

Development of the Compact FG201 Tiller

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ABSTRACT

The FG201 tiller was developed to realize the highest level of work performance among compact tillers while also achieving low weight. This tiller utilizes a specially-designed 4-stroke OHV engine equipped with a mechanical governor that maintains optimum rotor speed. This keeps the engine speed from falling off even when tilling hard soil, thus producing excellent tilling performance. The tiller is designed to keep the center of gravity low and near the tiller blade axis. The blades are newly designed to match the lightweight body. Special attention was given to the shape of the drag bar, and tine shaft rotation was set at an optimum speed. These measures achieved a low weight of 17 kg, making this the lightest tiller in the 4-stroke engine class, and also made it possible to achieve top class work efficiency for compact tillers. In terms of operability, the recoil starter force has been reduced 40% over conventional tillers by utilizing optimum decompressor valve lift and valve timing settings. A centrifugal clutch was adopted so that the throttle lever alone could be used to start and stop operation. This produces simplicity of operation, making the tiller easy to use for beginners and elderly people. This model was also made to easily carry around and stow in a passenger vehicle, with a folding handle for compact storage and a single handed carrying handle. In terms of environmental conformity, this model meets the EPA Phase II and CARB Tier II regulation levels, as well as European EN noise regulations for 2006 Stage 2.

1. Introduction

In recent years, there has been a global increase in the number of people planting domestic gardens. Accordingly, there has been a growing demand for suitable and diverse tiller features. Furthermore, there has been a notable change in the type of user with an increasing number of beginners and elderly. Also, there has been a significant change in the domestic garden environment brought on by an increase in the number of residences. The current trend in the domestic

garden market is for small 2-horsepower or under tillers configured with 2-stroke engines. Nowadays, in response to an increased sense of environmental preservation, a growing number of users are looking for an environmentally ‘friendlier’ tiller that embodies a high level of work performance and operability. The current domestic tiller market has an estimated 100,000 tillers, of which, Honda holds a 20% market share. These tillers typically weigh less than 40 kg and yield a tilling width of less than 600 mm. This report introduces the FG201, which has been designed to create a new market from this increasing global garden trend.

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2. Aim of Development

It is generally held that increasing the overall weight of the tiller unit will improve the depth of cultivation and overall working performance. In designing the FG201, the developers abandoned all preconceptions and returned to the basics in consideration of what is required in a tiller for the typical person who enjoys domestic gardening. From there, it was determined that the development design should embody a 4-stroke engine configuration of the lightest class possible and be easy to handle. Additionally, it should be easy to transport while providing adequate tilling functionality. Figure 1 shows the external view of the FG201 and its unique design features.

3. Basic Structure and Main Specifications

Table 1 lists the main specifications for the FG201, classified as a tiller within the category of walk-along plows. The FG201 is different from conventional power driven tiller units that incorporate both a drive unit and tiller rotor to perform tilling work. The FG201 utilizes only a tiller rotor to provide both forward movement and tilling work⁽¹⁾. The unit adopts a drag bar and handle bar, which are attached behind the rotor to control the propulsion speed and regulate the tilling depth.

Additionally, the FG201 has been configured with the engine mass mounted directly above the rotor. This effectively reduces the soil reaction force that naturally occurs during tilling.

The power generated from the vertical crankshaft type engine is directed 90° to propel the machine in the forward direction. This vertical crankshaft engine drives the tine shaft via a transmission fitted with a centrifugal clutch and worm reduction gear assembly.

The operator is able to control the tilling depth and propulsion speed by adjusting the height of the handle as required.

Table 1 Major specifications

Items	Specifications
Engine model name	GXV50
Engine type	Air cooled 4-stroke OHV single cylinder
Engine displacement (cm ³)	49
Maximum power (kW)	1.4
Rated power (kW/rpm)	1.1/4 600
Maximum torque (Nm/rpm)	2.56/4 600
Compression ratio	8.0
Minimum specific fuel consumption (g/kWh)	367
Fuel tank capacity (cm ³)	400
Overall length (mm)	1 050
Overall width (mm)	475
Overall height (mm)	995
Dry weight (kg)	16.5
Tine speed (rpm)	135
Tilling width (mm)	450
Tine diameter (mm)	φ 260
Starting system	Recoil starter
Main clutch type	Centrifugal clutch
Transmission speeds	1 Forward

