display the

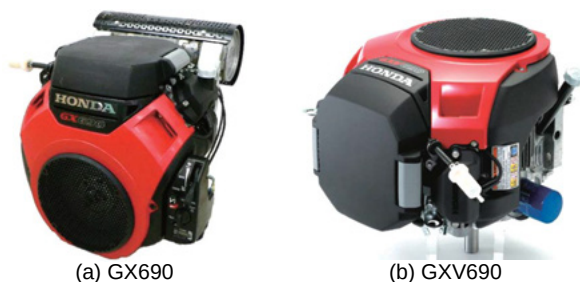


Fig. 2 External view of developed engines

external appearances of the horizontal and vertical types, respectively.

In the following sections, we will discuss engine output, fuel efficiency and exhaust emissions, and engine size.

3.1. Engine Output

In order to reconcile high output with reduced size, we set the displacement of new engine to be 688 cm³, 3% larger than the previous model. The bore was increased by 1 mm without altering the stroke distance to produce a bore/stroke ratio of ϕ 78/72 mm, and to minimize the total height.

As discussed later in Chapter 4, also, enhanced combustion, variable ignition timing, and increased cooling capability around the combustion chamber reinforced knocking toughness and enabled the compression ratio to be increased to 9.3 from 8.3 of the previous model.

By replacing non-advanced ignition system which was conventionally employed in general purpose engines with electronically-advanced capacitor discharge ignition coil, variable ignition timing became available to each engine speed. As Fig. 3 shows, this has increased torque in the entire operating range more than the previous model; the maximum torque has increased by 5% and maximum output by 8%, as observed in the engine performance curve.

3.2. Fuel Efficiency and Exhaust Emissions

Figure 4 shows the achieved figures in fuel consumption and exhaust emissions of new engine. As discussed later in Section 4.1., the use of technologies to facilitate combustion contributed to higher fuel efficiency by 10% in comparison with that of the previous model, while keeping HC + NO_x emissions in the same level, when the engine was operated in the EPA fuel efficiency mode for general purpose engines. Thus, the engine has

met the exhaust emissions regulations for general purpose engines (EPA Phase 3).

3.3. Engine Size

The intake manifold and carburetor of the new engine were lowered to a height enabling maximal reduction of the length of the inlet port. Also, the size of air cleaner was reduced without causing a decline in its filtering performance by using a filter material, which had a higher

dust holding capacity per unit of area as an air filter in the air cleaner. In this way, the total height of engine has been reduced by 19 mm.

In addition, the use of an oil filter base that has an oil cooling function (Fig. 5) has allowed us to remove the motorcycle-type oil cooler, which was used in the previous model, and reducing the total width of the engine by 61 mm and reducing the number of parts used.

As shown in Figs. 6 and 7, these contributed to reduce the total height by 4%, total width by 13%, and volume by 18% from those of the previous model. This enables the engine to be easily fitted in construction equipments, generators, and other working machines in which engines are installed in narrow spaces under the bonnets.

