

Development of GX25 4-Stroke Engine for Handheld Equipment

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ABSTRACT

The multi-position 4-stroke engine, GX25, was developed for handheld equipment such as string trimmers and brush cutters. The purpose of the development was to achieve weight and acceleration levels equivalent to 2-stroke engines with better startability than the current GX22/31. Further refinement was made to the Rotary Slinger Pump Lubrication system developed for the GX22/31. To achieve lightweight composition, an OHC structure with an in-oil micro timing belt was adopted. A new one piece Rocker Arm Assembly and sintered cam were adopted in order to fit the valve train in the limited space of the oil tank. As a result of above the improvements, the GX25 has 13% less weight, 13% more displacement, and 30% more power-weight ratio when compared to the GX22. Furthermore, the improved decompression system has reduced the pull load and enhanced startability. A newly developed acceleration pump has achieved the 2-stroke level acceleration. In addition, matched with the UMK425 brush cutter, the reduced inertial moment of a lighter engine makes it easier to operate the equipment.

1. Introduction

Approximately 12 million portable, handheld engines (1.8 kW or less) are sold yearly around the world and sales have been showing a slight upward trend.

2-stroke engines are less expensive and have simpler configurations than 4-stroke engines, and are also able to be operated in multiple-positions, making them extremely widely used in handheld equipment such as brush cutters. Exhaust emissions are, however, a serious issue with these engines.

In 1997, Honda responded to this issue by developing and

marketing the GX22/31, the world's first multi-positioned 4-stroke engine⁽¹⁾.

Since then, small engine manufacturers have examined various methods in their efforts to reduce exhaust emissions, some of which have been utilized in products on the market. These methods have included the transition to 4-stroke engines, the use of 2-stroke engines with exhaust gas after-treatment or scavenging control, and the development of 4-stroke engines using oil mixed fuels.

The GX25 handheld 4-stroke engine, which will be introduced in this paper, was developed against this market background to improve on the GX22/31.

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2. Development Concept

The development concept for this engine was “the lightest handheld 4-stroke engine in its class”.

Development targets were as follows:

- 360°-inclinable operation equivalent to the GX22/31
- 30% improvement in power-weight ratio
- Acceleration performance equivalent to a 2-stroke engine
- Able to be started with less pull load on the starter rope than the GX22/31

3. Main Specifications

The external design features a full cover to prevent the engine from catching on branches and the like when the machine is in use. Ease of maintenance has been considered, and the engine cover can be removed and reattached by removal of one bolt.

Extensive reexamination of the configuration of the GX22 led to the adoption of a belt drive OHC valve mechanism to decrease the size and weight of the engine. An external view of the GX25 is shown in Fig. 1; Figure 2 shows a comparison of engine size between the GX25 and the GX22.



Fig. 1 External view of GX25

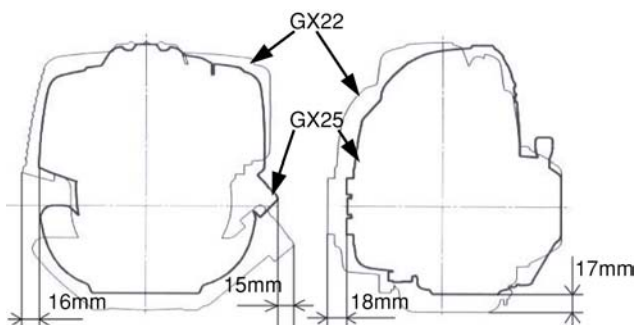


Fig. 2 Comparison of engine size between GX25 and GX22

The main specifications are shown in Table 1. Despite the fact that the new engine has a displacement of 25 cc, a 13% increase over the previous engine, its dry mass is 2.78 kg and its power-weight ratio is 0.29 kW/kg, putting it at the top of the 4-stroke handheld engine class. Figure 3 shows a comparison of power and weight for different models.

