

Development of a Small Tiller: The New Komame F220

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ABSTRACT

The small tiller “Komame” has been used for various agricultural tasks ranging from cultivation of small vegetable gardens to more serious vegetable growing processes for the last 20 years. This tiller has gone through a full model change this year to become the “New Komame F220.” The New Komame’s engine now has a rounded full cover that helps even novice users feel at ease. Reduced emissions from its OHV engine and 5.5dB (A) less noise (obtained by utilizing a resin cam and larger muffler capacity) enable the “New Komame F220” to meet the requirements of both the CARB and EPA emission regulations as well as the EU Noise Directive. The machine weighs 9% less due to the smaller engine and resin parts. Changes to the tilling blades by simulation analysis have provided simple handling together with ample performance. The force required for the recoil starter has been cut by 30% through decreasing engine displacement. The force required to operate the clutch lever has also been reduced by 20% through the use of a different shoe clutch lining material. The new easier to use F220 delivers useful functions and high performance.

1. Introduction

In 1980, Honda introduced the small tiller “Komame F200” to the market. The small and light weight “Komame F200” was easy to operate and could be used for a wide range of jobs in vegetable gardening, from simple tilling to total soil management including forming ridges, cultivation, working humus into the soil and weeding. All these capabilities enabled the F200 to create a new market for small, easy to use tillers as a replacement for hoes on farms and in small vegetable gardens. The Komame F200 soon proved popular in Japan, Europe, and North America. Including the “Komame F210”, which was introduced in 1982 as the result of some minor changes made to the original model, the Komame tillers have become one of Honda’s best selling general-purpose products, with a total of more than 550,000 units shipped from the factory.

As public concern for the protection of the global

environment has increased in recent years, Honda, which prides itself on its efforts to make its products even more environmentally friendly, undertook a comprehensive study of how to enhance the environmental friendliness of the “Komame” in regards to exhaust and noise. Furthermore, in the Japanese market, Honda found that the customer base for tillers contained fewer experienced farmers and more novices and elderly users every year, which meant that the market needed small tillers that were easier to use. To address these market trends, Honda developed the “New Komame F220” (“F220” hereafter), as described in this article.

2. Development Aims

The basic concept behind the development of the F220 was to produce a tiller that was easy to use and environmentally friendly. The development aims were:

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- (1) To meet lower fuel consumption and CARB and EPA emission requirements
 - CARB: California Air Resource Board
 - EPA: Environmental Protection Agency
- (2) To reduce noise in order to meet the EU Noise Directive
- (3) To produce a light machine that provides the desired tilling performance
- (4) To make the operability of the machine easier and to reduce the operating load

3. Styling

With “user friendliness” as a key theme, the designers sought styling that would not be intimidating to first-time users of a tiller. Fig. 1 shows an external view of the F220, and Fig. 2 illustrates the design concepts.

The main styling points are:

- (1) An overall rounded form that conveys a sense of compactness and lightness
- (2) A full cover that conceals the mechanical components
- (3) A symmetrical design that makes it easy to till in a straight line



Fig. 1 External view of F220

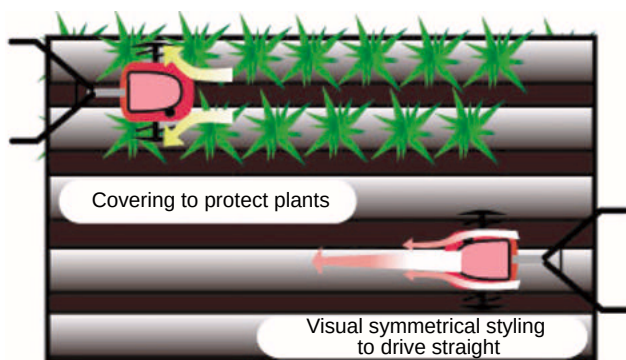


Fig. 2 Design concept

4. Basic Configuration and Main Specifications

Among walk-along plows, the F220 is classified as a tiller or soil management machine. Unlike motorized power tillers that have a drive section as well as a separate rotary tiller section that tills the soil, on the F220 the rotor is attached to the wheel shaft instead of the wheels so that the tiller moves forward as it tills⁽¹⁾. The drag bar and the handle, which control the forward speed and tilling depth of the tiller, are mounted behind the rotor. The heavy engine is positioned directly above the rotor, allowing the tiller to effectively absorb the soil reaction force that is produced while tilling.

