

Application of Modular Design Technology to Consumer-use General Purpose Engine

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ABSTRACT

A series of engines for the consumer market has been developed that responds to a range of demands by maximizing the sharing of constituent parts, which also realizes a reduction in the total number of parts employed across the series, a reduced cost, and a high level of environmental performance. Three different displacements engines have been realized in the series by changing only the cylinder modules, consisting of uniblock cylinders of differing bore diameters and pistons. Parts, for which a range of specifications are demanded across the series of different displacements depending on the engine framework, have been shared as a crankcase module, reducing the total number of parts employed in the engine block for engine variations by 43% against the previous models. Simplification of the crankcase shape and the realization of an increased cooling performance reduced the mass of materials in the engine block by 25% against the previous engines. These innovations have reduced the cost of the engines by approximately 15% against the previous models. The combustion chamber shape was modified and a long stroke was employed in order to boost the environmental performance of the low-displacement model, and each of the three different displacement models clears environmental regulations in its countries of sale. In addition, crankcase configuration modification and valve mechanism position have made it possible to realize a greater ease of maintenance than the previous models.

1. Introduction

Since Honda's consumer-use GCV engine series⁽¹⁾ went on the market in 1997, they have been fitted in home-use products such as home lawnmowers and high-pressure washers, mainly in the North American and European markets. A cumulative total of 36 million units have been sold. The GCV engine series is a series of three engines with differing displacements, 135, 160, and 190 cc. In addition to their use in Honda lawnmowers, approximately 80% of the unit volume produced is sold as OEM engines to the manufacturers of competitors' lawnmowers, high-pressure washers, and other complete machines. As OEM engines, it is necessary to provide a series lineup and specification variations in order to respond to series development and product requests from complete machine manufacturers.

At the same time, because price competition in the area of consumer-use products is fierce and low cost is also a strong demand on the engines fitted in products, low-cost engine frameworks that offer both engine performance and specification variations are a source of market competitiveness.

The recent tightening of environmental regulations has made it challenging to maintain a balance between exhaust emission reductions and low cost. Responding to this necessity was not easy, especially in the case of the low-displacement GCV135, and so this unit has been discontinued.

Honda has, therefore, developed a new GCV engine series that realizes a high-level balance between environmental performance, reliability, specification variations, and cost as Honda engines. Figure 1 shows the external appearance of the new GCV engines.

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Fig. 1 External view of new GCV engine

2. Development Goals

The development sought to realize a consumer engine possessing a high level of environmental performance, which responded to a range of demands via the engine framework renewal while also maximizing the potential for interchange of constituent parts, and which also reduced the total number of parts and realized low cost. The following main development targets were set:

- (1) A reduction of at least 10% in cost
 - A reduction of at least 30% in the total number of parts used across the series in the engine block section
 - A reduction of at least 20% in the aluminum mass in the engine block section
- (2) Clearance of a range of national environmental regulations
- (3) Realization of equivalent or greater ease of maintenance to the previous models

3. Basic Engine Framework

For the complete machine manufacturers who make up the customers to which we supply engines, variations in the power of consumer work equipment, such as lawnmowers and high-pressure washers are necessary in order to respond to differences in workload. Three displacements, 145, 170, and 200 cc, were set for the new GCV engine series. Table 1 compares the main specifications of the series.

Details of each component will be provided below:

3.1. Engine Block Structure

3.1.1. Cylinder module

The new GCV engines employ a uniblock cylinder that integrates the cylinder head and the cylinder. Together

with the piston system parts, this forms a cylinder module. As Fig. 2 shows, the series of three engines of differing displacements has been formulated using three cylinder modules in which only the bore diameter differs.

3.1.2. Crankcase module

The constituent parts of the crankcase module, the crankcase and the crankshaft, are the parts that connect with the mounting frame, and are, therefore, parts for which numerous variations in specifications are set in response to requests for different frames. Due to this, if dedicated parts were used for engines of each displacement in the series, the total number of parts used in the series would increase.