Table 1 Engine specifications

Model	GX25
Engine type	Air cooled 4-stroke OHC Single-cylinder
Bore × Stroke [mm]	35 × 26
Displacement [cm ³]	25
Compression ratio	8.0 : 1
Maximum power [kW/s ⁻¹]	0.81/116.7
Maximum torque [Nm/ s ⁻¹]	1.25/83.3
PTO shaft rotation	Counterclockwise
Fuel type	Unleaded gasoline
Fuel tank capacity [cm ³]	550
Fuel consumption [g/kWh]	340
Engine oil capacity [cm ³]	80
Oil consumption [cm ³ /hr]	2
Ignition system	Transistorized magneto
Starting system	Recoil
Lubrication	Crankcase pressure driven
Dry mass [kg]	2.78
Dimensions (L × W × H) [mm]	192 × 221 × 230

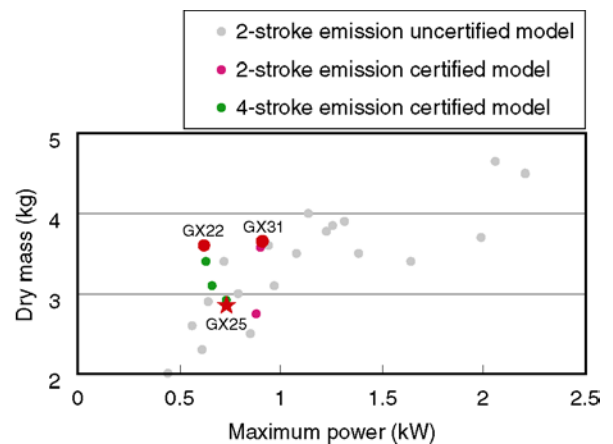


Fig. 3 Power/weight relation

4. Weight-saving Technology

4.1. Placement of Valve System

In the GX22/31, valve housing equipment such as push rods and cam gears (components of the OHV mechanism) were positioned between the cylinder and the cooling fan. An OHC configuration has been adopted for the GX25, and the valve housing has therefore been positioned on the opposite side of the cooling fan, close to both the cylinder and the

cooling fan. This configuration enables the new engine to equal the cooling performance of the GX22 with a 15% reduction in the area of the cooling fins. In addition, the length from the center of the engine to the power axis located at the tip of the cooling fan has been reduced from 100 mm to 83 mm, enabling size and weight reductions with no loss of overall engine rigidity. Figure 4 shows comparative cross-sections of the GX22 and GX25.

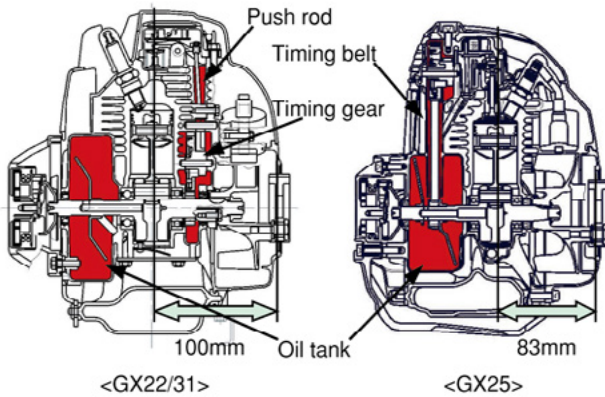


Fig. 4 Structural differences between GX22 and GX25

4.2. High-rigidity Block

Rigidity and strength are required in the support ribs for the attachment joint, because the attachment joint supports the entire weight of these small engines. In the GX25, support ribs have been located in six positions from the crank support and cylinder bore towards the fastening boss, balancing weight savings with rigidity. Block weight has been reduced by 25% against the GX22, from 967 g to 720 g, while up-down rigidity is 3.9 times higher and left-right rigidity is 2.4 times higher in the new engine. Figure 5 shows a three-dimensional image of the cylinder block and the attachment joint support ribs.

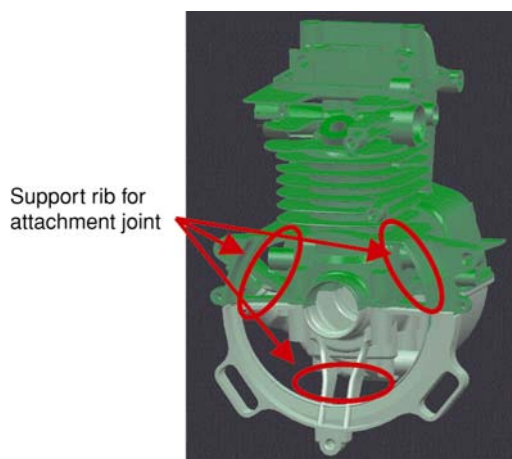


Fig. 5 Cylinder block

5. Lubrication Breather System

The following requirements were placed on the lubrication system of the new handheld engine:

- Able to be operated in any position.
- Able to be stored in any position when engine is stopped.
- As simple a configuration as possible, to achieve weight savings and cost reductions.

