

Development of BF250 Flagship Outboard Motor

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ABSTRACT

The BF250 large outboard motor was developed to achieve higher engine output using the first direct air intake system to be adopted for an outboard motor.

The conventional structure had the air intake inside the engine cover in order to prevent water infiltration into the engine combustion chamber. By contrast, the developed engine, which is the first in the world to incorporate a direct intake system, is formed with an intake duct that has drainage functionality inside the engine cover so that water is separated as outside air is inducted directly into the engine. This lowers the intake air temperature more than in the conventional structure and, in combination with other specification changes, it achieved 184 kW (250 HP) with a basic structure that is used in common with the current mass production model BF225. Revision of the lean burn control yielded a maximum 30% enhancement of fuel consumption in cruising speed range relative to outboard motors of the same class. In other respects, adoption of a high durability gear case at the top of its class, adjustable idle charge system, and shifting load reduction control system heightened both durability and convenience.

In order to accentuate the appeal of the BF250, a power intake form that achieves a high level balance of functionality and design was adopted. This raises the outboard motor to the level of a finished product well suited to be Honda's flagship model.

1. Introduction

Recent years have seen a trend to increase the horsepower of the boat type capable of coastal cruising that is known as an offshore boat, particular for those manufactured in North America and Europe. A large percentage of these outboard motors of the large class, which have output of 147 kW (200 HP) or more, are installed on boat types for commercial use that are used in long-term heavy duty environments. Durability and reliability are therefore demanded.

The flagship BF250 large outboard motor was developed in light of these requirements, and the technology adopted in the BF250 is introduced here. Figure 1 shows an external view of the BF250.



Fig. 1 External view of BF250

2. Large Outboard Motor Market Environment and Demands

2.1. Market Environment of the Large Outboard Motor

The main market is in North America. Figure 2 shows the changes in that market in maximum horsepower capacity of offshore boats capable of mounting large outboard motors.

Outboard motor manufacturers have continued to fill out their lineup of large models of 184 kW (250 HP) or more. At the same time, boat manufacturers have also been concentrating on their lineup of large boats (Fig. 2). For the outboard motors mounted on those large boats, there is a trend toward choice of 184 kW (250 HP) engines for their balance of price and performance.

In addition to general leisure use, a large percentage of this class of outboard motor boat has professional uses such as commercial and government. At approximately 30%,

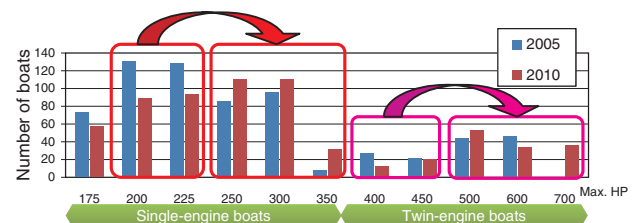


Fig. 2 Number of offshore boats by maximum mountable horsepower

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this figure is higher than will be found in other horsepower segments (Fig. 3).

2.2. Demands for Performance

As discussed above, there is a preference on the market for engines with 184 kW (250 HP) output. Furthermore, there is demand for high durability and reliability to withstand the harsh conditions of long-term, heavy-duty operation envisioned for professional uses. (As an example of use, Fig. 4 shows a boat type that is used in coastal patrol and other such work.)