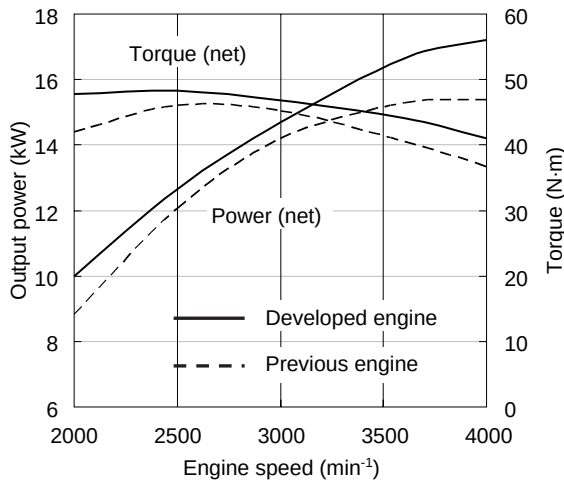


Fig. 3 Engine performance

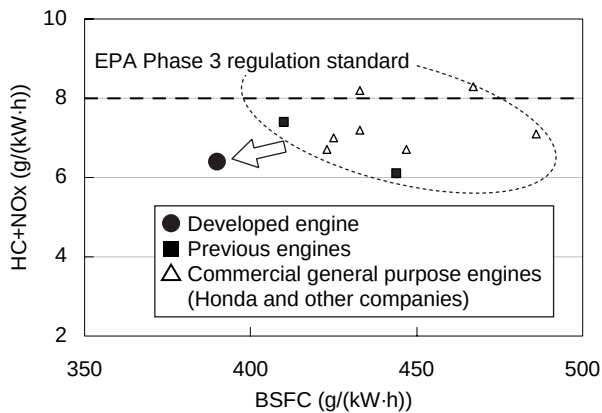


Fig. 4 Fuel consumption and mass emissions in EPA emissions mode

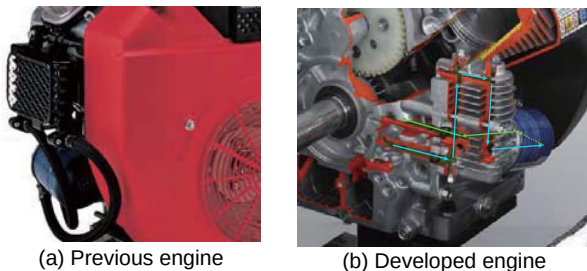


Fig. 5 Oil cooler

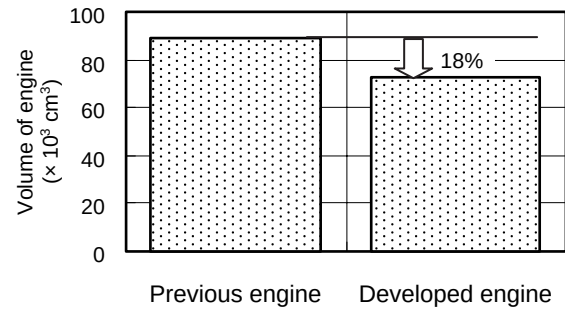


Fig. 6 Engine volume

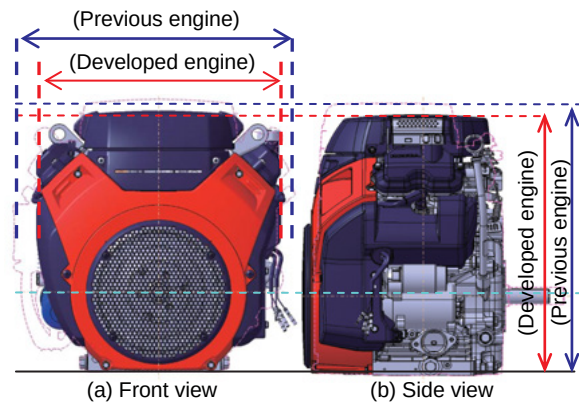


Fig. 7 External shape

4. Technologies to Facilitate Combustion and Enhance Cooling Performance

As seen in a generator, because most general purpose engines are air-cooled, the work load is high during stationary operation. For this reason, it was challenging for us to increase the compression ratio. Based on the knocking limit, therefore, the compression ratio was set at 8.3 in the previous model. In the new engine, on the other hand, the compression ratio was increased to 9.3 to help ensure higher thermal efficiency by suppressing knocking, based on the modification of the shape of

combustion chamber, which is discussed in the following section, the use of variable ignition timing, and the enhanced cooling capability around the combustion chamber.

4.1. Technologies to Facilitate Combustion

4.1.1. Combustion chamber/port configuration

Figure 8 shows the valve arrangements and port configurations of new engine. In the previous model, a parallel valve arrangement was adopted in the wedge-type combustion chamber. The new engine employs a valve arrangement with a valve included angle of 29° and hemispherical combustion chambers on the cylinder head side, in addition to concave piston heads, resulting in enhanced flaming.