The rotary slinger pumping lubrication system developed for the GX22/31 was utilized in the GX25 to enable these requirements to be satisfied.

The salient points of the rotary slinger pumping lubrication system are as follows:

- It is a dry sump lubrication system with a separate oil tank provided with an oil slinger (oil agitator) directly connected to the crank, enabling oil flow to the combustion chamber to be prevented.
- Crankcase pressure rather than an oil pump is used to supply and return oil, enabling simplification of configuration and consequent weight savings and cost reductions.

Because blowby gases and oil mist were separated and oil was collected in the cam case and rocker arm chamber, the GX22/31 had a complex oil path. The adoption of an OHC mechanism in which the timing belt is located in the oil tank for the GX25 has resulted in a simplified lubrication path in which oil mist separation and collection can be conducted in the rocker arm chamber alone. Figure 6 shows a comparison between the lubrication paths of the GX22/31 and the GX25. This configuration minimizes delay in lubrication of the cam sliding parts which experiences severe lubrication conditions when the engine is started. Figure 7 shows the lubrication path in the GX25.

In addition, the following modifications were made to the rocker arm chamber to enable breather function (blowby gas and oil mist separation) and oil collection in any engine position:

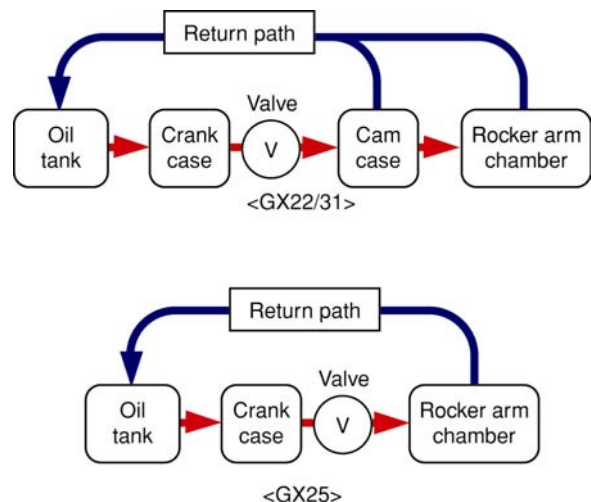


Fig. 6 Differences in oil path between GX22/31 and GX25

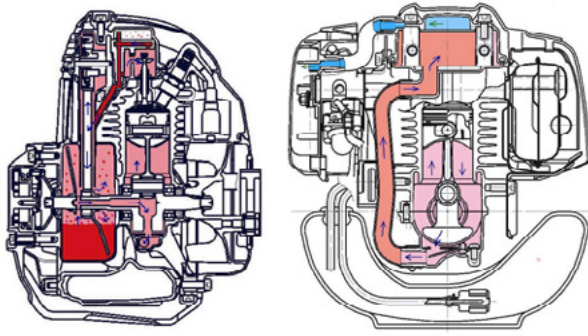


Fig. 7 Lubrication system

- A negative pressure chamber for oil collection was positioned close to the center of the rocker arm chamber.
- The first separator chamber, rocker arm chamber and breather chamber were positioned around this negative pressure chamber.
- Twelve oil suction holes were placed in the negative pressure chamber to enable oil to be collected regardless of engine position.

These modifications have enabled stable oil collection and return regardless of engine position, and the lightweight and simple configuration enables continuous multi-position operation. Figure 8 shows a cross-section of the rocker arm chamber.

