

Development of EU3200i Handy Portable Generator

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ABSTRACT

The newly developed EU3200i inverter generator of the 3-kVA class provides portability together with the ability to operate a variety of household appliances with leisure applications. The generator adds three key technologies to the 2-kVA class EU2200i to yield higher power output and enhanced usability while limiting increases in size and mass. The first was to mount a dedicated engine and alternator for compactness and high power output, increasing the specific power. The second was the initial adoption of a battery-less fuel injection system in the power product field, realizing simple startup capability while reducing fuel consumption. Finally, the new resin monocoque structure achieves noise levels on a par with previous products while limiting increases in mass. The power-weight ratio has been enhanced 15% over the preceding EU2200i, and with volume of 79 L and mass of 26.8 kg, the generator delivers the highest level of compactness and lightest level of weight in the 3-kVA class.

1. Introduction

Against a background of abundant demand for use as a power source for RV camping and other such applications in the leisure sector, the North America market for inverter generators is steadily expanding (Fig. 1). By power output, the 2-kVA class has a larger market, but in recent years, the 3-kVA class market has also been increasing. Where conventional use for generators in RV camping was mainly for air conditioning, the equipment used has grown more diverse (refrigerators, coffee makers, cooking appliances, and so on) so that higher power output became necessary, which is believed to be the reason for the rise in 3-kVA class unit sales.

In the leisure sector, generators are typically stored in the household then placed in the vehicle to be transported to the location where it is used. After arriving at the destination, there would also be many occasions when the generator is carried from the vehicle to where it is used, so the market considers portability to be important. For the 2-kVA class, therefore, a suitcase-style product that can be carried with one hand, like the EU2200i [Fig. 2(a)], is the mainstream. It was also determined that the need for portability is also high in the growing 3-kVA class. The 3-kVA class EU3200i generator (Fig. 3) was thus developed as an evolution of the suitcase-style EU2200i. The present paper introduces the technologies applied to the EU3200i to realize higher power output and enhanced usability.

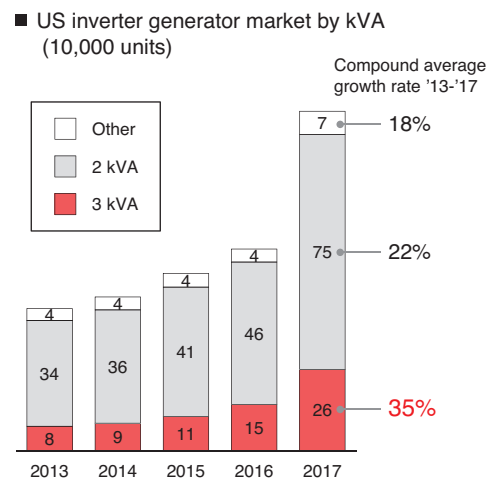


Fig. 1 US inverter generator market by kVA



Fig. 2 External view of previous Honda generators

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Fig. 3 External view of EU3200i

2. Model Overview and Main Specifications

The EU3200i product concept is a 3-kVA class generator that is lightweight, compact, and easy to use in leisure settings. Table 1 shows the main specifications of this generator in comparison with those of the base model EU2200i. The output to mass ratio has been increased from 104 VA/kg to 119 VA/kg, a 15% enhancement over the previous EU2200i. The new model has a volume of 79 L and mass of 26.8 kg. As shown in Fig. 4, this achieves greater compactness and lighter weight than existing products in the 3-kVA class from other companies or the EU3000i Handi [Fig. 2(b)]⁽¹⁾.

The exterior appearance was styled as “premium intelligence design” expressing the following three values.

- Change and evolution that are perceptible at a glance
- A small number of elements to give an appearance of simplicity and intelligence
- Senses of satisfaction, fulfillment, and superiority from possessing the product

In order to make the structure more attractive, a polyhedral shape utilizes the effects of light and shadow for an appearance of lightweight compactness, giving the product a uniquely distinctive appeal. The polyhedral shape also provides the product with surfaces that reflect light and others that are shadowed, further highlighting the product’s attractiveness. Removing the four corners also reduced the risk of damage and lowered the potential of bumping into a person, car, or other object during transport. This has also contributed to the product’s distinctive shape that conveys an impression of originality not found in any other company’s product.

Development used the existing EU2200i model with its high degree of portability as a base to which three key technologies were applied.

- (1) Dedicated engine and alternator that are compact and provide high power output
- (2) Battery-less fuel injection (FI) system, a first for power products, that realizes simple startup while reducing fuel consumption
- (3) A resin monocoque structure that achieves noise levels on a par with preceding products while limiting increases in mass.