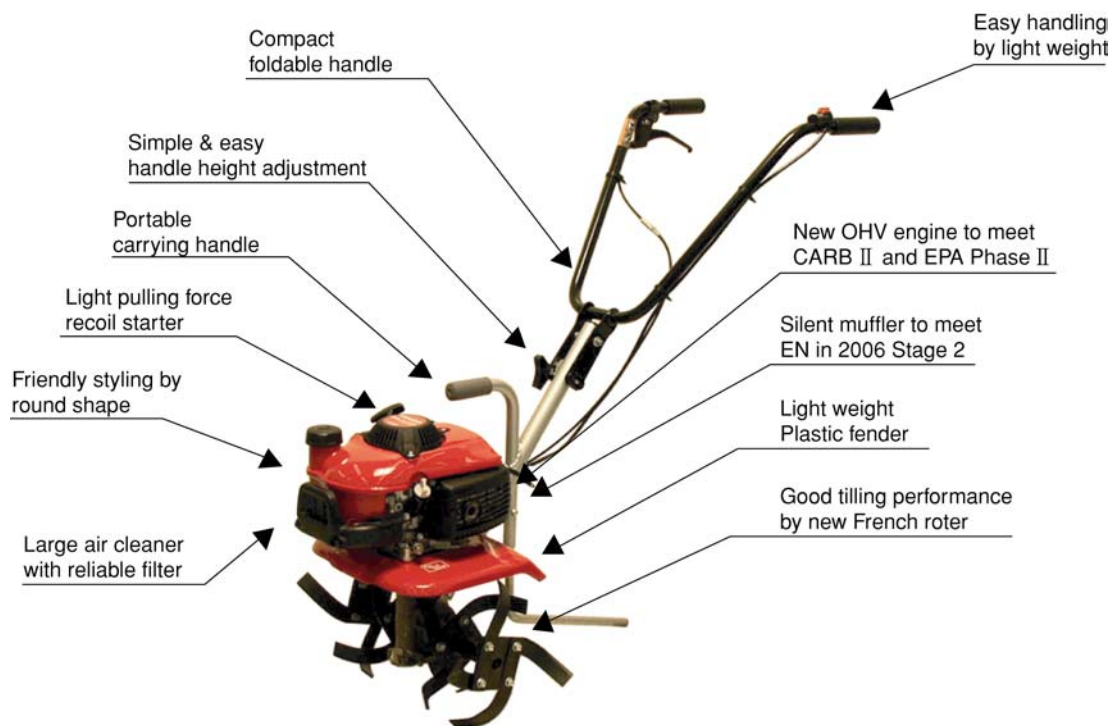


Fig. 1 External view and features

3.1 Engine

To facilitate ease of handling and transportability, a domestic tiller must be lightweight.

The FG201 has been configured with a 50 cc displacement overhead valve (OHV) engine to achieve such weight reduction. Also, by adopting a fan cover and fuel tank assembly made of lightweight plastic, 12 parts that were implemented in previous models have been eliminated in the FG201 thereby achieving an overall weight reduction. Figure 2 shows the layout of the FG201 engine.

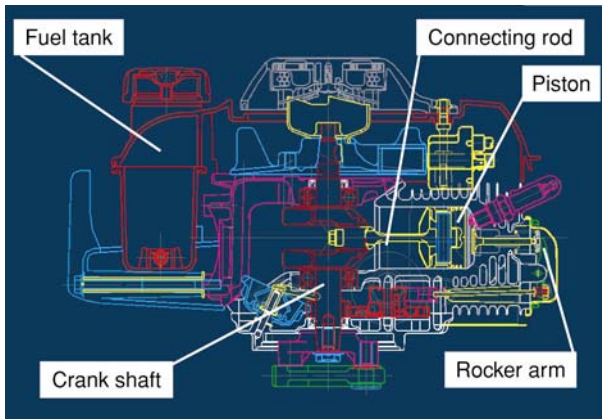


Fig. 2 Layout of engine

The FG201 engine has been configured with an OHV engine with a more compact combustion chamber, achieving a high compression ratio. This improves thermal efficiency and is compatible with EPA Phase II and California Air Resource Board (CARB) Tier II regulation levels for engine exhaust systems. The implementation of uniblock cylinders⁽²⁾ with reduced cylinder strain reduces oil consumption and contributes significantly to the reduction of carbon build up in the combustion chamber.

