

Development of Midrange Outboard Motor BF60 with Equipment for User Comfort

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ABSTRACT

Midrange outboard motors are installed on a variety of different boat types and used for a range of different applications, and customer demands are diverse. The newly developed midrange outboard motor BF60 was given a top speed 8.6% greater than outboard motors of the same class by increasing the engine power output and reducing the drag of the underwater portion of the motor. Fuel economy was also enhanced by 13% by expanding the range of situations where lean-burn control operates. Handling was also enhanced by devising the first wide-angle steering system for a midrange outboard motor, and the product was made highly convenient by incorporating such technologies as the newly configured multi-functional tiller handle with enhanced operability, the configuration with added Power Thrust gear case that yields higher thrust force, and the expanded range of options for attaching outboard motor gauges by complying with the NMEA 2000 standards. The adoption of the Wedge Shape form also gave material form to the concept of beauty, which is a theme common to Honda power products design.

1. Introduction

Honda has developed the BF60 to follow the BF75/90⁽¹⁾ and the BF40/50 in its new lineup of midrange outboard motors. Figure 1 shows an external view of the BF60.

1.1. Various Uses of the Midrange Outboard Motor

The midrange outboard motor has a variety of different

uses, from leisure uses like angling and pontooning to commercial uses like boat rentals and fishing. The boat types on which it is installed are also numerous, from aluminum light-weight boats (mass of 100-500 kg) to pontoon boats (mass of 400-1200 kg). The required functionality and performance vary with the boat type. The characteristics of major boat types are described below.

1.1.1. Aluminum fishing boat

The aluminum fishing boat in Fig. 2 is operated primarily for the purpose of fishing on lakes and rivers. In



Fig. 1 External view of BF60



Fig. 2 Aluminum fishing boat

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addition to long voyage range (low fuel consumption) and speedy movement from point to point in order not to miss the timing for fishing, this boat is also required to offer precise low-speed control for trolling.

The type of tiller handle shown in Fig. 3 may also be used, depending on the region and the application. The tiller handle is equipped not only for steering but comprises a centralized boat control system with throttle, shift, and so on.

1.1.2. Rigid inflatable boat

The rigid inflatable boat shown in Fig. 4 is used mainly for enjoyment of power performance on lakes, rivers, and the ocean. The bottom of the boat is given a deep V angle, which provides enhanced turning performance. The board



Fig. 3 Tiller handle type



Fig. 4 Rigid inflatable boat



Fig. 5 Pontoon boat

is also enclosed by floats, giving the boat high levels of stand-still stability and anti-overturn performance, so that these craft are commonly used for diving support, rescue, and other such applications. In addition to requiring high levels of power performance and steering stability, there are also strong demands for throttle linearity that provides a response from every point across the speed range.

1.1.3. Pontoon boat

The pontoon boat shown in Fig. 5 is a major boat type in North America. It has a flat deck with sofas and tables affixed to it, and is used on lakes, rivers, and bays with few waves. Its purpose is to serve as a waterborne base for parties or swimming, and for enjoyment of fishing and other such leisure activities. There is strong demand for this type as a rental boat in tourist resort areas, and it is not uncommon for it to be used by customers who are not accustomed to operating boats. The bottom of the boat is formed from a combination of two or three large aluminum tubes, giving the craft superior stability, but it is also unsuited to tight turns.

1.2. Concept

The BF60 was developed in line with three basic concepts: “Enjoyable to use: Fun,” “Economical to use: Eco,” and “Simple to use: Easy.” Not only do the specifications for this model place it at the top of the class for basic performance in terms of the power performance and high fuel economy characteristic of Honda outboard motors, but a variety of “comfortable equipment” was also developed with the aim of providing customers with satisfaction in their diverse kinds and patterns of use. The Wedge Shape was adopted as a new design that represents these enhanced elements of performance in order to position this as a premium midrange outboard motor.

2. Technology Employed in the BF60

The four key points on which the product appeal of the BF60 were determined were power performance, environmental performance and fuel economy, comfortable equipment, and design.

2.1. Power Performance

The BF60 does not simply realize increased power output in the engine. It also achieves the top level of power performance for outboard motors in its class by various means, including reducing the drag in the water of the gear case, propeller, and other underwater sections.