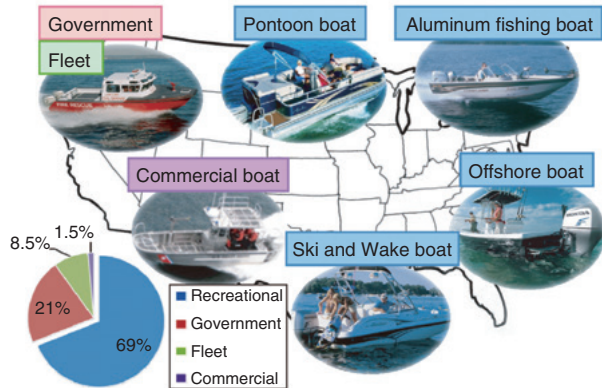


Fig. 3 Variety and percentage of large boat in the market



Fig. 4 Coastal patrol boat

3. Development Concept

In Customer Satisfaction Index (CSI) surveys conducted by J. D. Power and Associates from 2005 to 2009, the current mass production model BF225⁽¹⁾ won first place four times during the five-year period. With this kind of established reputation for performance and reliability, the BF225 was taken as the base for development of a product aimed to be appropriate as the flagship model in the Honda outboard motor series. Making minimal changes to the base engine specifications while raising the efficiency of the intake system to achieve 184 kw (250 HP), this development adopted a highly advanced design and achieved further enhanced reliability as well as power performance, fuel consumption, and utility at the top of its class.

Table 1 Specifications

Code name	BF250A X-type
Overall length (mm)	920
Overall width (mm)	625
Overall height (mm)	1887
Transom height (mm)	635
Dry mass (kg)	284
Engine type	4 stroke 60° V-Type 6 cylinder
Displacement (cm ³)	3583
Bore (mm) × Stroke (mm)	89 X 96
Compression ratio	10.0 : 1
Valve train	SOHC VTEC 24 valves
Maximum power (kW/rpm)	183.9/ 5800
Maximum torque (N·m)	320
Recommended engine speed range (rpm)	5300 - 6300
Fuel supply system	Programmed Fuel Injection
Ignition system	Programmed Ignition
Charge output (A)	60
Exhaust system	Through propeller hub
Gear ratio	2.00 : 1 (24/12)

4. Major Specifications and Overview

Table 1 shows the major specifications for the BF250.

Based on the BF225's 3.5-liter, 60° V6 engine, the Legend crankshaft was combined with connecting rods to extend the stroke by 3 mm, and the engine displacement was set at 3.6 liters. Furthermore, by changing the compression ratio from 9.4 (BF225) to 10.0, both high output and high efficiency were achieved.

5. Main Technology

5.1. Direct Air Intake System

Following the above concept, this direct air intake system is the technology adopted to achieve an increase in output with minimal changes to specifications of the base mass production model BF225.

The present system completely separates the engine intake and exhaust heat as a means of lowering the intake air temperature. It is structured with a separate duct through which exhaust heat is evacuated by a cooling fan.

This was done making the minimum necessary changes to the base model in the engine cover, cooling fan, and fan cover.

In order to minimize the increase in overall height relative to the base model, maximum use was made of the space inside the engine cover by optimal placement of the intake duct, exhaust heat duct, drain duct, and silencer system (Fig. 5).

The following will explain details of the various element technologies.

5.1.1. Intake air cooling and water separation system

Figure 6 shows the engine intake system of the BF225 base model. The structure not just of the BF225 but also of conventional outboard motors from other manufacturers brings outside air inside the engine cover and causes it to circulate within the cover to prevent water intrusion into the engine combustion chamber, perform auxiliary machine cooling, and reduce noise values. After that, it is taken into the throttle body. Consequently, the difference Δt between the outside air temperature and the throttle body intake air temperature is large. This is a factor that lowers engine output.

Figure 5 shows the BF250 direct air intake system. Here, by contrast, air inlets placed on both sides of the engine cover take in outside air that passes through an intake duct made up of an air guide and rear air duct inside the engine cover and then is guided directly into the throttle body. The air inducted by this direct air intake system is less likely to be affected by heat generated by the engine. Therefore, the Δt can be reduced by 14°C compared with the conventional construction, contributing significantly to increased engine output.

Adoption of the direct air intake was also accompanied by the addition of a water separation and drain structure. This was added on the assumption that bringing outside air directly in would cause water intrusion inside the intake duct.