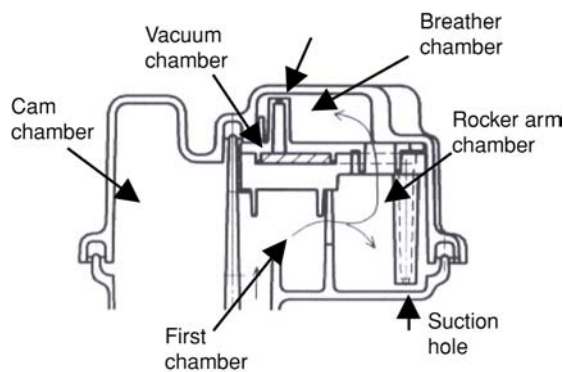


Fig. 8 Rocker arm chamber

6. Valve System

An OHC configuration driven by a timing belt has been utilized in the GX25. The layout is shown in Fig. 9.

6.1. Small, High-speed Oil-immersed Timing Belt

The specifications of the timing belt are shown in Table 2. An oil-immersible timing belt was adopted to drive the valve train to enable integration of the oil tank and valve chamber.

An oil-immersible timing belt was also utilized in the GC/GCV160⁽²⁾. The rubber material, canvas, core wire, etc., remain unchanged in the new belt, but the following points have changed in the new engine, affecting the conditions of belt use:



Fig. 9 Valve train layout

Table 2 Belt specifications

Model	GX25	GCV160
Belt length [mm]	320.6	533.4
Belt width [mm]	6	7
Maximum speed [s^{-1}]	200	60
Drive pulley diameter [mm]	20.6	39.3

- The new engine is high-speed and high-rpm, running from a normal operating speed of $116.7 s^{-1}$ (7,000 rpm) to a maximum engine speed of $200 s^{-1}$ (12,000 rpm).
- Drive pulley diameter has been reduced to contribute to the reduction of overall engine size.

These conditions of use significantly increase the damage caused to the core wire by polygonal behavior of the belt, and it was therefore necessary to increase bending fatigue resistance against the GC/GCV160. The dimensions of the teeth were accordingly reduced to achieve a balance between the level of bending fatigue induced and teeth jumping. The flexibility of the core wire was increased by reducing the diameter, and bending fatigue resistance in oil was increased by utilizing an adhesion treatment with superior oil resistance properties.

6.2. Assembled Rocker Arm

It was necessary to separate the rocker arm chamber and the valve housing (oil tank) to ensure the necessary pressure differential for oil return in the multi-position lubrication system. To achieve this, the rocker arm utilized in the new engine is assembled from two parts connected by a pin. The valve lifter, which slides across the cam surface, and the rocker arm, which pushes the valve head, are positioned in different chambers. The components of the rocker arm are



Fig. 10 Rocker arm

assembled by press fitting, and the pin is knurled to ensure slip torque after fitting. Sintered steel is used for the valve lifter and rocker arm, because of its superior strength, formability, and performance in sliding parts. An external view of a rocker arm is shown in Fig. 10.

6.3. Sintered Cam Integrated with Pulley

The driven pulley in the new engine has been integrated with a cam drive, as shown in Fig. 11.

To enable a biaxial tensionless belt drive to be used for the pulleys, they are formed from phenol resin, because of its ability to maintain its dimensions at high temperatures, and a mechanical decompression mechanism has been built in. Sintered steel has been integrated with phenol resin to produce the sliding parts of the cam and the bearings to increase durability given the high speeds and low diameters.

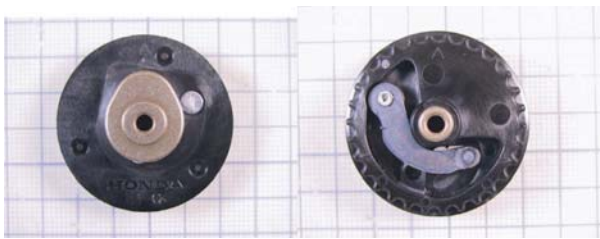


Fig. 11 Timing pulley

7. Improvements to Starting and Acceleration

7.1. Technology for Reduction of Recoil Pull Load

The GX22/31 utilized a decompression mechanism to open the inlet valve when the engine was started. The GX25 utilizes a decompression mechanism in the exhaust valve.

The GX25 is mainly used in brush cutters, and in these machines the throttle is normally closed when the engine is started. Because of this, decompression is more effective if pressure escapes via the exhaust valve when the engine is started. Lift timing has been set within a range which will minimize its effect on starting performance while enabling decompression, thus reducing recoil pull load. Figure 12 shows a three-dimensional model of the exhaust decompression.