The technologies that realize high power output and enhanced usability are described in detail below.

Table 1 Comparison of specifications

Model name	EU2200i	EU3200i
Max power [VA]	2200	3200
Rated power [VA]	1800	2600
Mass [kg]	21.2	26.8
Output to mass ratio [VA/kg]	104	119
Width [mm]	290	306
Enclosure volume [L]	63	79
Remote monitoring	Bluetooth	Bluetooth
Fuel supply system	Carburetor	Fuel injection
Run time (1/4 rated) [h]	8.1	8.6
Run time (rated) [h]	3.2	3.3
Noise level (rated) [dB(A)]	90	91

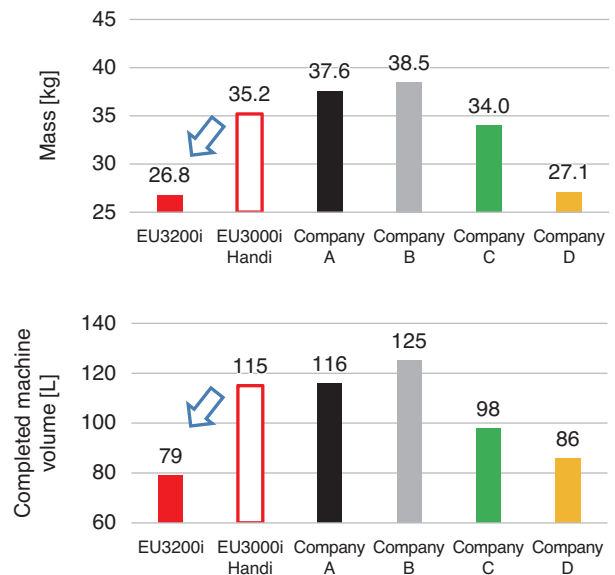


Fig. 4 Comparison of 3-kVA class generator mass and volume

3. Engine and Alternator

3.1. Compact, High-power GX130 Engine

The GX130 engine that is mounted in the EU3200i retains the width dimension of the GXR120 engine mounted in the EU2200i in order to realize the suitcase style. At the same time, the following three technological measures were also adopted to balance between engine power supporting increased power generation output and greater compactness and lighter weight.

- (1) High speed, high compression ratio, and increased intake air volume for higher power output

- (2) Reduced weight from bearing support structure
- (3) Enhanced cooling efficiency by separation of combustion chamber and valve chamber

3.1.1. Higher power output

First, a comparison of the GX130 and GXR120 specifications is shown in Table 2.

While GX130 displacement was increased by only 7% over the GXR120, the engine was given higher speed and a higher compression ratio. In order to realize stoichiometric operation, the stroke/bore ratio was set close to 1.0 and the in-cylinder flow was strengthened by a combustion chamber geometry that positions the valves at an angle.

It was also necessary to increase the intake air volume to raise the power output. The carburetor adopted with the EU2200i, however, had to have the throttle bore diameter take into consideration the venturi bore diameter, which is the smallest part of the intake path. Increasing the throttle bore diameter required use of a larger carburetor, necessitating adoption of FI for the EU3200i to enable the size of the fuel system to be kept unchanged while the throttle bore diameter was increased.

The above higher speed, higher compression ratio, and the greater throttle bore diameter increased the intake air, achieving a 43% increase in maximum power, as shown in Fig. 5.

3.1.2. Lighter weight from bearing support structure

Figure 6 shows a comparison of the GX130 and GXR120 engine structure. In the GX130, a bearing support structure [Fig. 6(A)] was adopted for the bearing on the timing belt side. This made it possible to position the

Table 2 Comparison of engine specifications

Model name	EU2200i	EU3200i
Engine name	GXR120	GX130
Engine type	Air-cooled 4 stroke OHC	
Displacement [cm ³]	121	130
Bore × Stroke [mm]	60 × 43	56 × 53
Compression ratio	8.5	10.0
Stroke/Bore ratio	0.72	0.95
Engine mass [kg]	5.6	5.0
Throttle bore diameter [mm]	15	18
Outer diameter of cooling fan [mm]	171.5	