The compact gear case on the standard model was newly designed to achieve increased maximum speed and enhanced fuel economy by holding down the size of the front projection area of the underwater section, and further reducing water resistance by using fluid analysis to smooth out pressure variations in the water flow. A somewhat high gear ratio (29:14) for this class was adopted in order

to heighten propeller efficiency with the greatest priority placed on maximum speed.

As a result of the above, in combination with the output power characteristics of the engine, the BF60 achieved maximum speed more than 8.6% (4.5 km/h) greater than an outboard motor of the same class on a 16-ft aluminum fishing boat. This model also adopted an ignition timing control interlocking air-fuel ratio (a boosted low-speed torque system) that enhances acceleration performance by increasing the mass of the fuel injection and advancing ignition timing up to the limit before knocking occurs during rapid acceleration.

Figure 6 shows the pressure distribution diagram produced by fluid analysis. Figure 7 shows the maximum speed. Figure 8 shows the acceleration time.

The BF60 was configured not only with the standard model gear case as mentioned above, but also with the Power Thrust model gear case. The purpose of these gear

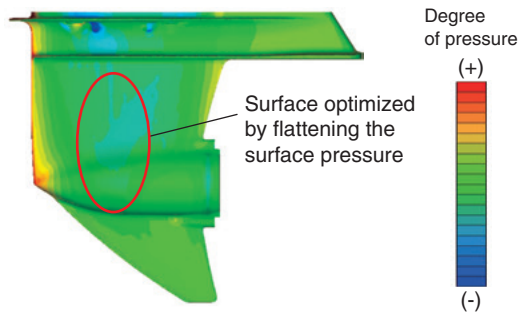


Fig. 6 Pressure distribution on the gear case

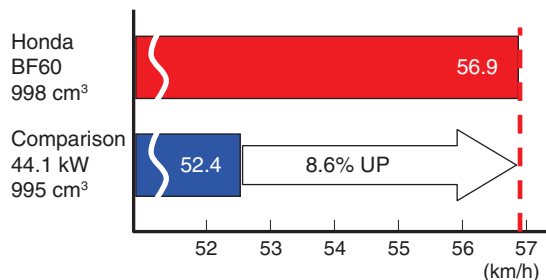


Fig. 7 Maximum speed

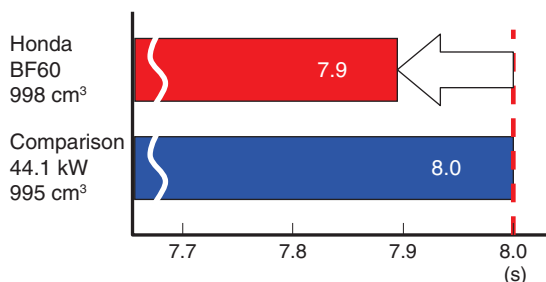


Fig. 8 0-50 m acceleration time

cases is to enhance compatibility with a variety of boat types, and its characteristics are described below.

The Power Thrust model utilizes the gear case of the next-higher model, the BF90. This specification turns a larger-diameter propeller at slow speed so that the propeller thrust force is increased without changing the engine displacement. Placing the propeller at an appropriate depth underwater limits the reduction in thrust caused by ventilation at the water surface, while also limiting the front projection area of the underwater section in consideration of the influence on maximum speed.

The Power Thrust model is frequently installed on heavy boats, where reverse thrust force also is an important performance element to change direction or stop a boat that is coasting forward (moving by inertia). Reverse thrust force was therefore considered important for the BF60, and the below exhaust system was adopted.

Ordinarily, outboard motors discharge exhaust gases through the center of the propeller out into the water in order to enhance exhaust efficiency during forward movement. During reverse movement, however, these exhaust gases can readily be ventilated around the propeller and it becomes difficult to obtain a high reverse thrust force. In addition to the exhaust outlet in the center of the propeller, therefore, another exhaust outlet was also placed higher up. This reduced the exhaust ventilation onto the propeller during movement in reverse without adverse effect on efficiency during forward movement.

Figure 9 shows the exhaust system around the gear case.