Recoil starters with power spring have recently begun to be commercially utilized to reduce recoil pull load; the GX25



Fig. 12 Exhaust decompression

pull load is equivalent to that of an engine utilizing a power spring starter. Figure 13 shows a comparison of recoil pull loads in engines of identical displacement. Figure 14 shows recoil pull load waveforms when the engine is started. The engine utilizing a power spring averages a high load over an extended period, requiring a considerable amount of work; the GX25 can be started with just half the effort.

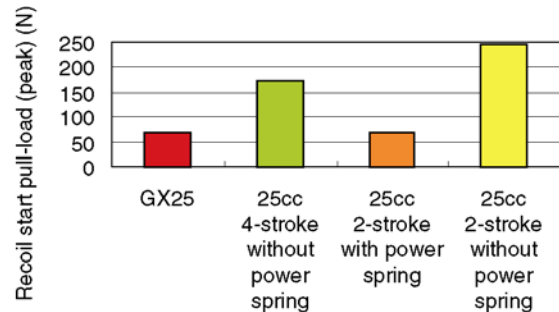


Fig. 13 Comparison of recoil pull-load (peak load)

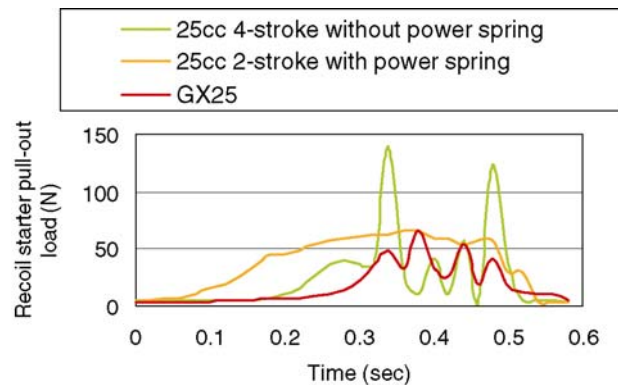


Fig. 14 Comparison of recoil pull-load

7.2. Diaphragm Carburetor with Acceleration Pump

The GX25 is provided with a newly developed carburetor with a built-in acceleration pump. The pump mechanism is a piston type synchronized with the throttle; size reductions have been achieved by constructing the pump from four components. Figure 15 shows the acceleration pump built in to the carburetor.

In this configuration, the path producing the main jet is pressurized by the cam, which is synchronized with the throttle, enabling fuel output to respond to throttle speed. This has improved acceleration at low temperatures.

Acceleration pump (piston)



Cam on throttle shaft

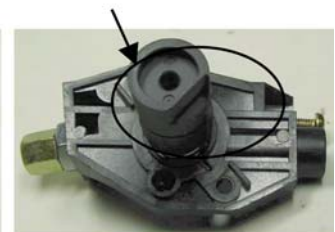


Fig. 15 Acceleration pump on carburetor

Figure 16 shows the operation mechanism of the acceleration pump. When the throttle is opened, the cam section of the throttle shaft pushes the piston, delivering fuel to the engine.

This configuration has greatly improved throttle response directly after the engine is started, which had previously been a point of concern in the development of 4-stroke handheld engines, and has enabled the achievement of operation with no feeling of stress in the engine. Figure 17 shows a comparison of engine speed response when the throttle is suddenly opened for several engines.