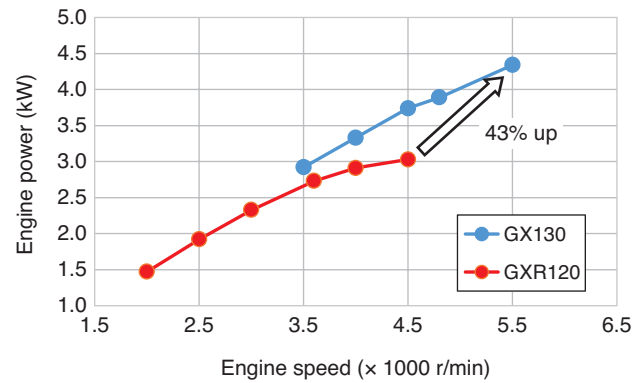


Fig. 5 Comparison of engine power

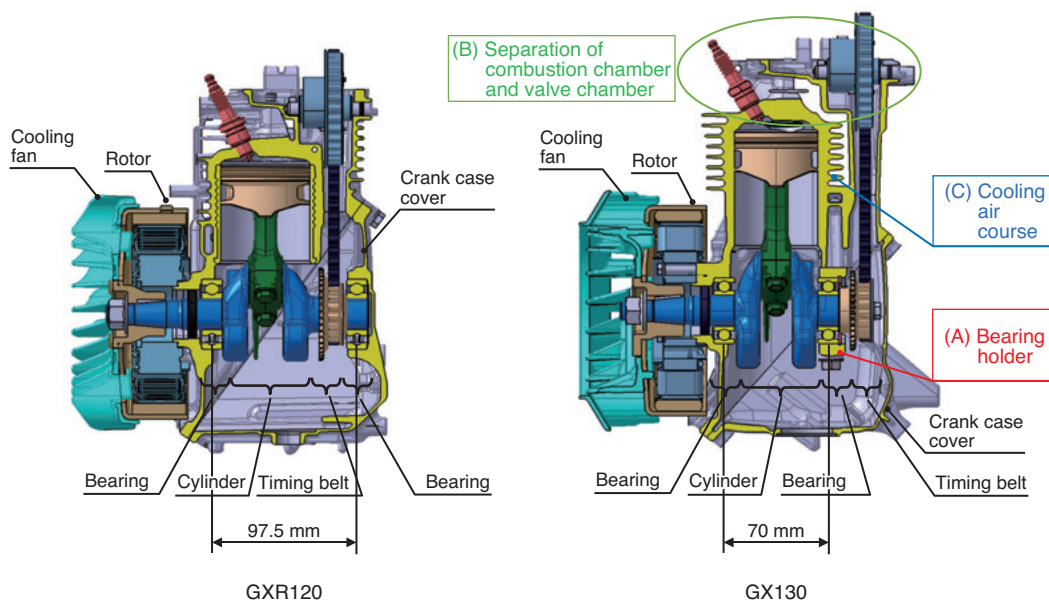


Fig. 6 Sectional view of GXR120 and GX130

timing belt on the exterior of the bearing, reducing the distance between crankshaft bearings from 97.5 mm to 70 mm. This measure helped ensure support rigidity for the increased load from the higher compression ratio while also concentrating the crankshaft bearings on the cylinder barrel side. This allowed simplifying the structure of the crankcase cover, reducing engine weight by 0.6 kg over the GXR120.

3.1.3. Heightened cooling efficiency by separation of combustion chamber and valve chamber

The increased power output described above and support for stoichiometric operation described below resulted in a higher engine temperature for the GX130 than in conventional models. Installing it in a suitcase-style generator raised issues in establishing the engine's cooling performance. In order to address these issues, the timing belt was positioned on the exterior (the shaft-end side), and as shown in Fig. 6(B), the combustion chamber and valve chamber were separated. This made it possible, as shown in Fig. 6(C), to create a new cooling air course between the cylinder and timing belt. The resulting increased heat-radiating surface area on the cylinder head enabled higher speed while retaining the same-size cooling fan. Figure 7 shows a graph comparing trends in inverter generator power output and cooling fan outer diameter. The ratio of generated power output and fan outer diameter in the EU3200i has changed, indicating an increase in cooling efficiency.

3.2. Greater Compactness and Higher Power of Alternator

At the same time as in the engine, a compact, high-power alternator was also introduced in the power generating unit. Table 3 shows the specifications of the alternator.

In order for the alternator to achieve higher power output while also maintaining the width dimension of