As a result, this motor achieved reverse thrust force that exceeds not just comparison motors with the same displacement, but also comparison motors with

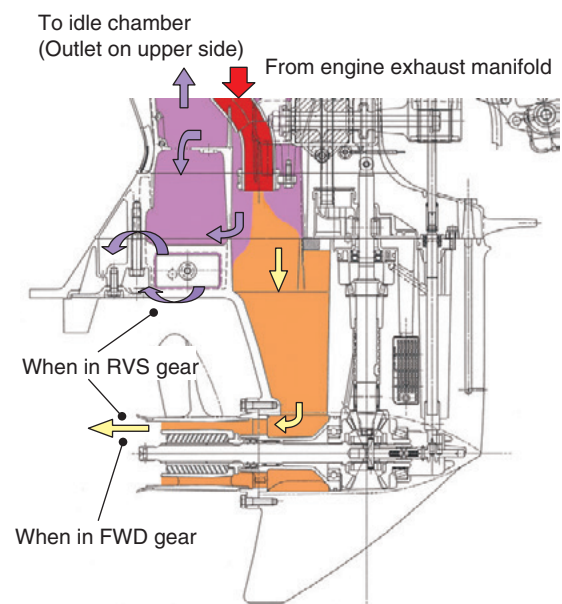


Fig. 9 Path of exhaust gas

displacement that is 1.3 times larger.

Figure 10 shows the comparison of propeller thrust force.

2.2. Environmental Performance and Fuel Economy

The BF60 achieves a balance between heightened fuel economy and enhanced environmental performance that complies with the new exhaust emission regulations of the U. S. Environmental Protection Agency (EPA).

The new exhaust emission regulations adopt the HC and NO_x regulation values of the California Air Resources Board (CARB) starting with the 2010-year model, and also newly added CO regulation values.

Additional regulations on the Not-to-Exceed (NTE) zone and regulations on fuel permeation have also been added for new models.

Figure 11 shows the low-permeation fuel hose that was adopted to support the fuel permeation regulations. Figure 12 shows an overview of the NTE zone regulations.

The BF60 embodies further refinements to the lean-burn control⁽²⁾ that is a characteristic of Honda outboard motors. The range of situations where lean-burn control operates was expanded, the control map was made more fine-grained, and thus a balance of environmental performance and fuel economy was realized. Through these measures, the BF60 achieved a 13% enhancement in fuel economy in practical use relative to outboard motors of the same class on a 16-ft aluminum fishing boat.

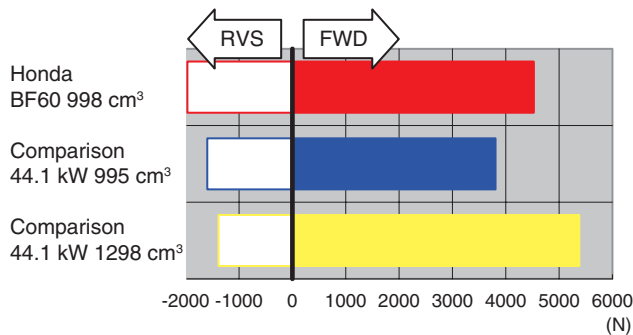


Fig. 10 Maximum thrust force of propeller

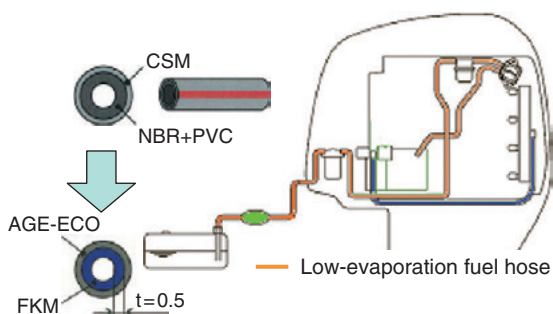


Fig. 11 Low-permeation fuel hose

Figure 13 shows fuel consumption during practical use of the motor. Figure 14 shows a conceptual map of boat load characteristics and air-fuel ratio.