Ease of operation and maintenance are another important aspect of domestic garden tillers. The FG 201 recoil force has been reduced to provide for easy starting, which was achieved through optimal decompressor valve lift and valve timing settings. Longer maintenance-free intervals were achieved as well, with use of an oversized air cleaner.

This design also meets Stage 2 level EN noise regulations set for 2006 thereby allowing the FG201 to be used for tilling within typical neighborhood settings.

3.2 Transmission

The basic design of the power train follows that used in the previously released FG200 and operates via a clutch which is attached to the power train output (PTO) crankshaft mounted on the vertical engine. The transmission drives the rotor via the tine shaft, which is controlled by a couple of worm gears, in a forward direction. See Fig. 3 for an illustration of the FG201 transmission power train construction.

The adoption of a centrifugal clutch in conjunction with the vertical engine design has contributed to the simplicity of operation and overall compactness of the tiller unit.

The tine rotor has been enlarged to improve tiller performance. The rotor diameter has been enlarged from ϕ 220 mm to ϕ 260 mm and the tilling width from 300 mm to 450 mm. Also, the screw gear used on the previous FG200

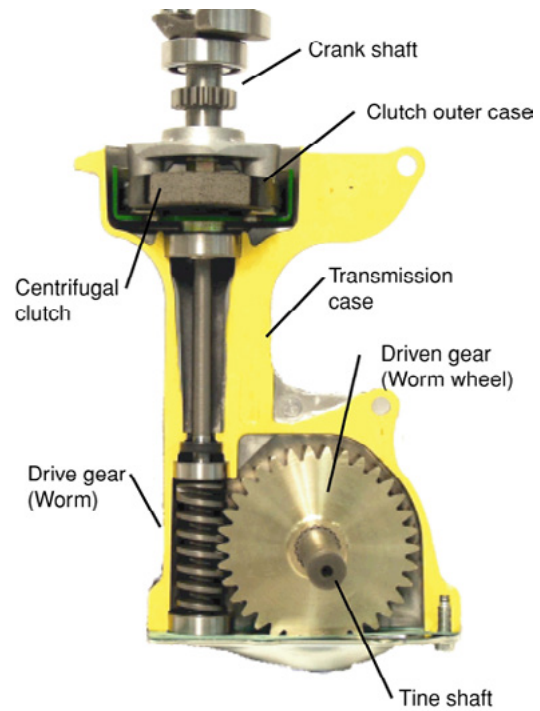


Fig. 3 Transmission of FG201

has been replaced with a new worm gear. This has contributed to the greatly reduced rotation speed (1/34), low noise level, and compact design.

A barricade has been built around the transmission case to prevent stones, which tend to be kicked up by the rotor activity, from getting lodged in between the plastic fender bolts and rotor while the tiller is being used. See Fig. 4 for an illustration of the transmission case barricade. The barricade is designed to stop flying stones and protect surrounding components. The barricade also allows the transmission to be placed at a lower position, contributing to an overall compact design.

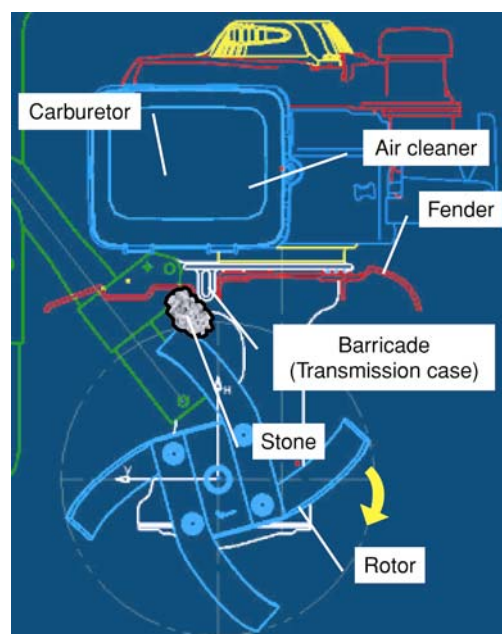


Fig. 4 Barricade of transmission case

3.3 Handle Operation

The handle unit has been fitted with a newly designed 3-level setting. The adjustable drag bar enables the user to adjust the handle bar height from 757 mm to 1,050 mm as required. Each height setting has been designed to provide the most natural posture for the respective work task. The Y-shaped handle was designed to provide firmness and is 450 mm wide, approximate shoulder width, to provide stability during operation.