The engine is a vertical shaft type, in which the PTO (power train output shaft) is oriented downwards, and is directly linked to the transmission with a built-in shoe clutch system and planetary gear drive system. At the very bottom, beveled gears turn the rotating shaft 90° so that the tine shaft propels the tiller forward.

While tilling, the operator can adjust the tilling depth and the forward speed by moving the handle grips up or down. The braking force (F_b) is controlled by moving the handle in the direction indicated by (A), which increases or decreases the vertical load on the drag bar. The braking force can thus be balanced with the soil reaction force (F_a) of the rotor, which rotates in the forward direction. Fig. 3 shows the overall layout of the F220, and Table 1 shows a comparison of the main specifications of the F220 with those of the F210.

4.1 Engine

When making enhancements to a tiller, typical goals are to increase engine displacement in order to obtain better performance, and to increase output performance. In the case of the F220, however, in order to further enhance the small size and light weight that were features of the F210, the decision was made to reduce engine displacement while still maintaining the output performance. The reason behind this decision was that, given the market background described earlier, the designers were confident that ease of use was more important than enhanced performance in a tiller for family vegetable gardens.

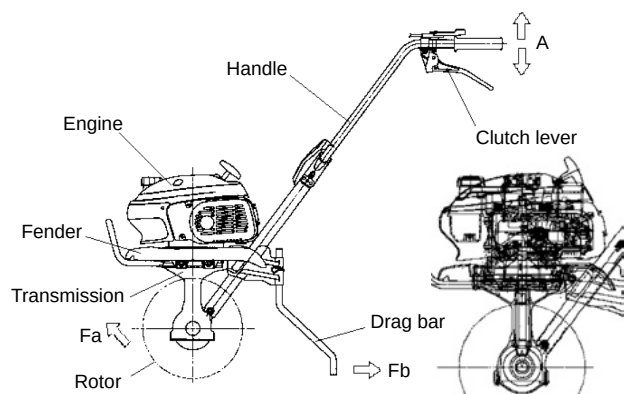


Fig. 3 Layout of F220

Table 1 Major specifications

Items	Specifications	
Model name	F210	F220
Engine model name	GV100	GXV57
Engine type	Air cooled 4-stroke SV single cylinder	Air cooled 4-stroke OHV single cylinder
Engine displacement (cm ³)	90	57
Maximum power (kW)	1.8	1.8
Rated power (kW/rpm)	1.0/4 000	1.0/4 000
Maximum torque (Nm/rpm)	3.0/3 000	3.0/4 000
Compression ratio	5.8 : 1	8.0 : 1
Minimum specific fuel consumption (g/kwh)	476	354
Fuel tank capacity (cm ³)	900	700
Overall length (mm)	1 070	1 115
Overall width (mm)	585	585
Overall height (mm)	960	975
Dry weight (kg)	27.5	25.0
Tine speed (rpm)	117	130
Tilling width (mm)	520	545
Tine diameter (mm)	φ 280	
Starting system	Recoil starter	
Main clutch type	Shoe clutch	
Transmission speeds	1 Forward	

While a side valve (SV) engine had been used in the F210, an overhead valve (OHV) engine was adopted in the F220. Thermal efficiency was enhanced by seeking to achieve a high compression ratio by making the compression chamber more compact. These changes made it possible to maintain output performance that was equivalent to the F210 while reducing engine displacement by 33%, and also resulted in a 26% improvement in minimum specific fuel consumption.

While the engine displacement was reduced, the air cleaner and the muffler positioned on the left and right sides of the engine were made larger than in the F210. These changes reduced engine noise and greatly extended the maintenance interval for the air cleaner.

The reduction of engine displacement also made it possible to reduce the height by 15 mm and to reduce the weight by 1.9 kg, even with a full cover added to the engine. Fig. 4 shows the layout of the engine, which was a significant factor in making the F220 easier to use.