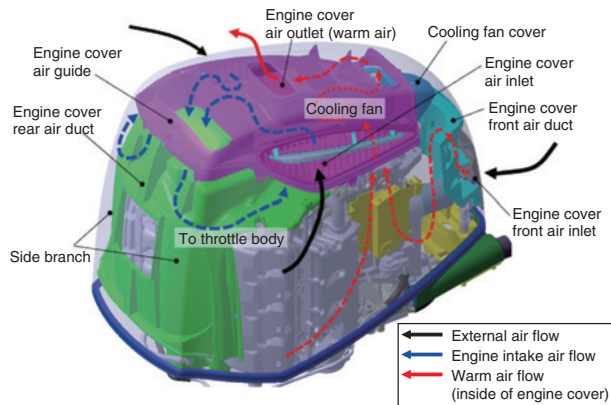


Fig. 5 Direct air intake system (BF250)

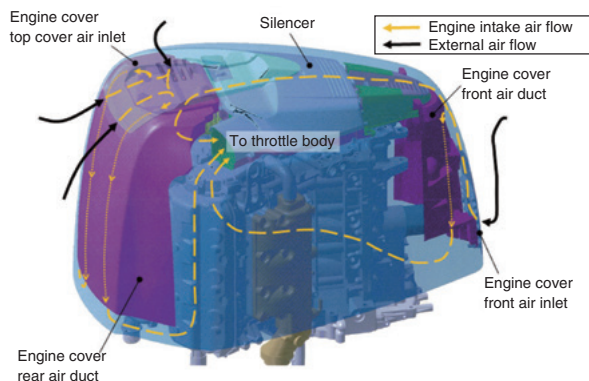


Fig. 6 Conventional air intake system (BF225)

Structures are set up to handle both large and small droplets of water carried along by the flow velocity from the intake. This prevents their intrusion into the throttle body side (Fig. 7). The large water droplets are prevented from intruding by means of a chimney shaped rib placed immediately behind the inlets on both sides. The small water droplets that are carried past this rib by the intake flow velocity pass through an intake duct that turns back 180°. In this arrangement, they are made to adhere to the inside wall of the engine cover while passing through the intake duct. There they are guided downward by vertical ribs in the inside cover wall (Fig. 8) and evacuated through a water drain at the bottom end of the air duct.

In addition to its function as a water drain passage, the side branch portion has the function of decreasing noise (Fig. 7). There, the intake pulsation is used to create a condition whereby the pressure at point B is lower than at point A. This moves water to point B where the pressure is lower, heightening drain performance at wide open throttle (WOT).

5.1.2. Auxiliary machine cooling structure

In adopting the direct air intake system for the BF250, it also became necessary to have a cooling passage independent from the intake duct to perform auxiliary machine cooling inside the engine cover. The BF250