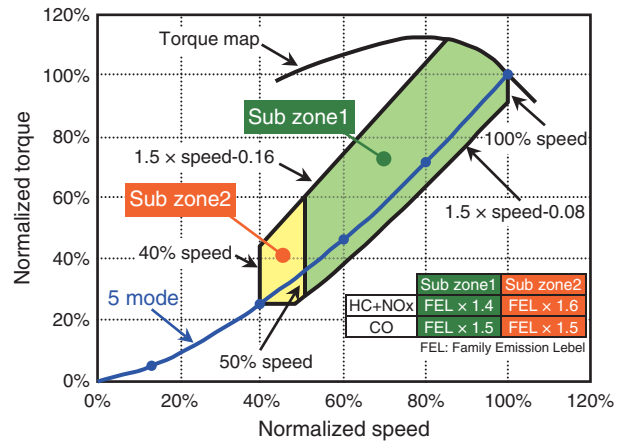


Fig. 12 NTE zone map under EPA regulations

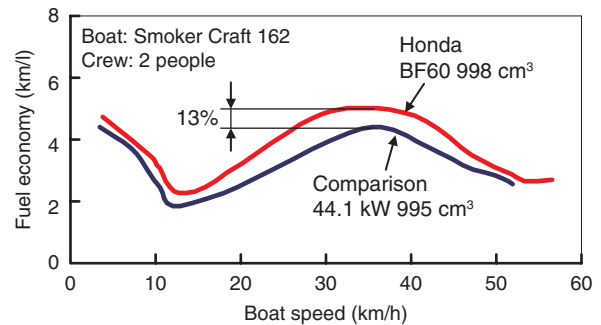


Fig. 13 Mileage in practical use

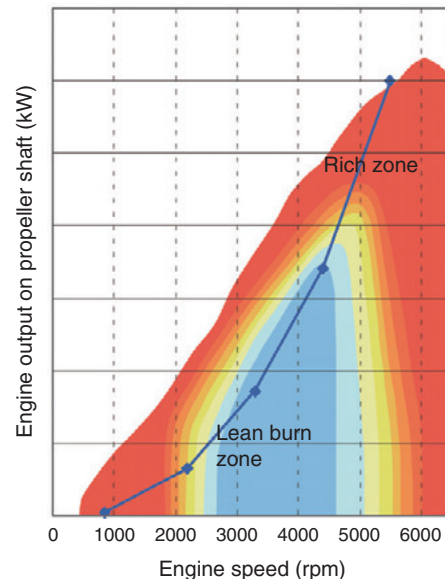


Fig. 14 Map of A/F ratio

2.3. Comfortable Equipment

2.3.1. Steering with wide steering angles

The pontoon boats that are commonly used in North America are a boat type with high cruising resistance. Consequently, even the installation of a high-powered outboard motor was not expected to yield very much greater power performance, and these boats can often be found, therefore, with underpowered outboard motors installed on them. When changing direction or in docking scenarios, for example, when the capability to make tight turns is required, it would be necessary to do repeated backing and turning with inadequate propeller thrust. It was in order to free users from this kind of troublesome maneuvering that ways were devised and adopted to give the BF60 a wider steering angle, increased from the industry standard of 30° to left and right to 50°.

These measures enable the BF60 to make turns with a minimum turning radius that is half or less than half that of outboard motors of the same class. This has yielded a significant enhancement in maneuverability.

Figure 15 shows a comparison of minimum turning diameters.

The outboard motor steering system has been configured from industry technical standards issued by such groups as the International Council of Marine Industry Associations and the American Boat and Yacht Council. The movement distance of the steering pivot is limited accordingly. This pivot and the outboard motor are connected by a steering rod that completes the outboard motor steering system. The steering angle is therefore determined by the distance between the center of the steering axis and the connection point of the steering rod. When this distance is made shorter, the outboard motor steering angle can be made wider.

The steering rod connection point is ordinarily located on the center line when the outboard motor is in a neutral

steering situation. If the layout is simply configured this way for 50° steering, however, the link ratio during steering will be 84% when steering left and 39% when steering right. This means that the operation load of steering will be conspicuously greater when steering right.

In the BF60, the steering rod connection point is offset from the center line. It is configured to make for a link ratio of 71% for both steering left and steering right.

These measures were taken to keep the steering load from becoming extremely heavy while also minimizing the load difference between steering left and right in order to enhance the steering feeling.