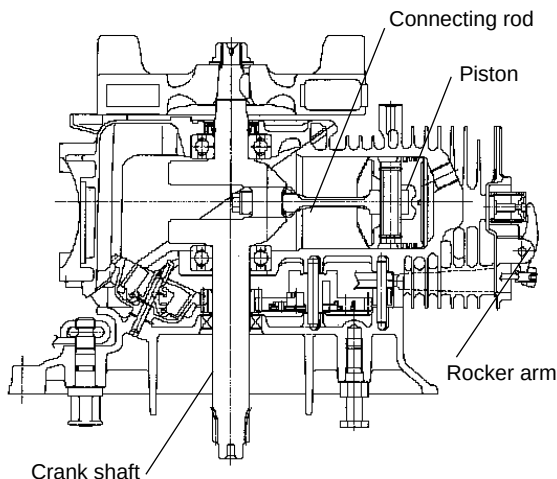


Fig. 4 Layout of GXV57 engine

4.2 Transmission

The basic configuration of the power train has been retained since the F200. The transmission combines a planetary gear drive system, in which the tip of the PTO (power train output shaft) of the vertical shaft acts as the sun gear, with a shoe clutch system. The planetary gear drive system, which produces a large deceleration ratio (1/10) on this shaft, is a unique feature of the “Komame” and is a major factor in making the transmission small.

The clutch is constructed so that it is engaged and disengaged by the operation of an internal expanding brake on the clutch outer, which also serves as the planetary ring gear. Squeezing the clutch lever, which is mounted on the handle, moves the internal expanding brake. The clutch shoe stops the rotation of the planetary ring gear, and the three rotating planetary gears begin orbiting around the sun gear. This in turn causes the drive shaft that is splined to the planetary gear carrier to rotate. The beveled gears at the

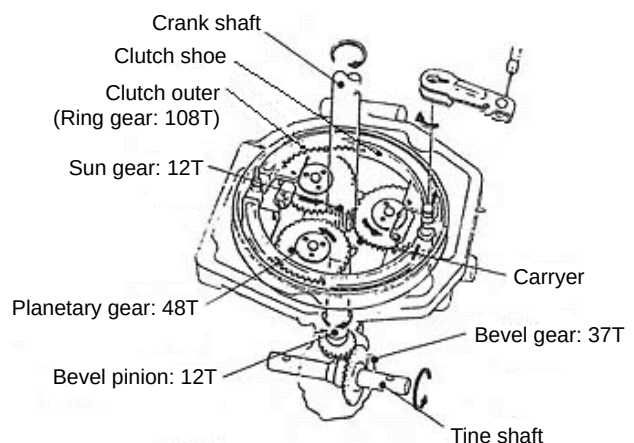


Fig. 5 F220 transmission layout

bottom of the transmission turn the axis of rotation 90°, and cause the tine shaft to turn in the forward direction. When the clutch lever is released, the planetary ring gear is again free to turn, causing the planetary gears to stop orbiting the sun gear and simply rotate. The planetary gear carrier, the drive shaft, and the tine shaft all stop rotating. Fig. 5 shows an illustration of the power train.

4.3 Handle Adjustment

The survey results of how tillers are used clearly showed the handle height that permits the easiest operation of the tiller also allows the operator to maintain an elbow angle ranging from 80° to 165° (120° being optimal) while gripping the handle. Users can set the height of the F220's handle at one of three positions ranging from 859 mm to 1003 mm and adjust the drag bar height to one of three positions. These adjustments allow users of various body sizes to work in a natural posture. Whether the tiller is being used for tilling, weeding, or working humus into the soil, the handle can be set so that the angle between the upper and lower arms can be kept between 118° and 139°. This holds true for users ranging from the 5th percentile among Japanese women (147 cm in height) to the 95th percentile among Japanese men (178 cm tall).

Furthermore, the overall length of the tiller can be reduced from 1115 mm to 690 mm and the overall height

of the tiller can be reduced from 975 mm to 690 mm by folding the handle forward. This feature makes it easier to transport the tiller by car and reduces the amount of space taken up by the tiller in storage.

In addition, in order to make the tiller easier to use next to walls in a greenhouse or similarly confined area, the handle is designed to swing 22° to the left or right. This feature allows the user to use the tiller right against a wall without the handle getting in the way. Fig. 6 illustrates the above described handle adjustments.

4.4 Attachments

By maintaining the same dimensions for the tine shaft and the drag bar holder in the F220 as in the F210, the various soil management attachments that are available for the F210 for tilling, ridging, cultivation, working humus into the soil, and weeding can also be used with the F220. Fig. 7 shows some typical attachments. From top to bottom, these attachments are used in forming ridges, working humus into the soil, tilling hard soil, and for weeding work in orchards.