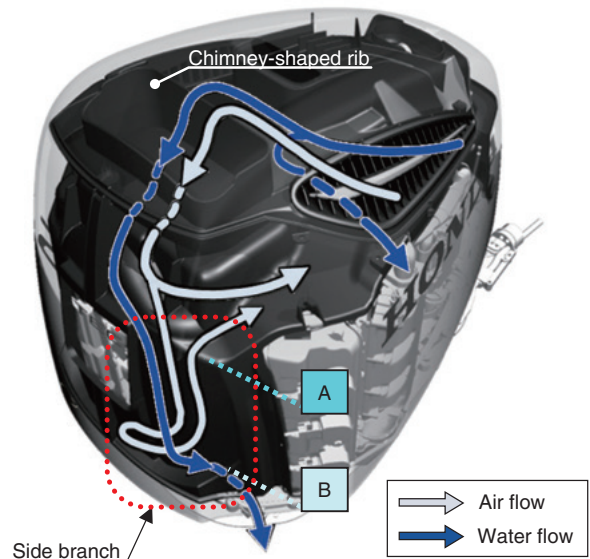


Fig. 7 Separation system of air and water

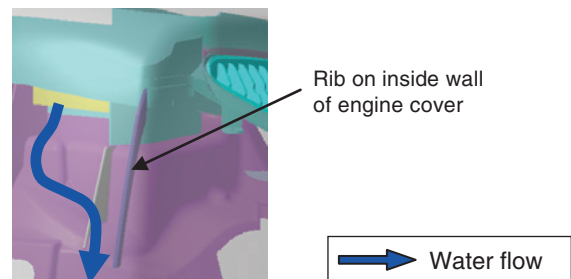


Fig. 8 Rib on inside wall of engine cover

therefore has newly included a fan cover consisting of a cooling fan directly coupled to the crankshaft and a scroll-shaped chamber that covers the cooling fan. Figure 9 shows a simplified diagram of the cooling system inside the engine cover. Figure 10 shows the form of the scroll-shaped chamber in the fan cover. The scroll-shaped chamber is made up of fan covers A and B, and is made as a form that is independent of the forms of the engine parts around it. This suppresses the turbulence around the cooling fan, separates the cooling fan from the high-temperature engine parts, and can suppress the thermal expansion of the air surrounding the cooling fan, thus achieving higher fan efficiency. The result enabled creation of a cooling system capable of efficiently exhausting the heated air inside the engine cover to the outside, allowing stable auxiliary machine cooling.

5.1.3. Structure to decrease noise

Adoption of the direct air intake system involved placement of intake and exhaust heat ducts. The result was an inability to place an intake silencer chamber with adequate capacity. Directly linking the throttle body to the outside of the engine cover with an intake duct made for a structure that discharges intake noise to the engine cover exterior. In order to reduce the intake noise, therefore, a side branch structure was adopted for the BF250. As shown in Fig. 11, this is a silencer that works by interference of acoustic waves.

A side branch of length L is located on either side

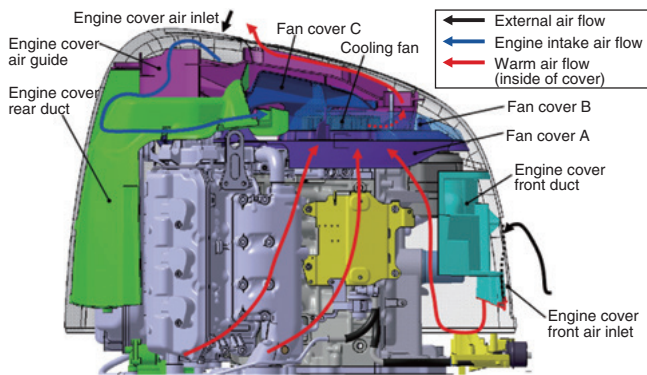


Fig. 9 Cooling fan system

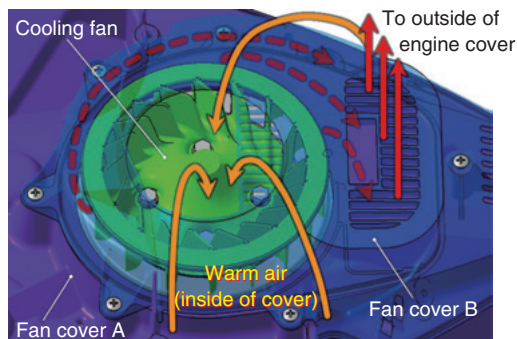


Fig. 10 Scroll shape of fan cover

partway along the intake duct that is composed of the engine cover and rear air duct. The purpose of this is to cause acoustic wave interference in order to reduce the intake noise of intake pulsation at the frequency of approximately 300 Hz at WOT.

The adoption of the direct intake structure for the BF250 resulted in an increase in WOT pass by noise⁽²⁾ of 4 dBA compared to the conventional model. However, the addition of the side branch structure to deal with intake noise, which is a factor in the increase in sound pressure, and measures to optimize the length of the intake duct to avoid resonance with the intake noise. This reduced intake noise by 10 dBA. This enabled the pass by noise to be suppressed to a level that does not exceed the limit value (≤ 75 dBA) (Fig. 12).

5.1.4. Effectiveness (power and fuel consumption)

Adoption of the direct intake structure enabled a 14°C reduction in the difference Δt between the outside air temperature and the throttle body intake air temperature compared to the conventional structure. As a result, the synergistic effect of the enhanced volumetric efficiency (η_v) due to increased density of intake air and the ignition timing advance due to the raised knocking limit yielded an increase of 6.6 kW (9 HP) in peak output (Fig. 13).