Figure 16 shows the layout of the steering system. Figure 17 shows the link ratio.

2.3.2. Multi-functional tiller handle

The outboard motor tiller handle is used to control the steering, throttle, and shift operations. In addition, it controls the power trim and tilt (a mechanism that changes the vertical angle of the outboard motor, thereby adjusting the boat's cruising posture and speed), which are distinctive

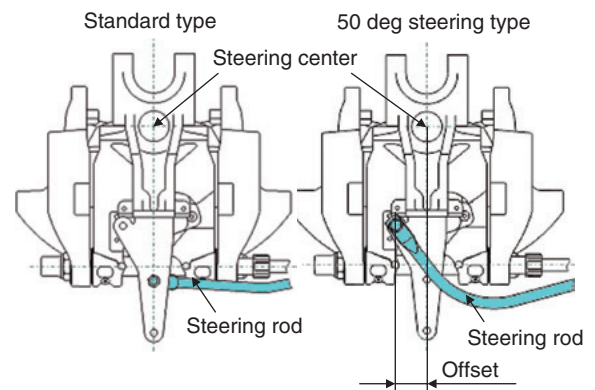


Fig. 16 Layout of steering system

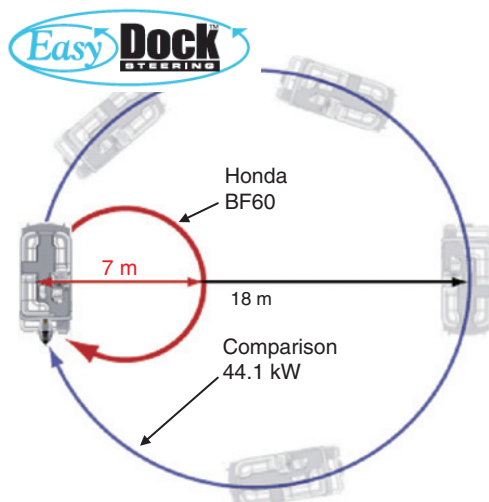


Fig. 15 Minimum turning diameters

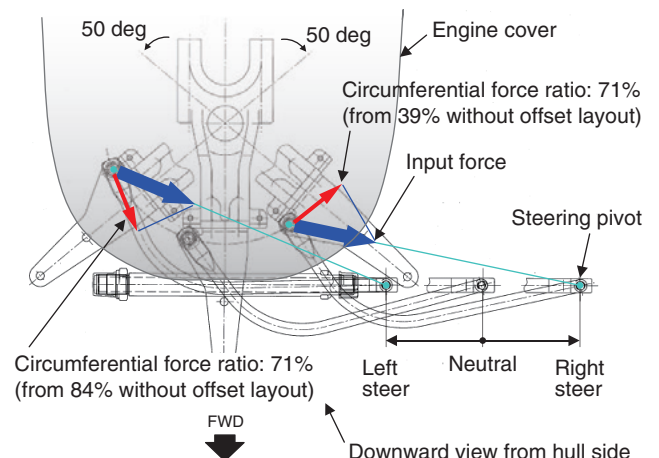


Fig. 17 Link efficiency

adjustment features of an outboard motor. As the tiller handle brings together these various functions, its ease of use is important. The BF60 tiller handle was newly developed with thoroughgoing pursuit of ease of use as an aim, and the shape and layout of the control systems were decided accordingly.

On craft with tiller handles, the operators ordinarily sit on the starboard side and operate the tiller with their left hands. The controls on the tiller handle are therefore configured on the assumption that the operator will be seated to starboard. Unlike automobiles and other such vehicles, however, the steering position taken in the case of an outboard motor is not defined by the seat. Depending on the shape of the craft or the handedness of the operator, the operator may in some cases sit on the port side. A reversible shift lever structure was therefore adopted for the BF60 tiller handle so that the operator can choose to attach the shift lever either to the left or to the right. This makes the shift lever easy to operate with either the left hand or the right hand.