5. Features

5.1 Reduced Emissions and Fuel Consumption

The change to an OHV configuration (described above in section 4.1) improved combustion and enabled the F220 to meet the requirements of EPA Phase II and the CARB Tier II emission regulations, which will be implemented in 2002. The OHV engine consumes less oil than an SV engine, and the adoption of a uniblock cylinder⁽²⁾ that suffers little cylinder distortion due to the effects of the joint axial force of the head bolt further reduces oil consumption. In addition, the amount of carbon that accumulates in the combustion chamber has been greatly reduced, which helps to minimize the increased emissions that occurs with the passage of time.

The decreased power required by the tines in comparison with the F210 (described later) has cut tilling fuel consumption roughly in half. The F210 had a range of 450 cm³/h minimum to 540 cm³/h maximum, whereas the F220 has a range of 225 cm³/h minimum to 330 cm³/h maximum. As a result, even though the fuel tank capacity was reduced from 900 cm³ to 700 cm³, the tilling time provided by a full tank has been extended from a range of 1.6 to 2.0 hours to a range of 2.1 to 3.1 hours. Furthermore, the amount of oil consumed while tilling has been reduced by 50%, from 5.5 cm³/h to 2.7 cm³/h.

5.2 Reduced Noise

As shown in Fig. 8, the noise experienced by an operator of the F220 compared with an operator of the F210 has been reduced by 4.5 dB(A) when the engine is running at maximum idling speed, and by 5.5 dB(A) while tilling.

The effects of the various noise reduction measures are described below.

(1) Adopting a large silent muffler

The muffler size was enlarged to 790 cm³, or 1.6 times the size of the muffler applied to the F210.

This has the effect of reducing the noise experienced by the operator by 2.0 to 2.5 dB(A).

(2) Increasing the thickness of the engine oil pan

Increasing the thickness of the oil pan from 2.0 mm in the F210 to 3.5 mm in the F220 reduced the propagation of transmission gear noise.

This has the effect of reducing the noise experienced by the operator by 0.5 to 1.0 dB(A).