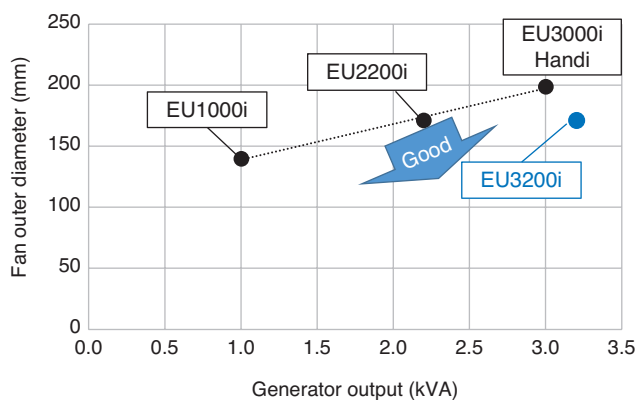


Fig. 7 Trends of fan outer diameter and generator power

Table 3 Comparison of alternator specifications

Model name	EU2200i	EU3200i
Outer diameter of rotor [mm]	150	
Continuous rated output of alternator [kVA]	2.4	3.7
Efficiency of alternator (rated) [%]	86<	
Thickness of stacking [mm]	24.15	21.00
Mass [kg]	3.2	3.0
Output weight ratio [kVA/kg]	0.75	1.16
Magnet type	Ferrite	Neodymium-based bond magnet
BHmax [MGOe]	5.5	10.0
Material of stator core	35A360	
Material of yoke	JSC270E	SPHC

the completed machine, it needed to have the same outer diameter as the EU2200i (rotor outer diameter of 150 mm) and be capable of producing 3.2 kVA of power. The measure to achieve this was to increase the alternator power output by adopting a neodymium bonded magnet with an energy product BHmax that at maximum is 1.82 times that of the ferrite magnet material in the EU2200i. Increasing the magnetic force in order to optimize every part also made it possible to reduce the stator thickness by 14%, reducing total mass of the alternator by 6.3%.

Using the above methods, this compact alternator retains the same outer rotor diameter as in the EU2200i while increasing maximum power output by 55%, as shown in Fig. 8.

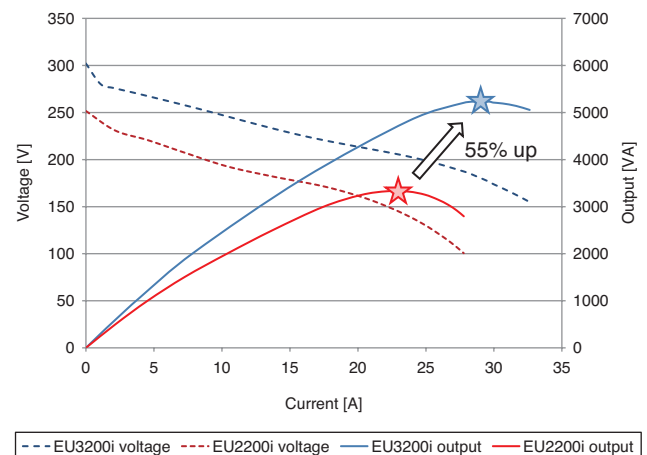


Fig. 8 Comparison of EU3200i and EU2200i alternator performance at 5500 r/min

4. Battery-less FI System

In order for the EU3200i to realize enhanced usability through simple startup while reducing fuel consumption by stoichiometric operation, it adopted the first battery-less FI system in power products.

4.1. Stoichiometric Operation for Reduced Fuel Consumption

In other than wide-open throttle usage, the EU3200i runs in stoichiometric operation mode by feedback control that utilizes the FI system and an exhaust O_2 sensor. As shown in Fig. 9, the engine maintains fuel consumption at the same level as conventional engines in terms of the power air-fuel ratio when running at maximum power. At or below the rated load of 4800 r/min, lower fuel consumption was actualized by stoichiometric operation. With this approach, as shown earlier in Table 1, the generator achieved a 44% increase in rated power over the EU2200i. The lower fuel consumption due to stoichiometric operation, however, made it possible to limit its increase in fuel tank capacity (from 3.6 to 4.6 L) to just 28% while maintaining continuous operating time at the rated power.

4.2. Simple Startup System

An FI system normally uses a battery-powered starter motor for startup. In the present development, however, an FI startup system was created that can start using a recoil starter operation just as in existing generators.

Portable generators are generally not started with the kick-starters used in motorcycles, instead using a hand-operated recoil starter. For this reason, it was necessary to generate electric power for the starter device at low rpm. This was accomplished by having the user pull on the recoil starter to turn the crankshaft, generating three-phase AC power with the alternator. The generated electric power is converted to DC power by the power source circuit inside the engine control unit (ECU), the DC power then being supplied to the FI device. The ECU also controls and drives the FI device,

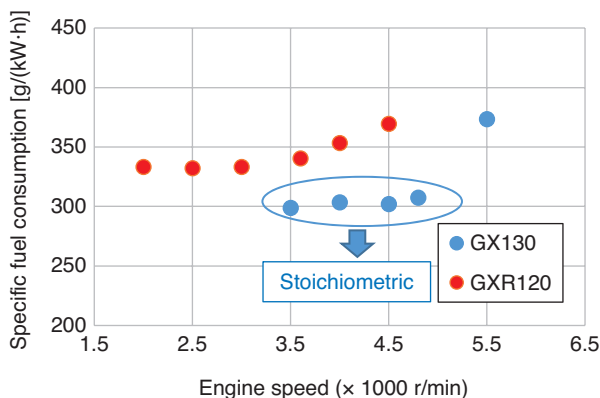


Fig. 9 Comparison of specific fuel consumption

consisting of fuel pump, injector, ignition coil, and throttle motor, thereby handling the starter control function.