As Fig. 2 shows, in the new GCV engine series, the crankcase module is shared by each displacement. This has made it possible to reduce the total number of parts used in the series. Figure 3 shows the configuration of the engine blocks for the entire new and old series.

Demand for engine start via a starter motor rather than a recoil starter has recently increased. The previous models employed a configuration in which the starter motor was attached to the cylinder. In the new series, the starter motor is attached to a crankcase cover with a simple shape. This has made it possible to produce variations at low cost.

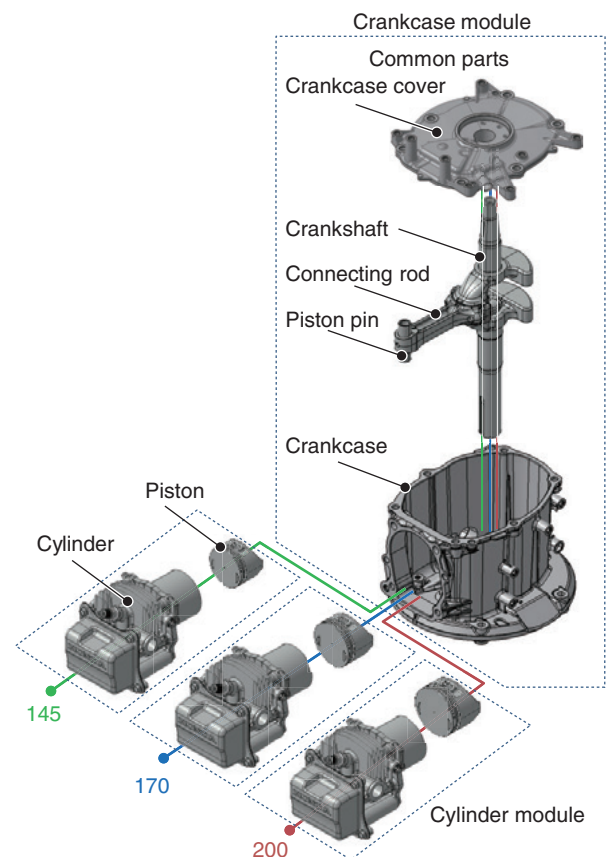


Fig. 2 Structure of engine block module

Table 1 Engine specifications

	Previous model			Developed model		
Model	GCV135 (Discontinued)	GCV160	GCV190	GCV145	GCV170	GCV200
Cam type	OHC			OHV		
Displacement (cm ³)	135	161	187	145	166	201
Bore x Stroke (mm)	64 x 42	64 x 50	69 x 50	56 x 59	60 x 59	66 x 59
Compression ratio	8.5			7.7	8.0	
Maximum power (kW/rpm)*	2.6/3600	3.3/3600	3.8/3600	3.1/3600	3.6/3600	4.2/3600
Maximum torque (N·m/rpm)*	6.9/2500	9.4/2500	11.3/2500	9.1/2500	11.1/2500	12.7/2500
Dry mass (kg)	10.4	10.5	12.4	10.1		

*According to SAE J1349

The dividing line between the crankcase and the crankcase cover was set at the upper section of the crankcase. This made it possible to realize a simple crankcase shape that is connected in straight lines, reducing the amount of materials employed. Figure 4 shows the cross-sectional shape of the crankcase.