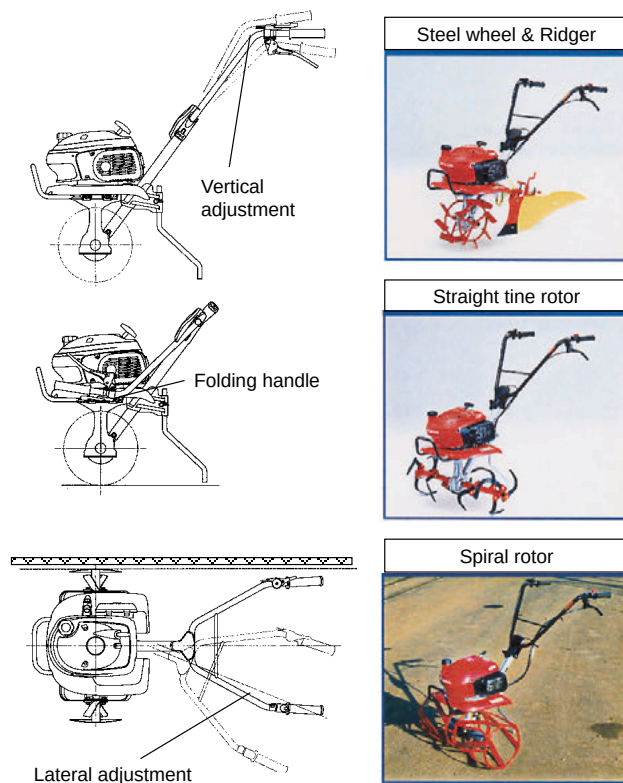


Fig. 6 Handle adjustment

Fig. 7 Attachments

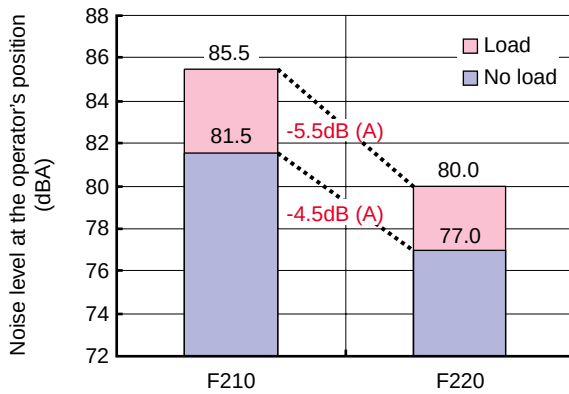


Fig. 8 Comparison of noise

(3) Adopting a noise-proof engine cover

The duplex construction of the fan cover and the recoil starter cover on top of the engine reduced the propagation of harsh engine noise and transmission gear noise.

This has the effect of reducing the noise experienced by the operator by 0.5 dB(A).

(4) Adopting a smaller engine displacement and plastic cams

The mechanical noise produced by the engine was decreased, by reducing the engine displacement by 37% compared to the F210, and by using plastic cams. This has the effect of reducing the noise experienced by the operator by 1.5 dB(A). These changes reduce psychological stress and fatigue in the user as a result of noise, and also make the tiller acceptable for use in a wider range of places and during a wider range of times during the day. Because they ensure a sound power level of 92 dB under EU Noise Directive regulations, these noise reduction measures also allow the F220 to satisfy the noise levels stipulated in the EU Noise Directive, namely 96 dB in 2002 and 93 dB by 2006.

5.3 Light Weight Without Sacrificing Tilling

Performance

In order to ease the handling of the F220, the weight of the unit was reduced by 9% compared to the F210, or about 2.5 kg. This was accomplished primarily by replacing steel parts with plastic, and by using a lighter engine. A breakdown of the weight reductions achieved in individual components versus the F210 follows.

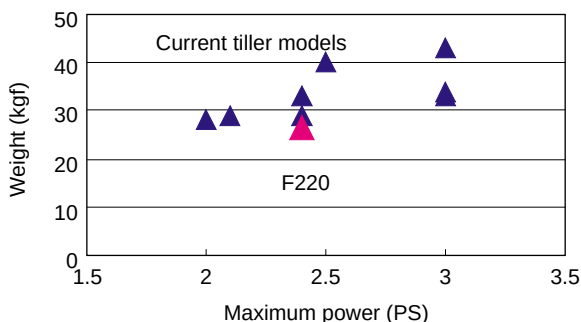


Fig. 9 Maximum power and weight

(1) Engine

A 1.9 kg weight reduction was achieved by reducing the engine displacement, reducing the number of components, and changing to plastic components.

(2) Fender

A 0.3 kg weight reduction was achieved by replacing steel with plastic.

(3) Rotor

A 0.3 kg weight reduction was achieved by changing the shape of the tilling blade in a way that reduced the amount of material used.

Typically, improving the working performance of a tiller in terms of tilling depth, for example, usually requires increasing the weight of the tiller. Fig. 9 shows that the more the engine output increases, the stronger the tendency for the tiller to be heavier. This is because increasing the working performance of the tiller causes an increase in the soil reaction force that pushes the tiller up and forwards, as described in Section 4. Accordingly, if the tiller is made lighter, the vertical load of the rotor may be inadequate compared to the size of the soil reaction force, preventing the tiller from tilling at an adequate depth.

A soil reaction force simulation⁽³⁾ was used to analyze the effect that the shape of the F220's tilling blade had on the soil reaction force in order to produce a shape that would guarantee adequate working performance even with a lighter tiller. The effect that the changes in the angles of each part of the tilling blade (shown in Fig. 10) have on the soil reaction force was analyzed for the direction of rotation (shown in Fig. 11) and the component forces (shown in Fig. 12). Figs. 13 and 14 show the results of the analysis.

The results of this analysis are summarized below.

- (1) By reducing the trailing angle (A), the average value of the soil reaction force FZ that pushes upwards on the tiller was reduced from 184.0 N to 116.1 N due to a multiplier effect with (4) described below.
- (2) By increasing the cutting angle (B), the angle (E) is made smaller, reducing the time that the tilling blade is actually working in the soil; as a result, the average value of the torque MX required for tilling was reduced from 19.9 Nm to 14.6 Nm.
- (3) By increasing the bending angle (C), the peak value of the soil reaction force FX that pushes sideways on the tiller was reduced from 49.1 N to 33.7 N for each individual blade.
- (4) By increasing the trailing angle (D), the compression of the soil when the tilling blade cuts the soil is reduced, resulting in improved bite, and as a result of a multiplier effect with (1) above, the average value of FZ was reduced from 184.0 N to 116.1 N.