The parts that require electric power to operate at startup are shown in Fig. 10, and a comparison with the existing EU2200i system is shown in Fig. 11. The differences in power required during startup because of the adoption of FI and other such reasons are that where the EU2200i has a “3 W” system (three power consuming parts), the EU3200i is “21 W” (seven power consuming parts). The parts that consume power during startup are shown below.

- EU2200i (three parts)
Ignition unit, ignition coil, throttle
- EU3200i (seven parts)
ECU, ignition unit, fuel pump, injector, engine temperature sensor (TE sensor), intake pipe negative pressure sensor (MAP sensor), throttle

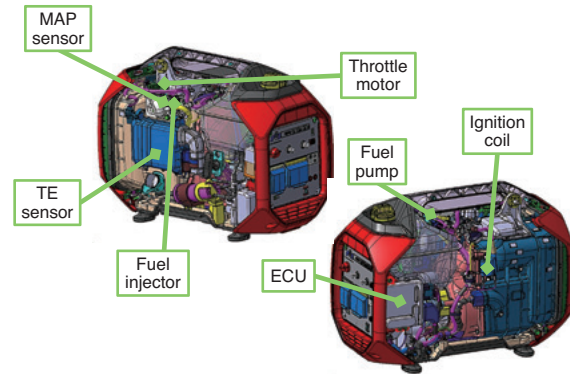


Fig. 10 Power consuming parts at startup

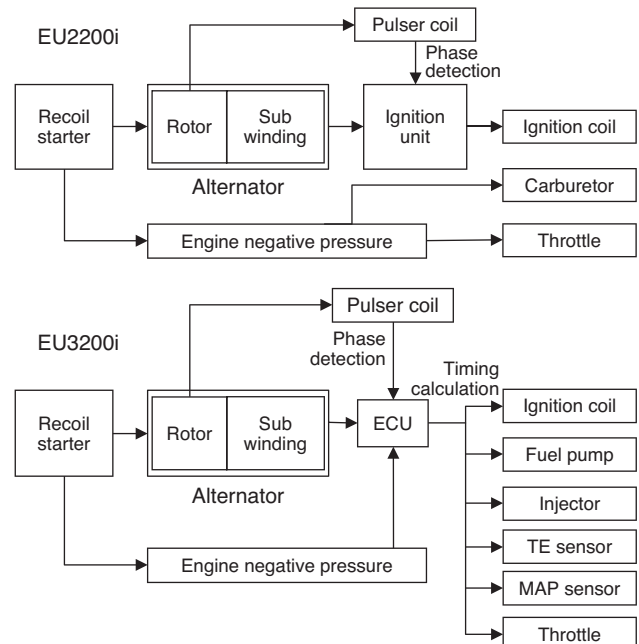


Fig. 11 Comparison of system with EU2200i

Table 4 Comparison of recoil specifications

Model name	EU2200i	EU3200i
Recoil reel diameter [mm]	100	65
Number of recoil rope turns	2.6	3.9

The following three technological measures were adopted to address the issues involved in generating electric power by a low-speed recoil starter without using a battery.

- Alternator specifications that meet the power requirement at low rpm.
- Control to supply a pilot injection of fuel immediately after the crankshaft turns to enable the engine to start at low rpm with fewer chances for ignition
- Recoil starter specifications (Table 4) with smaller reel diameter than in the EU2200i, and with the number of rope turns increased to obtain rotation speed when starting

Through these measures, a battery-less FI system was realized with enhanced usability that does not need choke operation at startup but that still provides the recoil starter operating feeling, number of starter operation times, and environmental temperature that allows equivalent starting with the existing EU2200i.

5. Packaging Technology

For the structure of the EU3200i housing, a single-handle suitcase-style shape was adopted to realize the convenient portability of a 2-kVA class inverter generator. In addition, a frame concept that would produce less noise than other products in the EU series was taken into consideration, revealing that the following four main measures would be required to address the issues.

- (1) Lower-noise housing by adoption of low-displacement, high-speed engine
- (2) Housing shape to realize greater compactness, lighter weight, and good portability
- (3) Structure that enables assembly while visually inspecting fuel pipe and electric parts
- (4) Support increased exhaust and exhaust air temperature resulting from stoichiometric operation

The housing structure of the EU3200i with these four measures implemented will be explained below.