In addition, the stroke was made longer, increasing the displacement; the compression ratio was raised; the

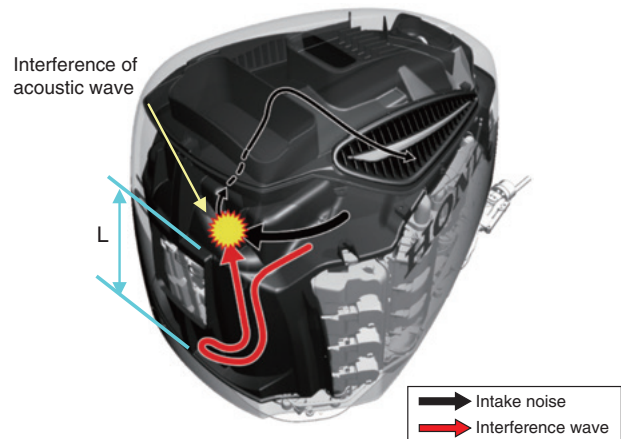


Fig. 11 Side branch system for noise reduction

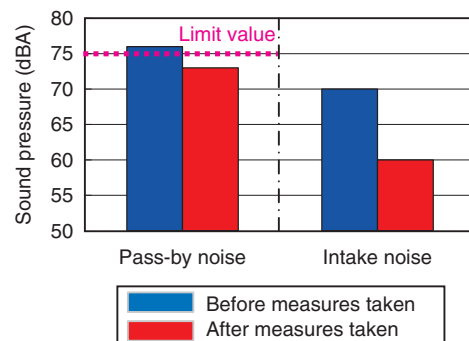


Fig. 12 Pass-by noise and intake noise

valve timing was optimized; the intake valve diameter was increased to heighten η_v ; the adoption of a large diameter thermostat and piston cooling oil jet raised the engine cooling capacity; and the rated speed was increased. By these and other such effects, the developed motor achieved a peak output of 184 kW (250 HP) while sharing the basic structure of the BF225.

In addition to the increase in engine output, a revision of lean burn control⁽³⁾ achieved a maximum 30% enhancement of fuel consumption in cruising speed range relative to outboard motors of the same class (Fig. 14).

5.2. High Durability Gear Case

Figure 15 shows a structural drawing of the BF250 gear case assembly. Generally, every effort is made to reduce the size of the shell shaped section that contains the bevel gear of the outboard motor gear case in order to reduce the water resistance. However, reducing the diameter of that section is disadvantageous in terms of gear strength design. As this indicates, power performance and strength are mutually antagonistic. In order to enhance the durability of the BF250, the diameter of the bevel gear was increased by 10% over that of the BF225.

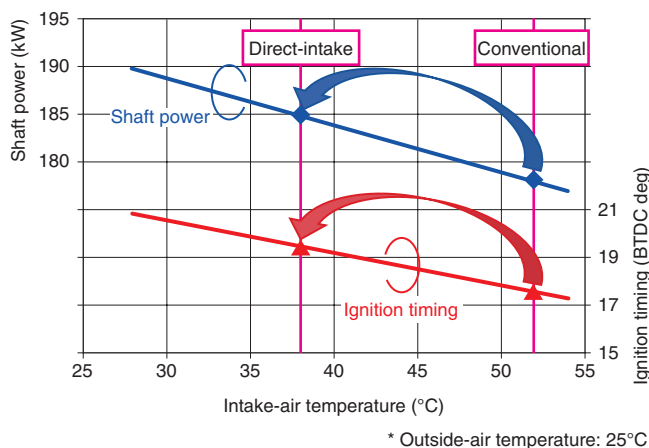


Fig. 13 Intake-air temp-shaft power/ignition timing

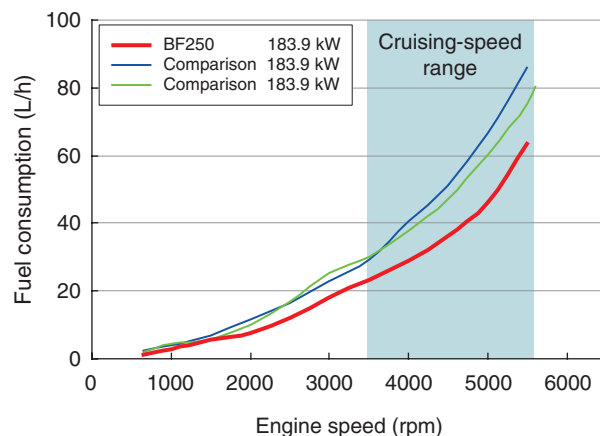


Fig. 14 Fuel consumption at cruising speed

The increase in water resistance resulting from the increased size of the bevel gear was addressed by performing a computer fluid analysis (Fig. 16) to find the optimal case shape. This yielded a 5% decrease in the Cd value, and the steps taken to reduce the water resistance secured power performance that yields nothing to the competition.