The handle is constructed to fold easily without the need of any additional tools. It provides added flexibility for transporting and stowing the tiller in small passenger vehicles. A carrying handle is positioned at the center of the unit to enable easy transport with one hand. The FG201 small tiller has been designed to provide the user with maximum benefits.

3.4 Attachments

The FG201 can also handle additional garden maintenance such as ground ridging, cultivation and weeding. Ridging is the process of turning the earth to facilitate lighting, respiration of roots, and to increase water drainage. Cultivation is when air and fertilizer are mixed into the earth as it is being lightly turned. Depending on which attachments are used and the positioning of the operating posture, users can set the ideal leg position spacing according to the tasks at hand thus providing the small tiller with comfortable working space. There are 16 different attachment settings possible and users can select the attachment as required. For example, the side disks can be attached to minimize vibration to further ease tilling work for the elderly and female users. Figure 5a shows the spiral rotor, 5b shows the steel blade and ridger, and 5c shows the side disk attachments.

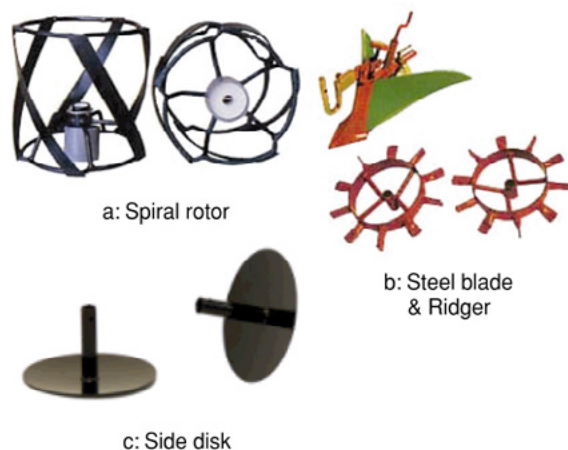


Fig. 5 Attachments

4. Characteristics

4.1 Combining Weight Reduction and Superior Tilling Performance

By using lightweight plastic parts and adopting a lightweight OHV engine, the FG201 has successfully

achieved an extremely lightweight configuration of 17 kg, making it very competitive in the dominant over 20 kg tiller class. Generally, as a tiller's performance is improved, the soil reaction force increases, further pushing the tiller in a forward diagonal direction. To counter the increased force, weight needs to be applied. Conversely, as the weight of the tiller unit is reduced, the vertical load exerted on the ground surface becomes insufficient against the soil reaction force resulting in inadequate tiller performance. By applying the following design points, the FG201 has successfully achieved a desirable degree of weight reduction while attaining excellent tiller performance.

1) Optimization of weight distribution

The number of parts surrounding the handle unit has been reduced, and the center of gravity is positioned in close approximation above the rotor shaft. The shift in weight distribution has produced a rotor to drag bar weight balance ratio of 9:1 while achieving a desirable weight loading of 14.7 kg exerted on the tilling blade and still maintaining a vertical load equal to that of existing 2 horse-power class tillers. The optimization of weight distribution and vertical load on the rotor provides sufficient tilling depth and a stable working process.

2) Reconsideration of the drag bar shape

The drag bar is fitted to tilling machines to adjust handle height and fine-tune propulsion force on the tilled soil. The heavier the unit's weight, the larger the torque exerted on the tine shaft. This can often cause the drag bar on 2 horsepower or higher classed tiller machines to jab the soil. Since the area where the drag bar collides directly with the soil is small, the drag bar can be disrupted by the fluctuating soil consistency making smooth tilling work difficult.