By reducing FZ, the lighter tiller is still able to achieve sufficient bite into the soil, maintaining a level of work performance equivalent to the F210. In addition, the tilling force was reduced by reducing MX. Because FX, which causes the tiller to vibrate from side to side, is cancelled out by the left and right placement of the tilling blades that comprise the rotor as a whole, the average value for FX obtained in simulations that assume a constant soil hardness was 0 N. However, by reducing the peak value, the vibration of the tiller when working with soil that is not of a uniform hardness was also lessened.

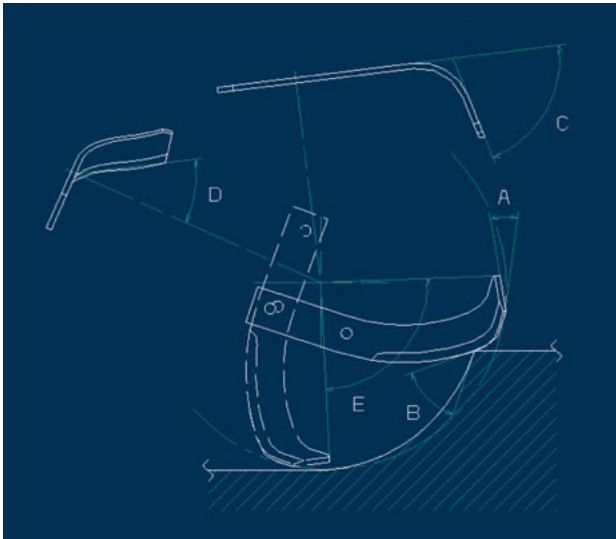


Fig. 10 Tilling blade

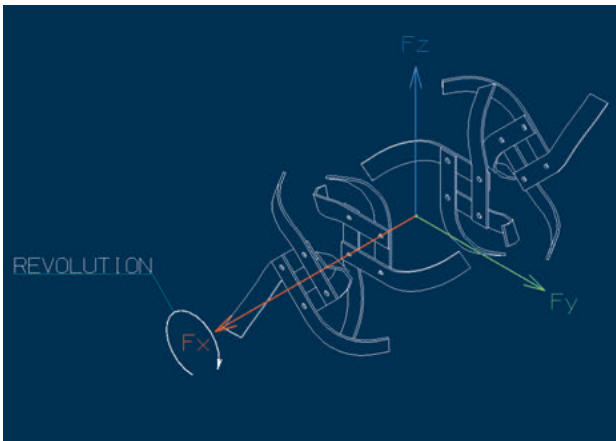


Fig. 11 Forces imposed on rotor shaft

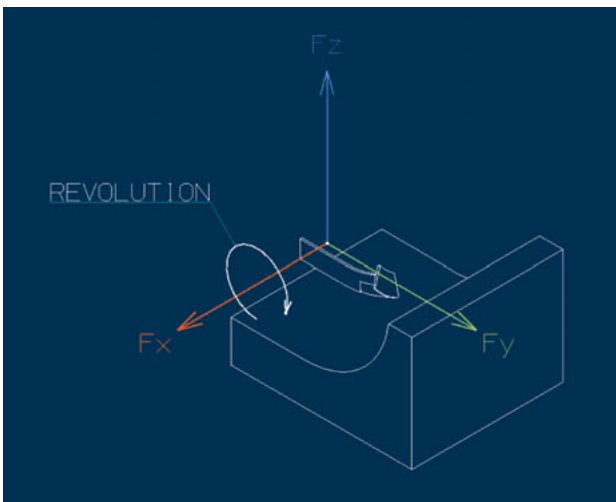


Fig. 12 Analytical model

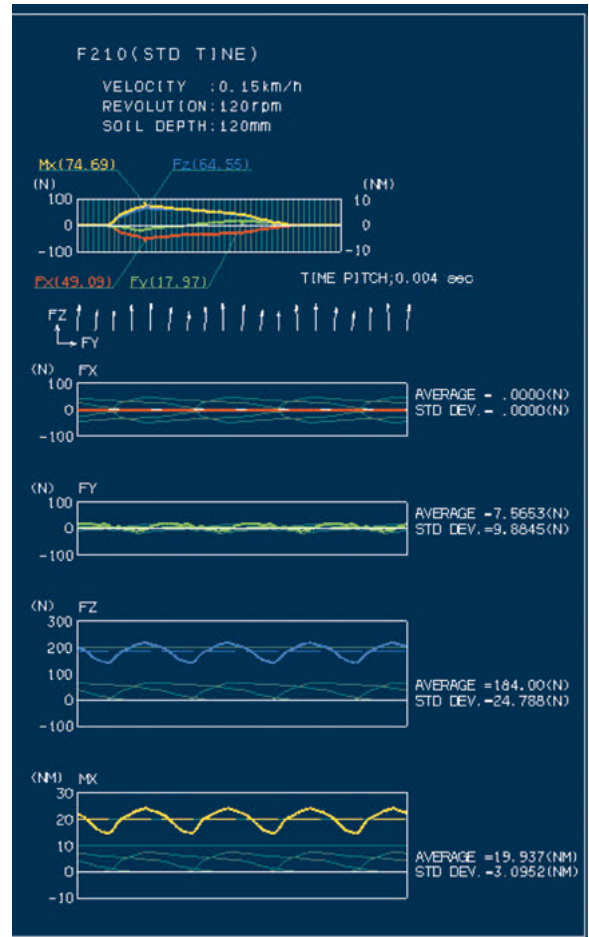


Fig. 13 Force and moment on rotor shaft of F210

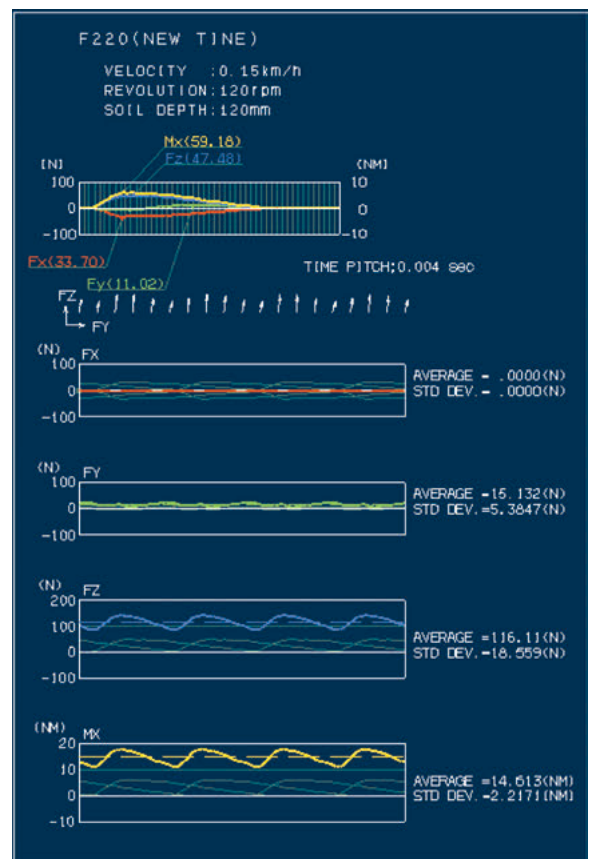


Fig. 14 Force and moment on rotor shaft of F220