Further, the angle between the valve shaft and the incident direction of inlet port has been reduced to 60°

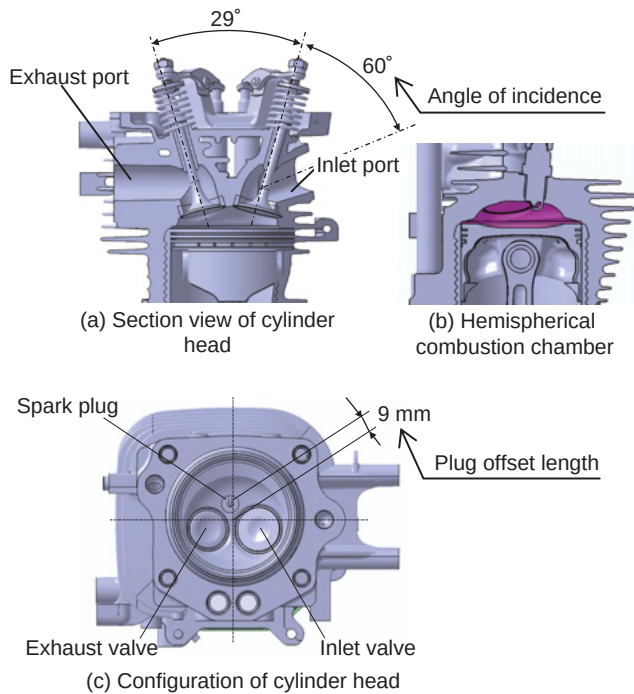


Fig. 8 Cylinder layout

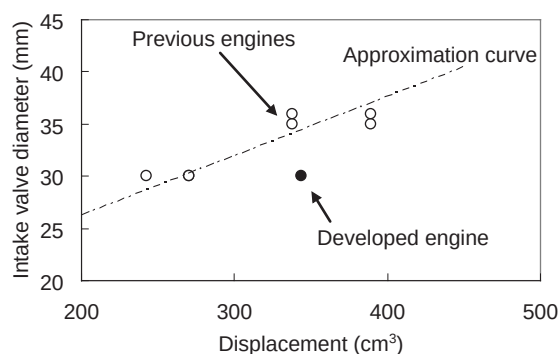


Fig. 9 Intake valve diameter

from 90° of the previous model to decrease duct resistance in the inlet port, and thus reducing pumping loss (losses that occur during intake).

As Fig. 9 shows, the inlet valve diameter has also been reduced to 30 mm (5 mm smaller than that of the previous model) to facilitate the boost flow velocity, and activated the in-cylinder flow. Similarly, the distance between the spark plugs and the center of combustion chamber has been decreased from 20 mm of the previous model to 9 mm to minimize the flaming distance in the combustion chamber. Based on these technologies to facilitate combustion, we have successfully increased combustion speed and enhanced knocking toughness.

4.1.2. Electronically-advanced capacitor-discharge ignition coil

In order to suppress knocking without affecting startability or engine speed stability during idle operation, the transistor magneto ignition system, which was used in the previous model, was replaced by an electronically-advanced capacitor-discharge ignition coil, which allowed the engine to vary the settings of ignition timing based on the engine speed. In this way, suppression of knocking is followed by the advanced ignition timing based on the engine speed, and which increased both the output and fuel efficiency of new engine (Fig. 10). Moreover, setting an acceleration map has increased the responsiveness of the engine, when it is accelerated.