As shown in Fig. 6, the drag bar for the FG201 has only one bend point with an obtuse angle. In previous drag bar designs that incorporated 2 bend points, the soil resistance was concentrated on one point. In contrast, the FG201 drag bar has a larger contact area that reduces surface pressure and provides less resistance fluctuation due to changes in soil consistency.

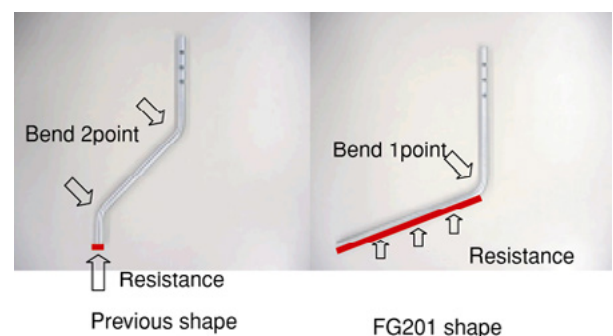


Fig. 6 Drag bar

3) Adoption of a new shaped French rotor

The plate shaped rotor type blade used in the previous FG200 tiller unit has been replaced with the French blade design in which each blade functions independently. The French rotor is lighter and provides better soil biting functionality and improved propulsion.

The bite of the French rotor is improved by increasing the trailing angle of the tilling blade, which helps to reduce the amount of pressure exerted when the tilling blade cuts the soil. Also, the increased bending angle of the blades has reduced the amount of soil that tends to accumulate beneath the transmission case. This has solved the issue of poorer propulsion caused by soil accumulation under the transmission case. The French blade has contributed to the overall lightweight feature of the tiller unit while providing effective penetration of even the hardest ground conditions. Figure 7 shows the French rotor used on the FG201.

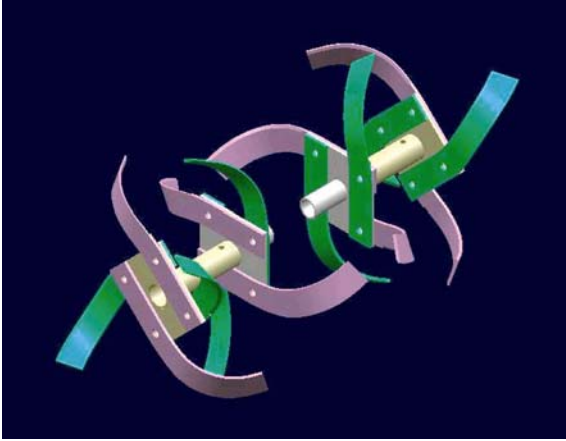


Fig. 7 French rotor of FG201

4) Optimized axial rotation

The rotor diameter and tilling width has been enlarged to 260 mm and 450 mm, respectively, for improved work performance. In comparison with the previous FG200 model, the rotor diameter of the new FG201 has been increased by 30 mm and the tilling width by 150 mm thereby causing a tine shaft torque increase of 1.5 times, from 19.6 N•m to 29.4 N•m. The load factor has been kept at the same level as the previous FG200 model by increasing the rotation speed to 135 rpm and increasing tine shaft torque capacity 1.5 times.

The blade rotation has been increased to 135 rpm to provide stable performance and good work results as well as prevent scattering of soil due to variations in its consistency.

The above listed characteristics have made the FG201 the lightest model in the small tiller class while providing the highest level of work performance. Figure 8 provides a comparative weight analysis and Fig. 9 provides a comparative analysis of work performance for the new FG201 and other current tiller models.

4.2 Reduced Operation Force and Improved Operability

To minimize the recoil starter operation load required to start the engine, the decompressor, which was previously set to the inlet on the FG200 model, has been reconfigured to the exhaust. Also, the angle of decompressor has been adjusted from 240° to 275°. This has reduced the compression exerted when initiating the recoil starter by 40%, from 0.5 Mpa to 0.28 Mpa, achieving a low-effort sure start. Figure 10 shows a comparative analysis of the recoil starter operation load.