5.4 Reduced Operating Load and Easier Operability

The reduction in engine displacement reduced the recoil starter pulling load needed to start the engine by 30%. Fig. 15 shows the relationship between engine displacement and the recoil starter pulling load.

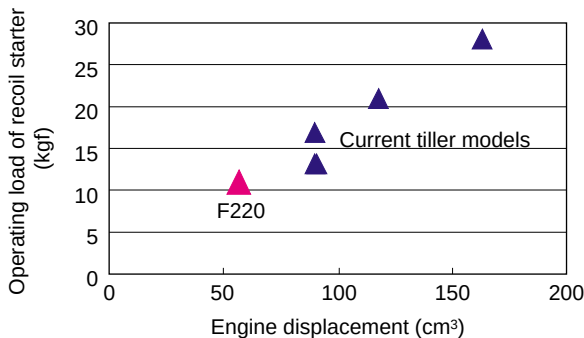


Fig. 15 Operating load of recoil starter

The clutch in the F210 had a lock mechanism for locking the clutch while tilling, but in the F220 a deadman's clutch mechanism was adopted because its simple operation is easier for novices to use. With this mechanism, squeezing the clutch lever causes the tiller to move forward and releasing the lever causes the tiller to stop. However, because the clutch lever is used more frequently and for a longer period of time with this mechanism than with a lock mechanism, a new clutch that can be operated with a low load was developed. Figs. 16 and 17 show the results of evaluations of the frictional properties of the clutch lining and the stroke characteristics.