4.2. Technologies to Facilitate Cooling Capability

4.2.1. Cylinder head

Because the previous model employed a split cylinder head configuration, which entailed bolts to fasten and bosses to fix in the cylinder head, the flow of cooling air was disturbed. Considering this issue, we adopted a uniblock cylinder, which integrated cylinder heads and cylinder blocks, in the new engine, in order to enhance cooling capability around the combustion chambers (Fig. 11). This uniblock cylinder obviates the necessity for the bolts and fixing bosses around the combustion chambers,

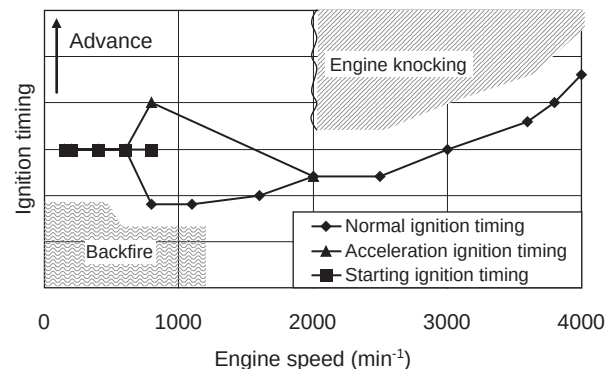


Fig. 10 Ignition timing

facilitating the flow of cooling air around the chambers.

In addition, the pushrod chamber of previous model consisted only of aluminum cylinder heads. The fixing bosses that coupled this aluminum pushrod chamber with cylinder head, which was mentioned in the above,

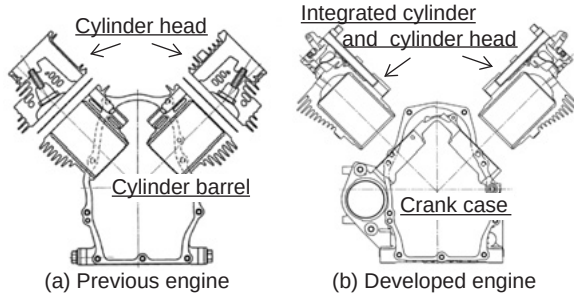


Fig. 11 Engine configuration

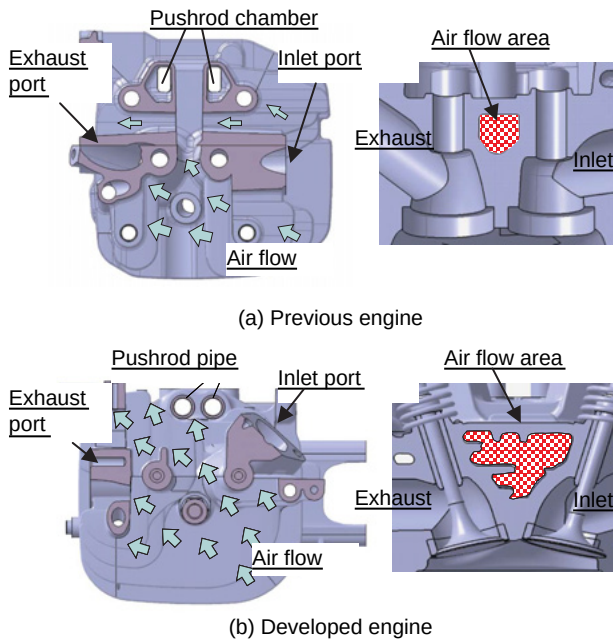


Fig. 12 Section view of air jacket

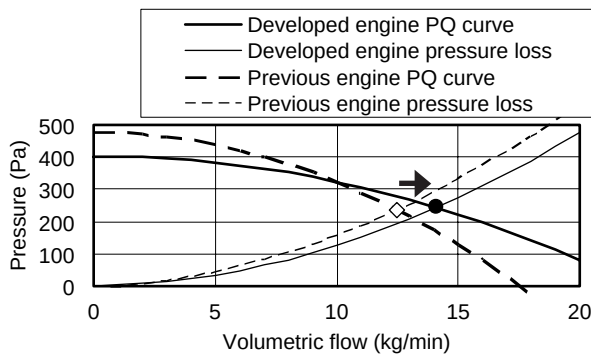


Fig. 13 P-Q curve of fan

involved excessive thickness of aluminum, due to the die-casting manufacturing method. This eventually narrowed the flow path for cooling air. In the new engine, the fixing bosses have been removed, and separate aluminum pipes have been used as the pushrod chambers. As a result, while die-casting method is still employed, the amount of excessive aluminum has been decreased, expanding the flow path of the cooling air in the upper section of the cylinder head (Fig. 12).