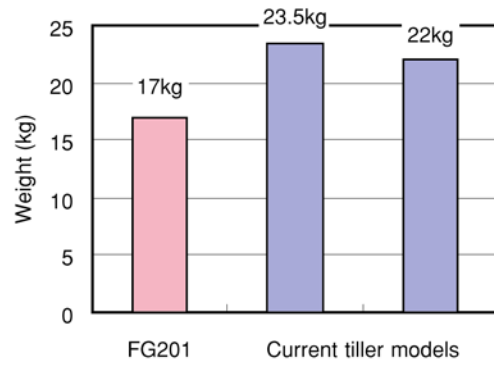


Fig. 8 Comparison of weight

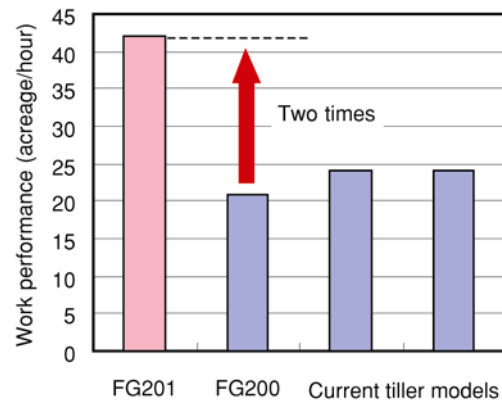


Fig. 9 Comparison of work performance

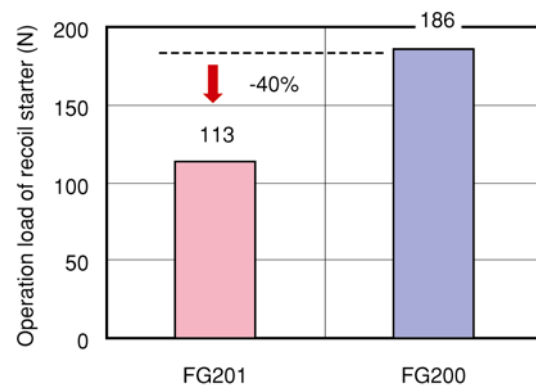


Fig. 10 Operation load of recoil starter

The tiller control is a single lever that incorporates throttle and rotor control, its function is made possible with the use of a centrifugal clutch. This combined control system is responsible for both engine speed and rotor engagement. The operator simply grips the lever to start the rotor and releases the lever to stop it, making this tiller easy and safe to use.

The lever operation load is 14.7 N and the holding load has been set at a low level of 11.8 N. Accordingly, the lever shape is designed so the operator experiences no discomfort after prolonged use, ultimately resulting in minimal operator effort.

4.3 Improved Handling and Transportability

As shown in Fig. 11, the center of gravity on the FG201 has been positioned closer to the tine shaft in comparison with that on the FG200 model. This reduces the operation load for raising and lowering the handle while tilling by 20%. The adjustment in the center of gravity position was made in line with the overall weight reduction of the unit to improve the handle maneuverability when turning the tiller.

This model has been equipped with a convenient folding handle for compact storage and a carrying handle for easy transport as standard features. The handle can be easily folded without the need of any additional tools. The handle can be folded forward or backward as required to enable storage into the most compact locations. The carry handle has been positioned at the unit's center of gravity to provide excellent balance when lifted and makes it easy to carry or change the tiller's direction when used in the garden. Figure 12 provides a comparative analysis of the handle lift operation load. Figure 13 shows the FG201 being transported by the carrying handle and Fig. 14 shows the storing capacity of the FG201.