3.2. Auxiliary Equipment

In the engine block module made up of the cylinder module and the crankcase module, the intake system, exhaust system, fuel system, and cover have been modularized for their respective functions in order to satisfy the demands of complete equipment manufacturers

for specification and design variations. This has made it possible to create specifications suiting the country of sale. For example, in regions such as North America that have

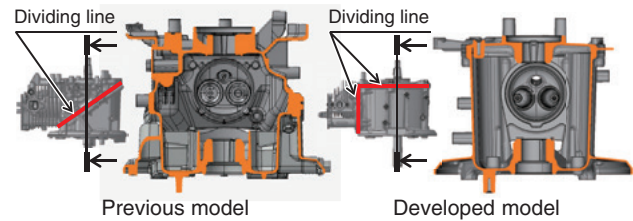


Fig. 4 Shape of crankcase

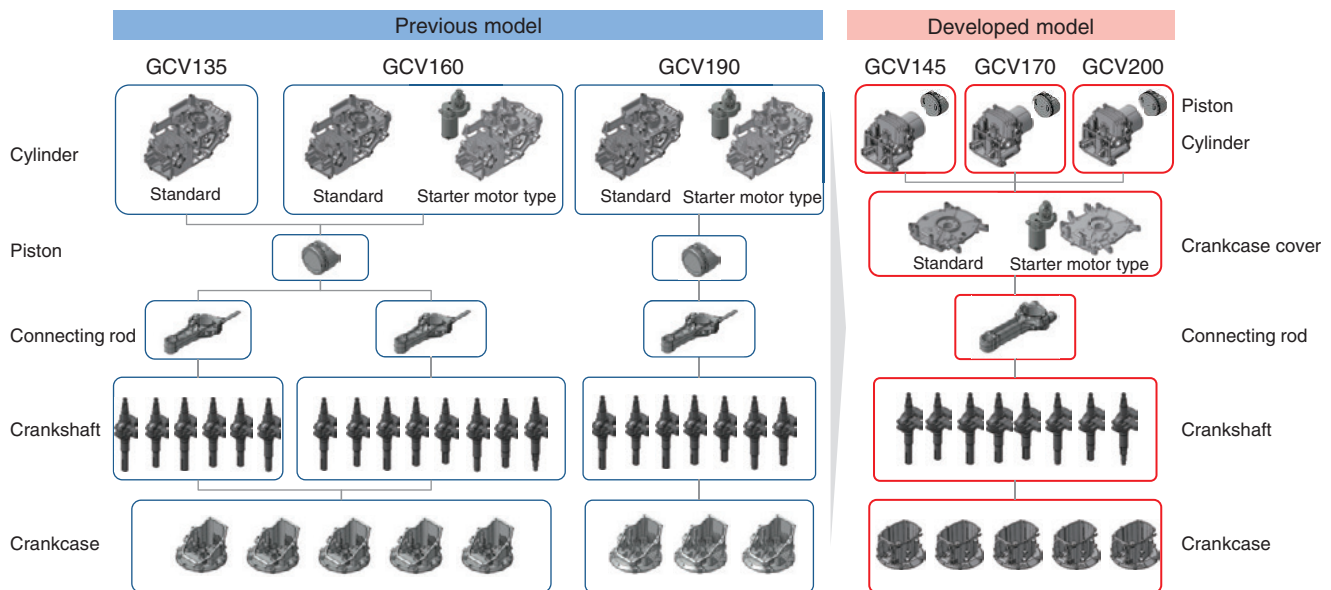


Fig. 3 Comparison of engine block structure

evaporative emissions regulations, it is possible to select a fuel system module made up of a fuel tank cap fitted with activated carbon, a multilayer blow-molded fuel tank, and a low-permeation fuel tube. Figure 5 shows the auxiliary system module configurations.