In addition to the above modifications, the use of a radial valve arrangement has made the cross-sectional area of flow path for cooling air between the valves 2.8 times larger than the previous one. By securing the flow path for cooling air in the exhaust side of combustion chamber, which reaches high temperatures, and assisting the cooling air to flow more efficiently, we have successfully increased the cooling capacity of new engine.

4.2.2. Cooling fan

The external diameter of cooling fan has been increased from 228 mm of the previous model to 241 mm.

As discussed later in Section 5.1., the stud bolts, which impeded the flow of cooling air within the scroll of fan cover in the previous engine, have been removed. Also, a resin fan cover and shroud have formed a smooth scroll shape, enabling optimal allocation of cooling air around the combustion chamber of each cylinder and around the cylinders, which resulted in the reduction of airflow resistance in the engine.

The volume of the air produced by the fan in operation, which is indicated in the intersection of the pressure/quantity curve and the engine airflow resistance curve in Fig. 13, has eventually increased by 14% with the same pressure as that of the previous model.

5. Technologies to Reduce Noises

As Fig. 14 shows, the noise level of new engine has been reduced by 1.5 dBA from that of the previous model, when the engine is operated under three-quarters of the rated load, at an engine speed of 3000 min^{-1} and output of 8.6 kW.

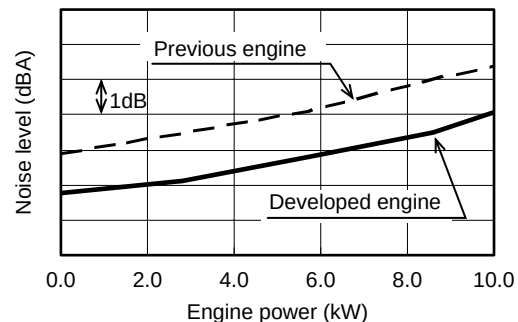


Fig. 14 Noise level (3000 min^{-1})

As indicated by the noise attributable ratios in Fig. 15, this reduction of engine noise level has been actualized mainly by a reduction of radiation noises resulting from an increased surface stiffness of crankcase, of mechanical noises, including those attributed to the resin cam gears, of cooling fan and fan cover noises, and of exhaust noises.

The technologies employed to reduce the noises from cooling fan and fan cover as well as the exhaust noises are discussed in the following sections.

5.1. Cooling Fan and Fan Cover Noises

As Fig. 16 shows, the structure with a sub-plate at the top of cooling fan blade has prevented air recirculation from the tip of the blade, and reduced fan noise.

In addition, a high-stiffness resin, which has approximately 1.5 times higher bending elasticity modulus than that of the resin material used in the previous model, used for the fan cover, has increased the surface stiffness