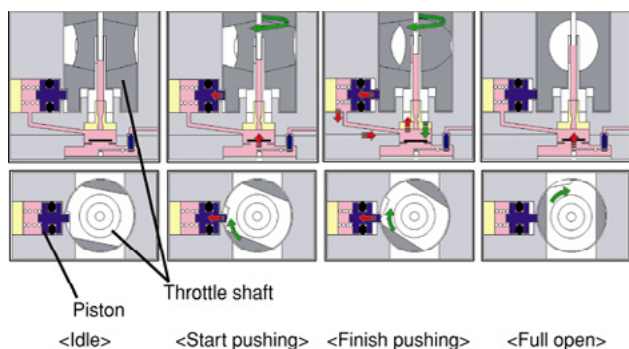


Fig. 16 Acceleration pump operation mechanism

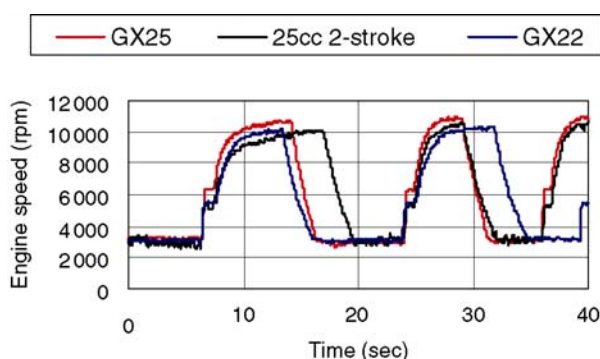


Fig. 17 Throttle response

8. Practical Application

The main application of the GX25 is in the UMK425 4-stroke brush cutter, the lightest in its class.

The main characteristic customers demand from a brush cutter is lightness, and the various companies in the field have continued to reduce the weight of their products. The UMK425 is made up of the lightweight GX25 and a lightweight frame, and is 20% lighter than the previous model, the UMK422, making it equivalent to the lightweight 2-strokes of the same displacement, despite its 4-stroke engine.

The operator of a brush cutter cuts weeds, grass, etc. by swinging the machine's pole to the left and right, moving the cutting blades at the tip. This swinging motion therefore has a significant effect on operator fatigue. Because the center of gravity is normally constant with respect to the operator, the moment of inertia of the completed machine is an important

element in operator fatigue. The moment of inertia has been reduced by 20% in the UMK425 against the previous UMK422, enabling the achievement of an ease of swing equivalent to that of lighter brush cutters. Figure 18 shows a photograph of the UMK425 in operation, and Fig. 19 shows a comparison of the moment of inertia of various models.



Fig. 18 UMK425 in operation

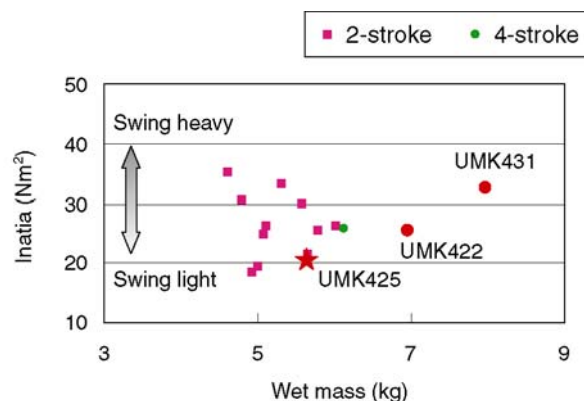


Fig. 19 Relation between swing light and inertia

In addition to the benefits of ease of starting and fuel economy achieved by using a 4-stroke engine, the UMK425 is lightweight and therefore easy for the operator to carry and to swing. This product has done away with the conventional image of 4-stroke brush cutter as being heavy.

9. Conclusion

The GX25 engine was developed as an engine for handheld equipment.

- (1) Improved valve placement and the adoption of an OHC mechanism with an oil-immersed belt has enabled a 30% improvement in power-weight ratio against the GX22.
- (2) The utilization of an exhaust valve decompression mechanism and an acceleration pump integrated with the carburetor has enabled improvement of acceleration when the engine is started.
- (3) The moment of inertia of the completed UMK425 has been reduced by 20% against the UMK422, and ease of swing has been increased.

10. Afterword

The authors hope this engine will increase the recognition and evaluation of 4-stroke engines in the handheld market, currently dominated by 2-strokes, and help to increase the level of use of cleaner engines in the future.

In closing, the authors wish to sincerely thank all those who contributed so extensively and generously to the development of this engine.

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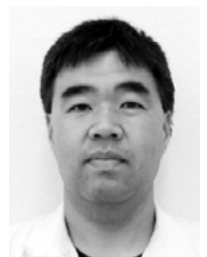
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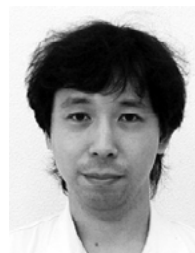
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