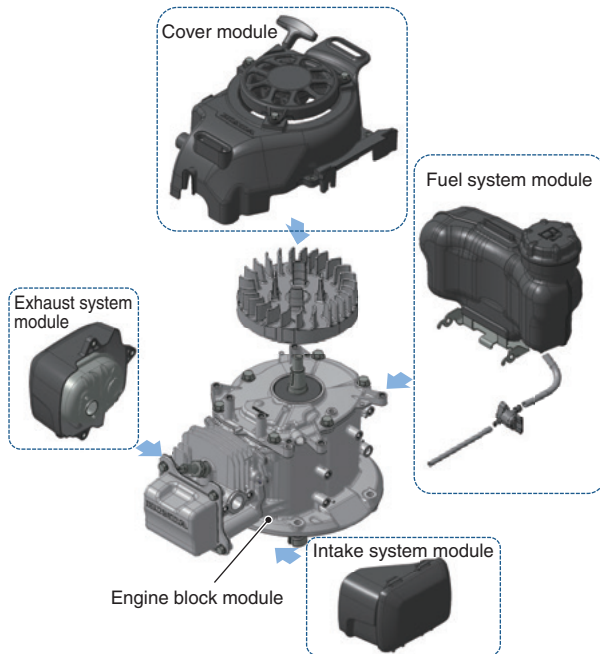


Fig. 5 Engine structure



Fig. 6 Top cover and fan cover of developed model

With regard to the covers, the use of a configuration in which a top cover is fitted over a fan cover that has the function of guiding cooling air has made it possible to respond to the demands of OEM for the use of brand colors and shapes. Figure 6 shows the top cover structure.

3.3. Cooling System

If cooling air can be used efficiently in forced air-cooled engines, it is possible to reduce the size of the cooling fins and this contributes to reducing the amount of materials employed. A numerical analysis was conducted in order to effectively concentrate cooling air on high-temperature sections. The results of this analysis are shown in Figs. 7 and 8. By this means, it was possible to reduce the cooling fin area of the new GCV200 by 28% against the previous GCV190 model, despite the fact that displacement had increased.

In addition, in order to fit the cooling fins in the most effective position for cooling, a configuration was adopted in which a flange bolt was used at the upper section of the cylinder and was fastened from the inside of the crankcase, balancing cooling performance and low cost. Figure 9 shows an engine cross-section of the fastening section.

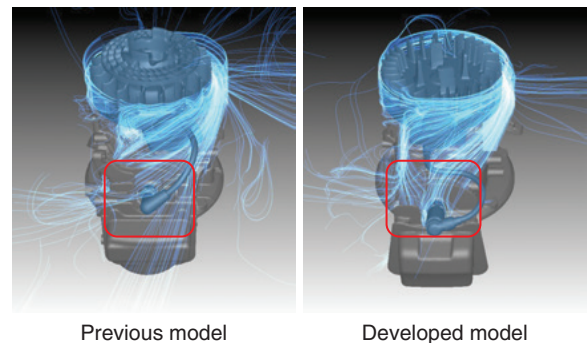


Fig. 7 Flow lines of cooling air

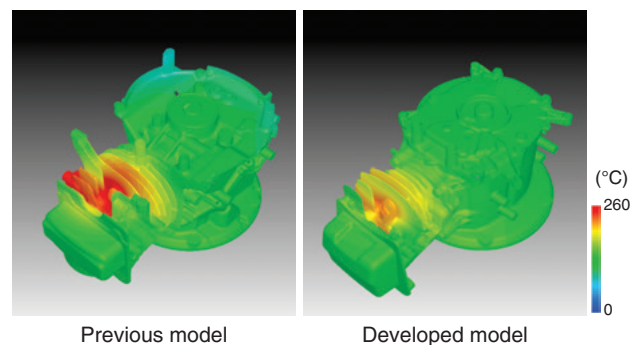


Fig. 8 Temperature of engine surface

3.4. Combustion Chamber

In developing the series towards lower-displacement engines, it was necessary to realize better environmental performance. In the new GCV engines, the combustion chambers are compact pent-roof chambers, and a longer stroke than the previous models has been employed. This has strengthened the in-cylinder flow motion and increased turbulence kinetic energy (TKE), making it possible to realize stable combustion with low emissions and high fuel efficiency. Figure 10 shows the results of the TKE calculations at the ignition timings employed in the engines.

In addition, the intake and exhaust valve diameters and spark plug position are the same for all the models of differing displacements, which has increased productivity by sharing machining.