For the gear material, a modified material with superior durability was adopted. This is a nickel-chrome-molybdenum steel material refined to remove impurities to the utmost degree. This also enhanced the machining precision of the tooth surfaces, reducing the deviation in gear engagement and thus realizing higher durability.

5.3. Adjustable Idle Charge System

The electronic control unit (ECU) detects the charge output from the AC generator during idling. When it detects the connection of a load exceeding the charge output at the normal idling speed of 650 rpm, the system can raise the engine speed in 100 rpm, thus increasing the charge output by 29%.

5.4. Shifting Load Reduction Control System

Unlike the conventional control, this system adds ignition timing variable control at deceleration to generate engine torque fluctuation and so reduce shifting operation load.

As shown in Fig. 17, changes in engine speed and throttle opening detected by the ECU are used to predict the operator's shifting operation. The ignition timing of cylinders 4, 5, and 6 is retarded to cause fluctuation in the engine torque. This causes variable of transmission

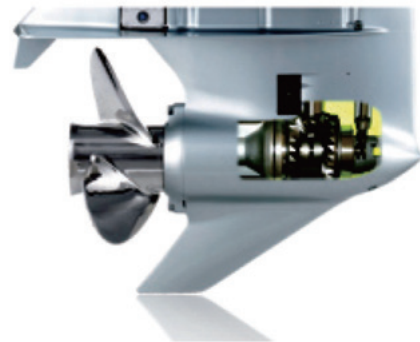


Fig. 15 High durability gear case assembly

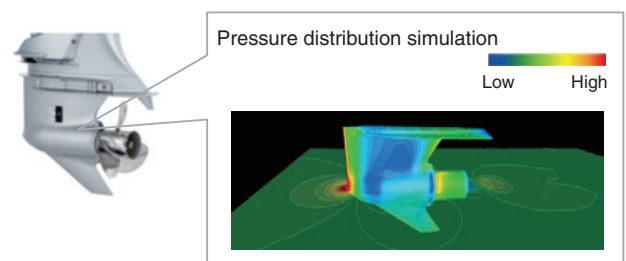


Fig. 16 Fluid analysis simulation

torque in the dog clutch that connects the engine side and the propeller shaft side, reducing the pull-out load on the dog engagement part. This has enabled a 30% reduction in shifting operation load, as shown in Fig. 18.

This does not detect the operator's shifting operation by using a dedicated sensor. Rather, a new control method was developed to make predictions based on changes in the engine speed and throttle opening and reduce the operation load accordingly.