5.1. Lower-noise Housing

The technological method used to downsize the EU3200i housing to the size of a 2-kVA class generator was adoption of a compact, lightweight, high-speed engine. With the installation of this engine in mind, a study was made of a housing structure that would be compact and lightweight, that would have cooling performance capable of handling continuous operation, and that would achieve a noise value of 91 dB(A) at the rated output of 2.6 kVA. The

frame structure of the EU3200i is shown in Fig. 12.

First of all, in order to decide on the packaging, a study was made of the layout of the main engine accessories in addition to a noise-reducing structure for the housing.

Sound-absorbing material was positioned in the resin shrouds that are nearest the high-speed engine and that direct cooling wind to raise engine cooling performance. This constituted a structure that fully covers the engine.

In further combination with the resin cover of the housing, this forms a full-cover resin structure in two layers that also has sound absorbing material to reduce mechanical noise from the engine.

5.2. Frameless Monocoque Structure and Housing Side Surface Shape

While the housing panels in a single-handle suitcase style provide for great compactness, lighter weight, and reduced noise, they also need to serve as a framework that protects interior parts in addition to providing a shape that realizes good portability.

When the suitcase style is used, the side surfaces of the housing are of a shape that may sometimes contact the user's leg during transport. The side surface was therefore given a rounded shape in order to reduce any unpleasant sensation. Figure 13 shows the shape of the housing side surfaces in cross-section.

If the side surfaces are too round, however, they will add dead space to the storage space for the engine, electric parts, and so on, potentially enlarging the housing.

In order to realize good portability together with reduction of dead space as much as possible, the curvature of the round side surfaces was studied. A continuous change was applied to the curvature of the middle part of the housing side panel as well as the upper part, where there is the greatest likelihood of contact when carrying the generator.

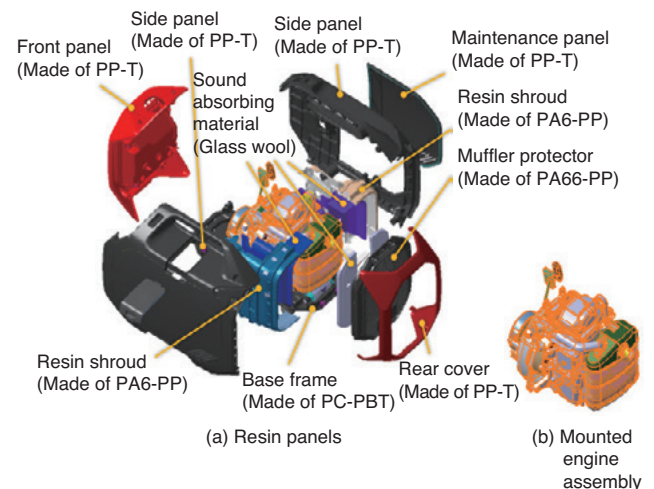


Fig. 12 Frame structure of EU3200i

Giving the side surface a curved shape and making it a shell structure heightens the strength and rigidity of the housing panels that comprise the monocoque frame. In this way, the housing was successfully shaped to realize greater compactness of the housing panels with good portability.

5.3. Fuel Tank Mounting Structure

Assembly of parts in conditions that do not allow visual inspection can cause fuel leaks, startup malfunction, or other serious quality imperfections. It is necessary that parts related to fuel leakage and generator startup and output, in particular, be housed in a structure that can be assembled while being visually inspected. Figure 14 shows a comparison with the structure of the previous model (the EU2200i) using a monocoque structure.

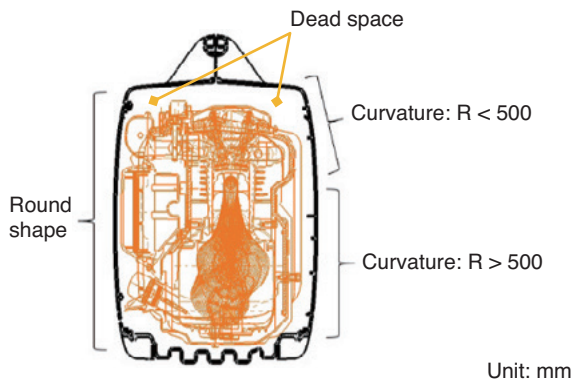


Fig. 13 EU3200i housing side shape (sectional view)