3.5. Valve System

The valve mechanism was changed from the overhead camshaft (OHC) mechanism with a timing belt built into the engine employed in the previous models to an overhead valve (OHV) mechanism using push rods and valve lifters. In the previous models, the cooling air channels were positioned close to the combustion chamber, and the

timing belt chamber obstructed the flow of cooling air. The use of an OHV mechanism has made it possible to expand the cooling air channels, contributing to increased cooling performance. Figure 11 shows a comparison of the previous and developed shapes.

In addition, cost was reduced by situating the valve mechanism in the oil at the bottom of the cylinders, and adopting a plastic camshaft. Furthermore, the system configuration makes it possible to remove the crankshaft without disassembling the valve mechanism when the engine is undergoing maintenance. Figure 12 shows a cross-section of the engine.

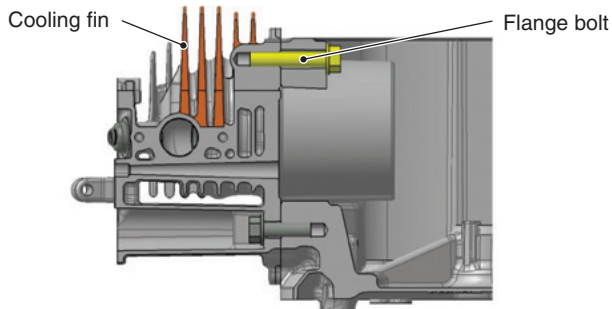


Fig. 9 Cross-section of cooling fins

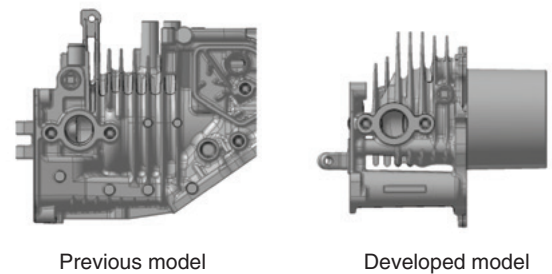


Fig. 11 Side view of cylinder

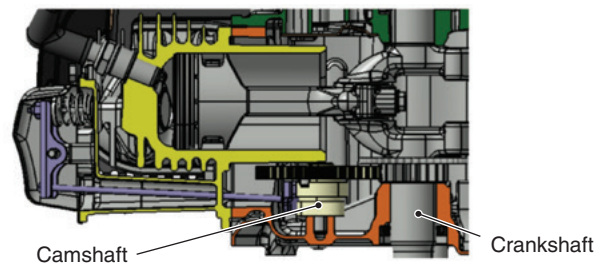


Fig. 12 Layout of camshaft

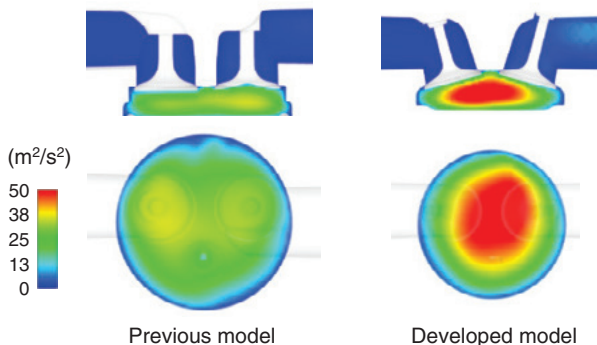


Fig. 10 Results of TKE calculations

4. Effect of Application of New Technologies

4.1. Cost

Reduction of the amount of materials used through the realization of mass savings and the sharing of parts across the differing-displacement engines in the series realized a reduction of approximately 15% in cost against the previous GCV series engines.

4.1.1. Total number of engine block parts across series

The sharing of parts has reduced the total number of

parts used across the series in the engine block section, which is shared by the variations, by 43% against the previous models.