When adjusting the maximum speed while cruising at full throttle, it is also common for operators to operate the throttle and steer with one hand while using the other hand to hold on to some part of the hull so as not to be thrown from the boat. Under these circumstances, throttle operation and trimming are performed simultaneously, and it is desirable, therefore, that the trim switch allows operation with the hand that is holding the throttle grip. The BF60 tiller handle has the power trim and tilt switch built into the grip near the end of the throttle grip. This places the switch in a constant fixed position relative to the hand that is holding the throttle, so that operators can readily operate the switch without changing their grip on the throttle.

Figure 18 shows an external view of the tiller handle.

On the other hand, a craft can be affected by wind and tidal flow during troll fishing and other extremely low-speed movement, so that fine adjustment of boat speed is required. The BF60 was designed to enhance this kind of use by configuring a trolling control system that can adjust the engine speed by 50-rpm increments when operating at low speed between 750 and 1000 rpm.

Figure 19 shows a conceptual image of speed adjustment using the trolling control.

This allows the trolling speed of a 16-ft aluminum boat using a 15-inch-pitch propeller to be adjusted at 0.3-km/h increments from 3.5 km/h to 5.0 km/h by the operation of a single switch. This enables easy fine adjustment of boat speed for troll fishing.

This functionality can also be provided with the remote control handle specification by the use of an added panel switch.

2.3.3. Expanded selection of gauges for use with outboard motors

In the case of outboard motor craft, there is a strongly

rooted practice of having dealers provide finished boats as a customized package with rigging, including fuel gauge, battery voltmeter, and other electronic instruments, from different manufacturers than the outboard motor. However, choices of speed gauges, tachometers, and other instruments have come to be practically limited to genuine branded products from the same manufacturers as the outboard motors due to issues of compatibility with the engines. In other words, there has been a narrowing of the choices whereby customers could exercise their preferences. This was addressed by the NMEA 2000 standards, adopted in 2001, that unify the communication protocols for marine electronic instruments, making it easier to connect all types of electronic instruments.

NMEA 2000 standards⁽³⁾ are unified communication protocols for marine electronic instruments defined by the National Marine Electronics Association in the United States. Worldwide, 500 or more companies that are manufacturers and dealers subscribe to the standards.

Making the BF60 compliant with the NMEA 2000 standards has enabled it to use a wide range of marine



Fig. 18 Multi-functional tiller handle

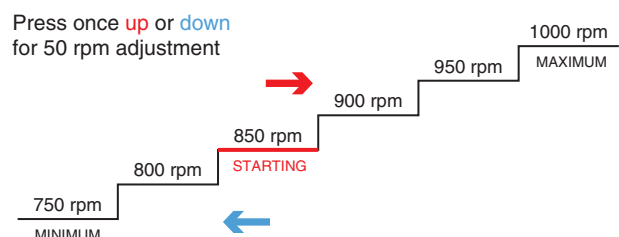


Fig. 19 Variable trolling speed control

Table 1 Specifications

Code name	BF60A L-type
Overall length (mm)	777
Overall width (mm)	417
Overall height (mm)	1397
Transom height (mm)	521
Dry mass (kg)	110
Engine type	4 stroke water cooled in-line 3 cylinder
Displacement (cm ³)	998
Bore (mm) X Stroke (mm)	73.0 X 79.5
Compression ratio	9.2 : 1
Valve train	SOHC 12 valves
Maximum power (kW/rpm)	44.1 / 5500
Maximum torque (N·m)	79
Recommended engine speed range (rpm)	5000 - 6000
Trolling engine speed (rpm)	850 (750 - 1000)* ¹
Gear ratio	2.07:1, 2.33:1* ²
Fuel supply system	Programmed fuel injection
Ignition system	Programmed ignition
Charge output (A)	22
Exhaust system	Through propeller hub

*1 : () under variable trolling speed control

*2 : Power thrust model

electronic instruments of various types that support this standard in addition to genuine Honda brand gauges. This has greatly expanded the range of choices in electronic instruments open to users.

The NMEA 2000 standards do not cover only those items of engine information that support the standards. It includes domains of information that can be defined at each maker's discretion, and in the BF60, these domains are used for output of Eco Lamp signals. NMEA 2000-compliant instruments that support the Eco Lamp signals have also been configured for Honda use.