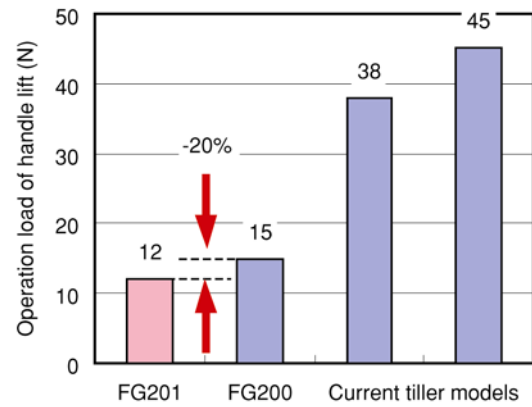


Fig. 12 Operation load of handle lift



Fig. 11 Center of gravity



Fig. 13 Carrying handle

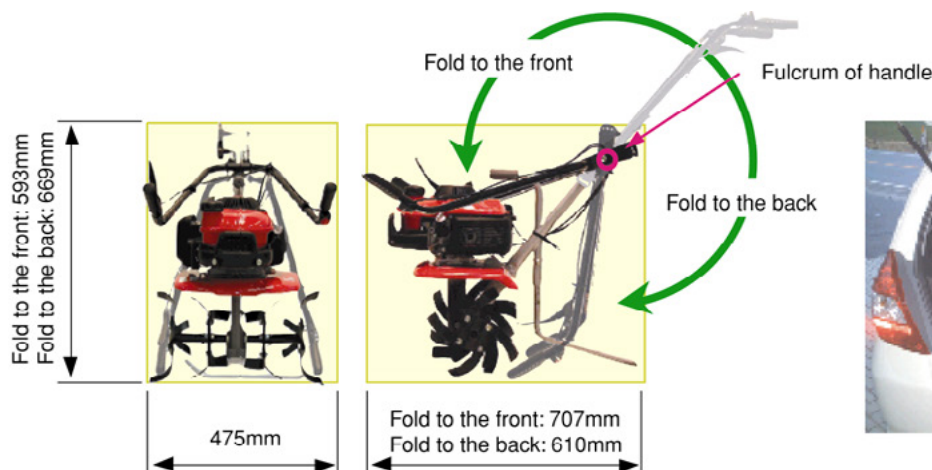


Fig. 14 Storing capacity of FG201

4.4 Improved Maintenance Features

As dust is easily produced during tiller operation, a key criterion in the design of the FG201 was to allow for longer intervals between air cleaner maintenance. The FG201 air cleaner element is a large dry type element that is sufficient for use on a standard engine with 160 cc displacement. The additional surface area enables the FG201 to function well despite large deposits of dust being on the air cleaner. The mouth of the airflow channel has been connected to the inside of the air cleaner case to help prevent dust from being easily pulled into it. This also improves the air cleaner purification performance under normal user conditions by 100 hours, or 5 times that of the 20 hours normally associated with the previous FG200 model. Figure 15 shows the layout of the FG201 air cleaner assembly, and Fig. 16 shows the external view of the air cleaner.

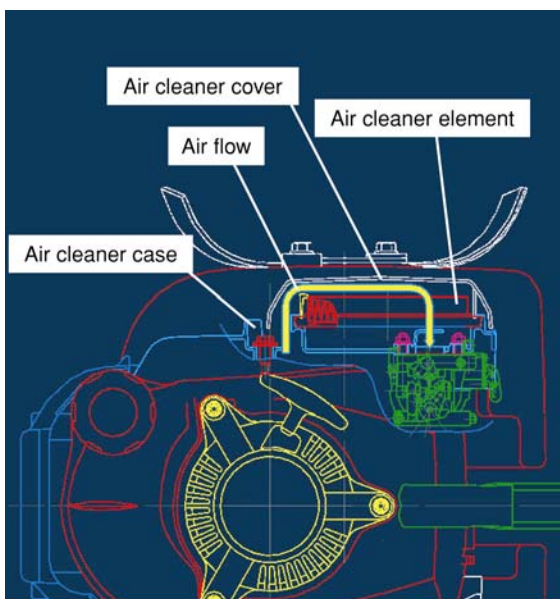


Fig. 15 Layout of air cleaner



Fig. 16 External view of air cleaner

5. Conclusion

The FG201 has been developed as an easy and fun to use compact tiller offering domestic users practical features to provide enjoyment in the cultivation of domestic gardens.

In meeting user demands for a lightweight, easier-to-use tiller offering advanced features and tilling performance, this tiller has been configured with an engine having the same displacement normally found in higher ranked cultivator machines while still maintaining a lightweight design. The transmission has been modified, and optimal tiller blades fitted to satisfy all functional and design requirements.

The FG201 offers the domestic user an easier-to-use set of features achieved through a less complex design, improved workability and improved maintenance features.

Members of the development team hope that this product will bring enjoyment and satisfaction to many domestic users.

The authors would like to express their gratitude to the many people within the organization that have made the development of this product a success.

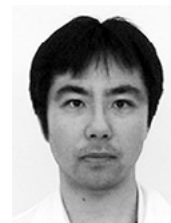
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