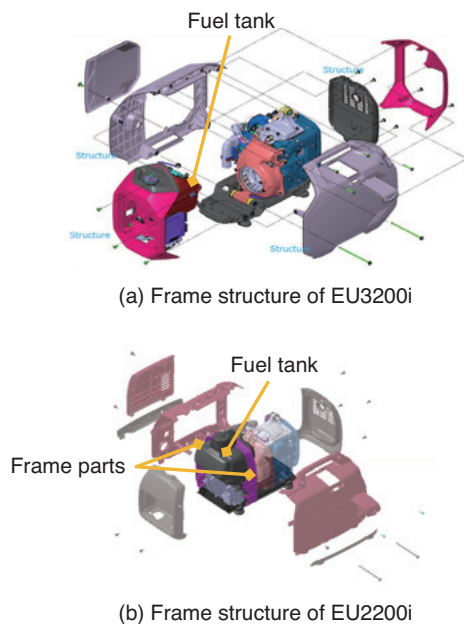


Fig. 14 Comparing frame structure of EU3200i and EU2200i

In the EU3200i, the fuel tank was designed to be assembled in a structure with a stand-alone front panel. As a result, the housing can be assembled with the side panels removed, allowing assembly while visually inspecting the fuel pipe and harness with electric parts.

In the EU3200i, the brackets for mounting the engine, the head cover, and the fan cover that also has an engine mount function are made of diecast aluminum. These all provide support for the engine main body, and are in turn supported by attachment through rubber mounts to the rear portion of the handle part on both side panels of the housing and to the base frame part.

In addition, the metal fuel tank and inverter unit are attached through rubber mounts to the front panel, and are assembled into a structure that can stand alone. Fastening this to the housing to form an integrated unit provides it and the engine mount structure with the strength and rigidity needed when the generator is being handled. An overview of the structure is shown in Fig. 15.

The following two items describe unique characteristics of this structure.

First, in addition to using the housing panels to comprise a monocoque structure, the panels were also given the function of holding the fuel tank in place, allowing the structure to stand free without an internal frame.

Second, this structure provides the internal constituent parts of those housing panels, the engine, and so on, with the strength and rigidity needed when the generator is being handled while also holding the mass of those parts directly in place by means of the housing handle.

The adoption of this structure reduced the number of

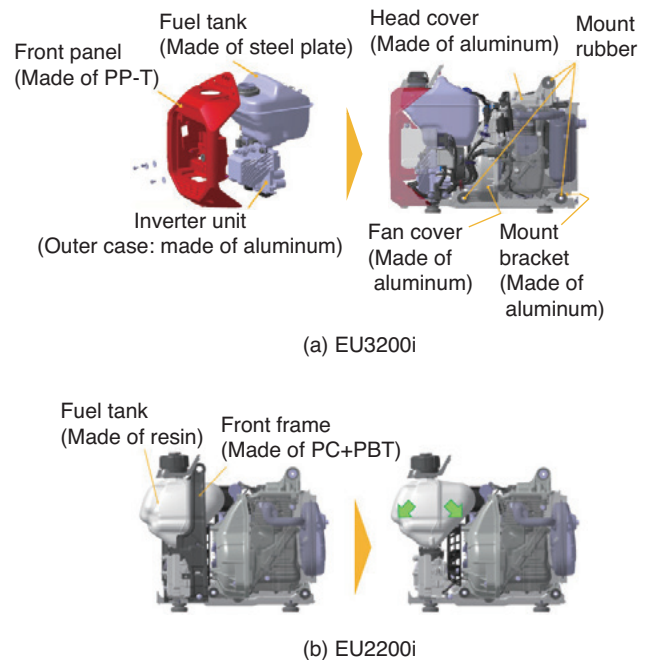


Fig. 15 Fuel tank supporting structure

parts and enhanced the packageability, contributing to a more compact size and lighter weight.

5.4. Support Increased Exhaust and Exhaust Air Temperature That Result from a Shift to Stoichiometric Operation

In conjunction with the rise in exhaust temperature during operation that results from the shift to stoichiometric operation, the positions of the muffler protection exhaust air outlets in the rear part of the generator were concentrated in the upper middle of the generator with the aim of enhancing the cooling performance of the muffler. The flow of cooling air around the muffler is shown in Fig. 16.

Arranging this structure so that cooling air flows over the surface of the muffler enhanced its cooling performance.

This structure also provides a labyrinthine structure that suppresses the emission of mechanical noise from the engine. Sound absorbing material realizes a mechanical noise reduction of -1 dB(A), contributing to achievement of the target noise value for the completed machine.

On the other hand, the amount of heat that the cooling air carries away from the muffler has increased, also raising the exhaust air temperature. The shape of the exhaust air louvers therefore takes into account the effects of the exhaust air on the environment where the generator is used.

In studying that shape, the environments in which the generator is used during operation were surveyed and needed target values were established. As a result of the survey, many of the environments in which the generators are used were found to be lawns. Figure 17 shows a location that is typical in terms of usability.