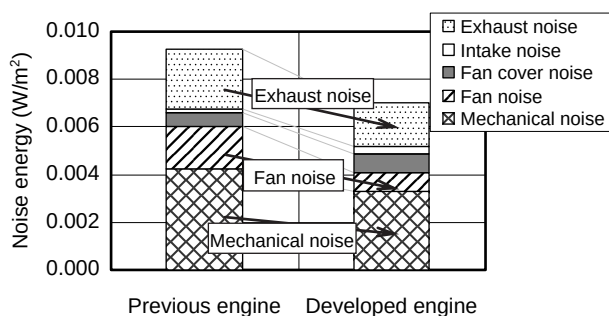


Fig. 15 Noise contribution

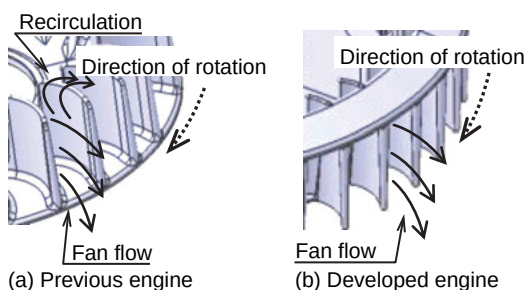


Fig. 16 Fan cover layout

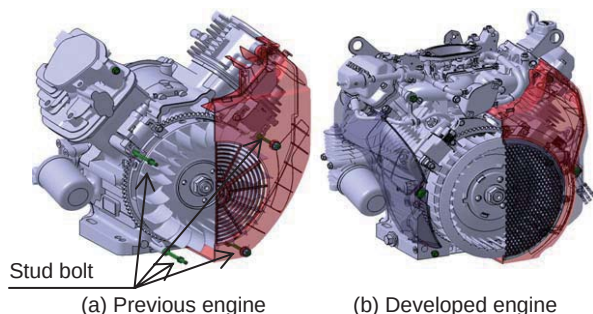


Fig. 17 Fan cover layout

of the fan cover. As shown in Fig. 17, this has allowed us to remove the stud bolts that supported the fan cover in the previous model. In this way, we minimized the wind roar produced by the cooling fan that struck the stud bolts, and thus decreased the level of fan noise.

The technologies employed in the cooling fan and cooling fan cover noises, as discussed in the above, have achieved the reduction of the noise level by 1.5 dBA (Fig. 18), while providing a 14% larger volume of wind than that of the previous model.

5.2. Exhaust Noises

We display the muffler configuration of new engine in Fig. 19, and its effects and details below.

- (1) Three-chamber muffler configuration in the exhaust path of each cylinder has reduced exhaust pulsation noise to 100-200 Hz.
- (2) Double-plated wall has reduced the higher frequencies of noise radiation than 2000 Hz, which was produced from the muffler wall.
- (3) Glass wool, which was arranged in the exhaust pipe, has reduced the higher frequencies of exhaust discharge noise than 2000 Hz.

Measures (2) and (3) above have reduced the harsh frequency components of 2000 Hz and higher (Fig. 20), resulting in a noise feeling with minimal harshness. In addition to this, the structure that was described in (1) in the above has effectively decreased 100-200 Hz exhaust noises, and have achieved the reduction of the exhaust noise level by 1 dBA.

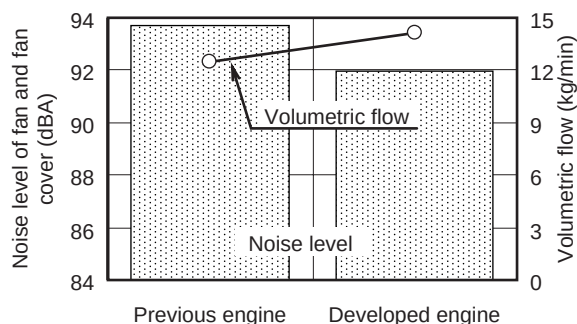


Fig. 18 Noise level of fan

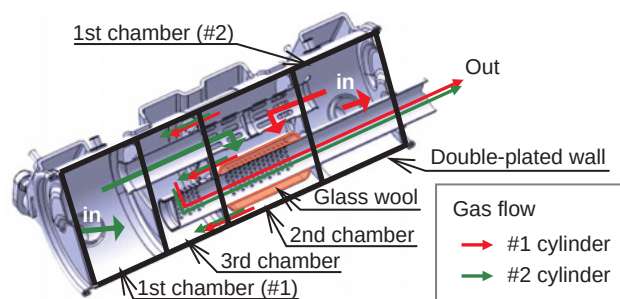


Fig. 19 Internal configuration of muffler

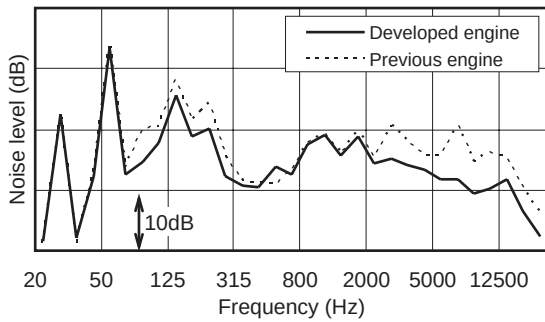


Fig. 20 Frequency characteristic of muffler

6. Enhanced Usability

In this chapter, we will discuss main features of the equipments mounted in the new engine.