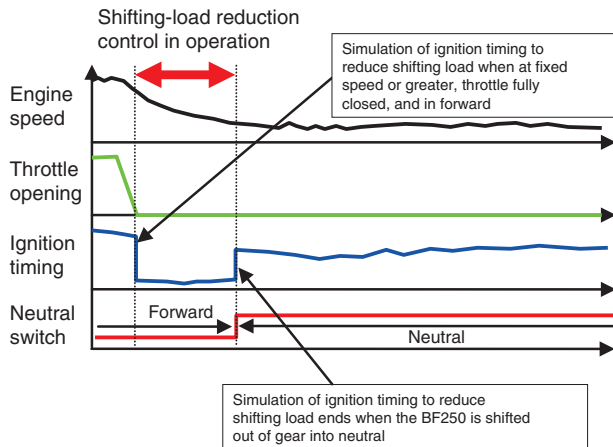


Fig. 17 Shifting-load reduction control

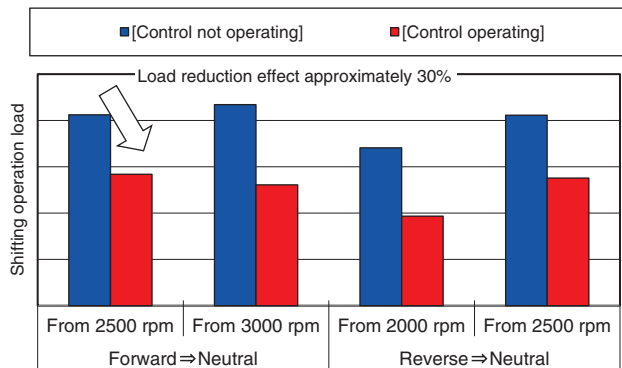


Fig. 18 Shifting-load test results

6. New Design

6.1. Power Intake Form

The direct air intake system is a major feature of the BF250. In order to highlight the appeal of this engine, the “power intake form” was taken as the concept and the following methods were incorporated to realize the design in concrete form.

The intake ports on both sides of the outboard motor top cover, as seen from the operator's point of view, tighten up the bulky appearance of the top cover. This presents a sense of sharpness as an element of appeal (Fig. 19).

A chrome part with a Japanese sword motif was placed in the central part of the intake sections. This underscores

the sense of speed while also adding an expressive element never used before. The fin shape in the intake helps prevent the intrusion of splash water from the front while also directing the intake noise toward the rear where it will have less impact on the operator and the surrounding area. It also takes in fresh air from the rear. This achieves a high-level balance of functionality and design (Fig. 20).

6.2. Color Graphic

The color is not the previous silver from a warm color group, but rather a silver with a strong feeling of transparency that gives a sense of depth. This highlights the higher quality and sharper appearance of the engine. The font was also upgraded, and a new typeface with a sense of speed and heightened visibility was adopted (Fig. 21).

The new BF250 design concentrates these elements and qualities, enabling it to convey a powerful image suitable to the flagship model of Honda's BF series.



Fig. 19 Design concept of BF250



Fig. 20 Power intake design

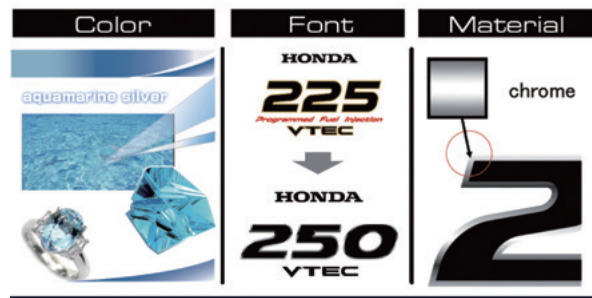


Fig. 21 Color graphic design

7. Conclusion

In development of the BF250, the basic structure of the base model was borrowed while the output power was raised. The durability and reliability were also increased to enable the engine to fully withstand harsh conditions of use while advances were made in utility and design. Development carried out with these aims yielded the following results.

- (1) The adoption of a direct air intake structure reduced the difference Δt between the outside air temperature and the throttle body intake air temperature by 14°C and raised output by 6.6 kW. Revision of the lean burn control achieved a maximum 30% enhancement of fuel consumption in cruising speed range relative to outboard motors of the same class.
- (2) Adoption of a high durability gear case supported the increase in power output while achieving durability at the top of its class.
- (3) Adoption of charge output variable control during idling increased the charge output by 29%.
- (4) Adoption of a shifting load reduction control system reduced shifting operation load by 30%.
- (5) Adoption of a new power intake form as the flagship model of the BF series clarified the differences from other manufacturers and realized the expression of a “new identity.”

These results were very well received. At IBEX 2011 (The International Boat Builders' Exhibition & Conference) held in Louisville, Kentucky, in the United States on October 17-19, 2011, the BF250 received an IBEX 2011 Innovation Award in the outboard motor category from the National Marine Manufacturers Association (NMMA).

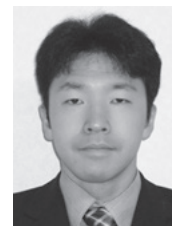
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