The target temperature for the exhaust air that is produced by operation of the generator was set at a value such that the grass would not be withered by contact with the exhaust air.

The shape for the exhaust air louvers was studied in light of their influence not only on the cooling performance of the generator but also on its noise characteristics. The angle of the louvers in the rear part of the housing was therefore set by determining the temperature requirements for each part of the generator while also confirming their influence on noise values. Figure 18 shows the area where the exhaust air louvers are located. Figure 19 shows the exhaust air contact surface temperature and the noise value at rated output that were achieved by the adoption of this structure. Setting the housing shape to take into account



Fig. 17 Example of typical placement location of single-handle portable generator

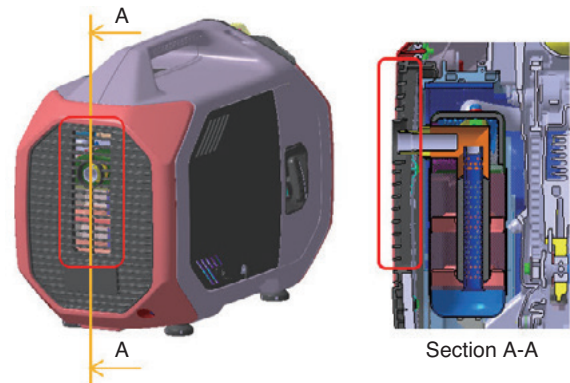


Fig. 18 Exhaust louver of EU2000i

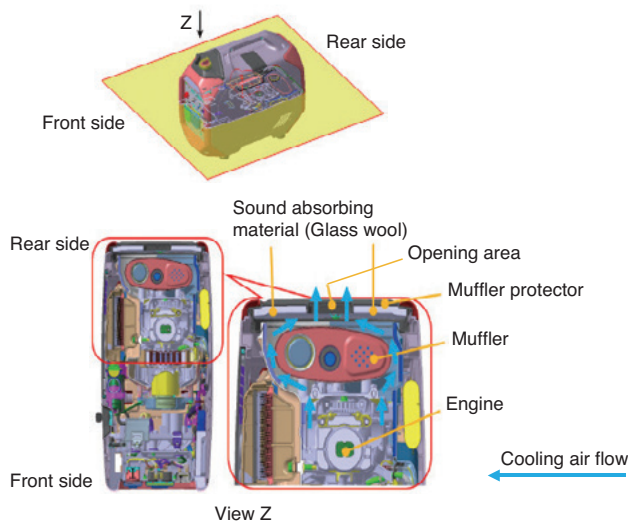


Fig. 16 Cooling air flow in muffler labyrinth structure

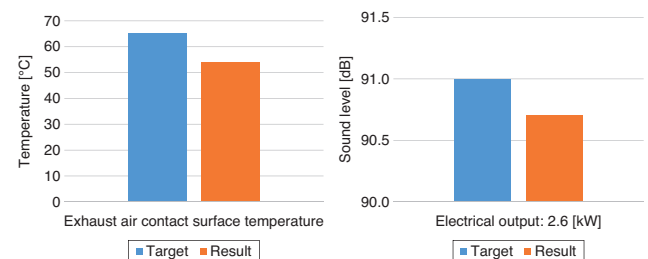


Fig. 19 Exhaust air contact surface temperature and sound level at rated output

the above factors of actual usability and influence on the environment where used achieved housing packaging that is unprecedented in its increased compactness, lighter weight, and lower noise as well as in its good portability, and that is also in conformity with its environment of use.

6. Conclusion

The EU3200i was developed on the concept of a lightweight, compact 3-kVA class generator that is easy to use in leisure scenarios. The power-weight ratio was enhanced 15% over the preceding EU2200i with its suitcase style. With a volume of 79 L and mass of 26.8 kg, it has achieved the top level of the 3-kVA class as a compact, lightweight generator. The following three main technologies applied to this model achieved a balance between higher power output and enhanced usability.

- (1) The dedicated GX130 engine with low displacement, high speed, and high compression ratio and the alternator that adopts a neodymium bonded magnet provide compactness and high power output.
- (2) While removing the need for a battery, which increases mass, the generator has stoichiometric feedback operation to hold down fuel consumption and at the same time realize simple startup as the first power product to adopt a battery-less FI system.
- (3) Use of a resin monocoque structure removes reinforcing frame members, achieving noise levels on a par with previous products while limiting increases in mass.

Through adoption of the above main technologies together with the immediately recognizable new “premium intelligence design,” the EU3200i is expected to become a product that customers will thoroughly enjoy not only in North America but worldwide as well.

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