Eco Lamp signals belong to the system that causes a green lamp to illuminate on NMEA 2000 instruments that support the Eco Lamp when the engine satisfies lean-burn control conditions. This enables users to visually confirm the range of situations where lean-burn control operates,

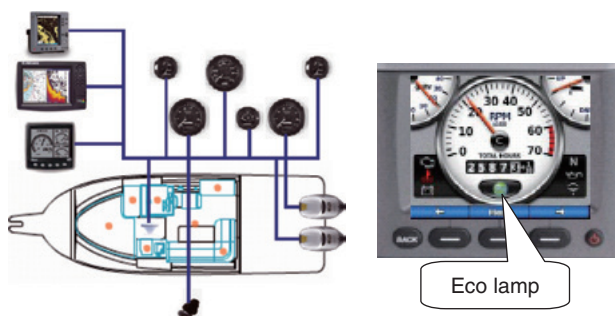


Fig. 20 NMEA 2000 instrument network

which had been difficult to perceive up to this time. This capability allows users to sense more easily when they are cruising under positive fuel economy conditions.

Figure 20 shows a conceptual image of electronic instruments networked under the NMEA 2000 standards.

2.4. Main Specifications

The BF60 engine was newly designed as a three-cylinder version of the 1496 cm³ in-line four-cylinder engine for the Fit, making it a 998 cm³ dedicated outboard engine. The mainstream of outboard motors in the same class are four-cylinder engines. The choice of a three-cylinder format allowed the engine to be made lighter and more compact.

The main specifications of the BF60 are shown in Table 1.

3. Wedge Shape Design

The concept for the exterior design was the dynamic Wedge Shape design that alludes to power performance that leads its class. This builds the product's identity as a new generation of Honda outboard motor. The key appeal made with the BF60 to differentiate it from other companies' products was its premium quality, and it was formed with persistent attention to quality down to the smallest details of design. Specifically, the top cover was divided into two parts, the Wedge Shape character line was highlighted, and the water through-gate on the front was sculpted using the motif of an animal's eye, adding an individualistic expression. The splash line on the lower cover was modeled in relief, which heightened the variety of the surface and also contributed to prevention of fouling resulting from splash run-up on the upper part of the main body.

The incorporation of these methods realized the creation of a premium-quality midrange outboard motor that gives material form to the concept of *beautility*, which is a theme common to Honda power products design.

Figure 21 shows the BF60 design concept. Figure 22 shows the top cover.

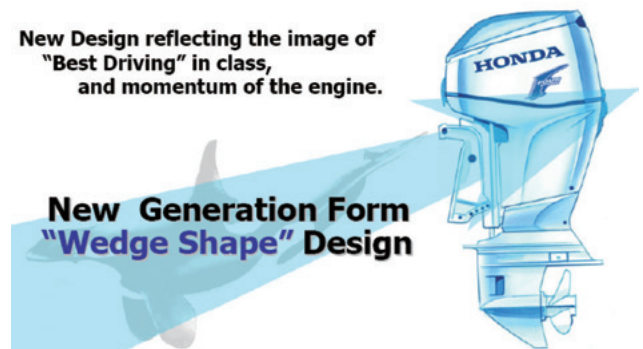


Fig. 21 The BF60 design concept



Fig. 22 The top cover of the BF60

4. Conclusion

The development of the BF60 not only sought enhanced driving performance and environmental performance. It also involved developing comfortable equipment in order to address the variety of demands made of a midrange outboard motor. This gave concrete form to the following:

- (1) The maximum speed was increased by 8.6% relative to outboard motors in the same class.
- (2) A fuel economy enhancement of 13% was achieved relative to outboard motors in the same class.
- (3) Steering with a 50° steering angle left and right was devised and adopted, enhancing maneuverability.
- (4) Two types of gear case were configured, enhancing suitability to boat types.
- (5) The new configuration of a multi-functional tiller handle enhanced operability.
- (6) The range of choices of marine electronic instruments that comply with the NMEA 2000 standards was expanded.
- (7) The adoption of the Wedge Shape design realized *beautility*.

5. Epilogue

The developers intend to make use of the technology and know-how acquired through development of the new model BF60 in developing the outboard motors of the future, and hope to continue building products that embody the customer's desires.

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