6.1. Control Box

As Fig. 21 shows, the operating controls, such as throttle lever, choke knob, and engine switch have been concentrated in a control box in new engine. This has eventually enhanced visibility of the engine operating controls, and enabled the user to start-up and shutdown the engine with the same panel.

Also, a new oil alert indicator and hour meter have been fitted in the control box. When oil runs low during engine operation, the oil alert is activated. The oil alert indicator lights concurrently with engine shutdown. This makes the user instantly aware that the oil is insufficient.



Fig. 21 Control box

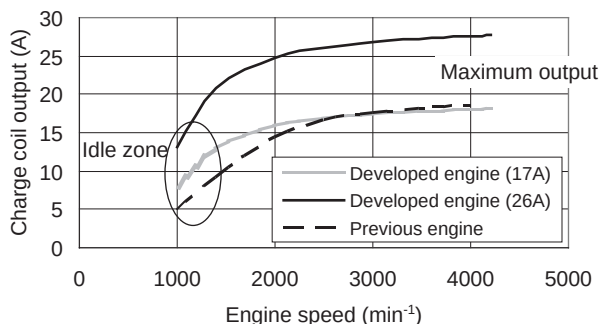


Fig. 22 Charge coil output

In addition, the LCD display clearly indicates cumulative operating time of engine, which the user can rely on for their maintenance of the oil, air cleaner filter, etc.

6.2. Increased Low-speed Output and Maximum Output of Charge Coil

For the charge coil which is used for battery charging, a multi-pole winding configuration is adopted instead of single-pole winding used in the previous model. By this, the charging frequency is raised and then the charging efficiency is increased. As a result of this, the charge output characteristic has increased by approximately 1.6-fold against that of the previous model at the idling speed of 1000 min^{-1} , while the maximum output of the charge coil has remained the same. This increases charging performance and enables more electrical loads to be used in working machines that are operated for long periods at idling speed.

In addition, a new charge coil has been added as an option. This new charge coil is enabled to output 26 A at maximum engine speed, as shown in Fig. 22, by adopting a three-phase winding structure instead of a single-phase. This enables the engine to be used in working machines that have electrical parts with high electrical loads, such as machines with large headlights or electric power tools.

7. Conclusion

The technologies, which were employed in a newly developed air-cooled 4-stroke V-twin cylinder 688 cm^3 general purpose engine, allowed us the following performances that enhance combustion, increase cooling capability, and reduce noises:

- (1) Maximum output has been increased by 8% and maximum torque by 5% in comparison with those of the previous model.
- (2) Fuel efficiency has been increased by 10% in the EPA operating mode for general purpose engines.
- (3) Exhaust emissions clear the figures stipulated in the EPA Phase 3 Small Nonroad Spark Ignition Engine Class 2 regulations, without using catalysts or any other devices.
- (4) While interchangeability has been enhanced, the volume of the new engine has been reduced by 18% in comparison with that of the previous model.
- (5) The noise level of engine during operation has been reduced by 1.5 dBA, and noise feeling has also enhanced, in comparison with that of the previous model.
- (6) Usability has been enhanced by adding the following equipments:

- Operating controls have been concentrated in a control box with a new hour meter and an oil alert indicator.
- The low-speed charge output performance of charge coil has been enhanced, and a new charge coil with a maximum output of 26 A has been added as an option.

References

- (1) U.S. Environmental Protection Agency: Title 40 CFR, Part 90, Subpart E, p. 219-247 (2000)
- (2) Shinoda, A., Moriyama, H., Suzuki, T., Tabata, Y.: Development of General Purpose V-Twin Cylinder Engine GCV530/520, HONDA R&D Technical Review, Vol. 12, No. 2, p. 23-28

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