4.1.2. Mass reduction

Minimization of the cooling fin sizes and modification of the engine block shape reduced the mass of the aluminum diecast parts that form the engine block in the new GCV200 by 25% against the previous GCV190. Figure 13 shows the aluminum mass employed in the engine blocks of the previous and developed engines.

As indicated by Table 1, despite the fact that displacement was increased against the previous model, the overall mass of the GCV200 was reduced by 18% against the previous GCV190.

4.2. Environmental Performance

An increase in combustion performance has reduced HC and NOx emissions in the low-displacement GCV145 by 22% against the previous GCV135. Figure 14 compares

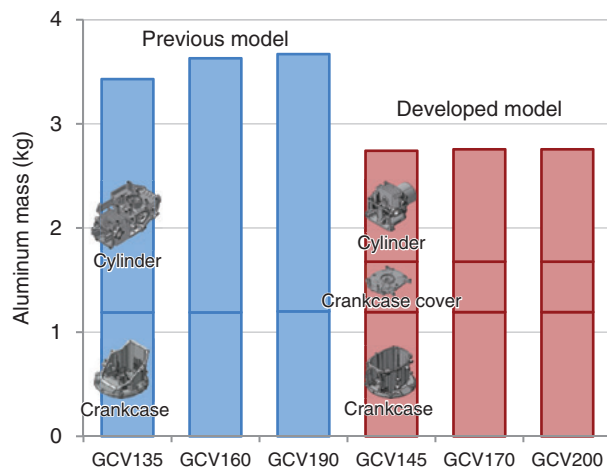


Fig. 13 Aluminum mass of engine block

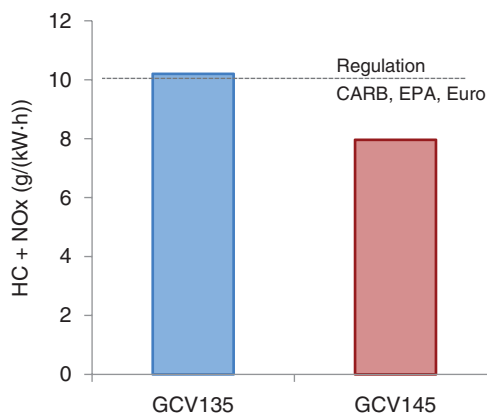


Fig. 14 Mode emissions

emissions in the developed and previous models. These results have made it possible for all models to clear national exhaust gas regulations in their countries of sale.

4.3. Ease of Maintenance

The crankcase configuration, discussed in 3.1.2., has made it possible to disassemble the engine while it is still attached to the frame during work to replace a lawnmower crankshaft. In addition, the use of an OHV mechanism does away with the need to disassemble and reassemble the valve mechanism for adjustment, reducing the man hours involved in maintenance by 60%. Figure 15 shows a diagram of engine parts during replacement of the crankshaft.



Fig. 15 Replacement of crankshaft

5. Conclusion

A series of general purpose engines for the consumer market has been developed that responds to a range of manufacturer demands by maximizing the sharing of constituent parts, and which realizes a reduction in the total number of parts employed across the series, a reduced cost, and a high level of environmental performance. In order to maximize the interchangeability of constituent parts in the design of the basic framework of the engines, the engine block and the auxiliary parts were modularized.

The use of different cylinder modules with the largest module, the crankcase module, as a shared part, made it possible to realize a lineup of three engines.

This development produced the following results:

- (1) The cost of the engines was reduced by approximately 15% against the previous models.
 - The total number of parts employed across the series in the engine block was reduced by 43%
 - The mass of the aluminum employed in the engine block was reduced by 25%
- (2) All the engines of three differing displacements satisfy the environmental regulations of their countries of sale.
- (3) The engines realized greater ease of maintenance than the previous models.

Reference

- (1) Suzuki, T., Hojo, H., Inoue, S., Moriyama, H., Fujinaga, Y.: Development of General Purpose OHC Engine with Built-in Timing Belt, HONDA R&D Technical Review, Vol. 10, p. 122-127

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