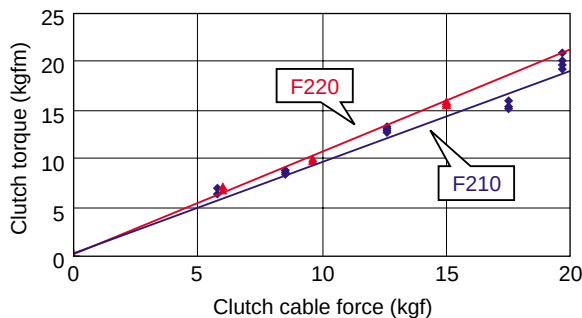


Fig. 16 Clutch capacity

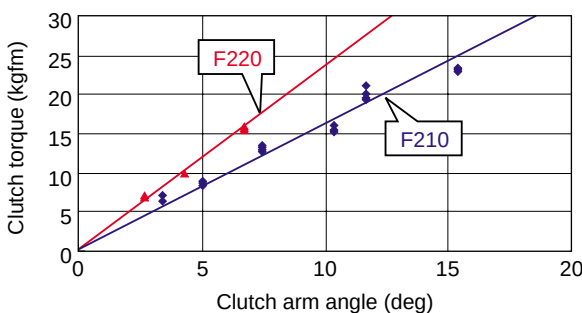


Fig. 17 Clutch capacity (Stroke)

The frictional properties were improved by changing the material used in the clutch lining, and the cable pulling load needed to obtain the clutch torque that is necessary in order to transmit the engine output was reduced. Furthermore, by improving the stiffness of the lining, the stroke characteristics were improved and the clutch arm angle needed to obtain the necessary clutch torque was reduced. The result of these changes was that the clutch lever operation load in the F220 was reduced by 20% with the same stroke as in the F210. These results are shown in Fig. 18. In addition, by changing the clutch lever from pressed steel to molded plastic, it was possible to reduce the coldness of the grip and to enhance the shape of the grip.

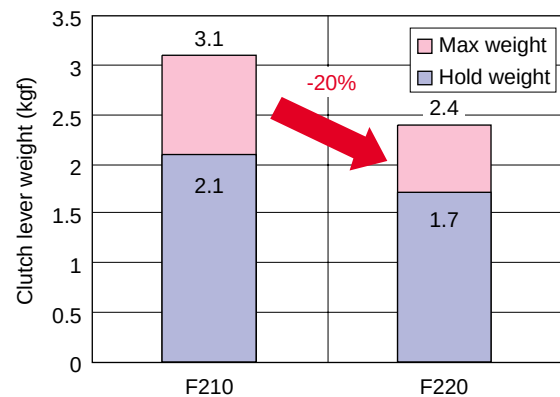


Fig. 18 Operating load of clutch lever

6. Conclusion

Based on past experience and common sense, it was believed that reducing the weight of the tiller and the engine displacement would make the tiller easier to handle, but would also cause a decline in work performance. By running simulations with new blade shapes and performing a variety of tests, it became apparent that the conflicting goals of a light weight, easy to use tiller and a tiller with good performance could all be achieved. Thus, the bold decision to use an engine with a smaller displacement was made.

This counterintuitive decision made it possible to retain the outstanding work performance of the "Komame F210" while further enhancing its characteristic compact size, light weight and ease of use, while also permitting the development of a product that addresses changes both in environmental awareness around the world as well as in the needs of the market.

The development team hopes that customers around the world will enjoy using the "New Komame F220". This development project was made possible with the cooperation of many people inside and outside Honda. Furthermore, much valuable advice was received from members of the editing staff in the writing of this article. The development team would like to express their thanks to all who helped in the course of this project and in the writing of this article.

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