

Development of HSL2511 Large-sized Snow Thrower

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ABSTRACT

The HSL2511 residential-use large-sized snow thrower was developed on the concept of a flagship model that realizes ease of use and simple operation for tidy leveling of the snow-clearing surface.

An auger height motor and auger rolling motor move the snow-clearing system (auger) vertically and laterally using a control unit with built-in acceleration sensor to determine the inclination. This is also the first snow thrower in the world to be equipped with an auger assist function that remembers the vertical and lateral inclination of the snow-clearing system and keeps it steady while in operation. This reduces the need to expend care and attention on the inclination of the snow-clearing system during operation as well as the need to frequently manipulate the system controls. This model also has increased workability, so that even beginners can easily produce a smooth, orderly surface of cleared snow, or shape the cleared snow surface to the desired slope.

This model has a four-stroke V-twin engine with an electric governor and electronically controlled fuel injection system. It achieves increased workability and more efficient snow clearing by an operation mode change function, which switches to different engine power curves according to various operating conditions, as well as a speed guide function, which helps the operator find the optimal working speed.

The increased working efficiency achieved by the new model engine and the snow thrower's various functions has realized a 16% improvement in fuel efficiency.

1. Introduction

Honda developed its first residential-use small-sized HS35 snow thrower for the American market in 1980, when it entered the snow-thrower market. In Japan, Honda started selling the HS50 (5-PS class) residential-use small-sized snow thrower in 1982. Honda snow throwers are now being sold in 20 or more countries worldwide⁽¹⁾.

The line-up of snow throwers with gasoline engines on the Japanese market now includes models from 2 to 24 PS. Cumulative sales have reached 360,000 units.

The amount of snow coverage has been increasing in recent years, and areas experiencing heavy snow (snow with a high specific gravity) have been tending to expand. The labor of snow-clearing has been growing progressively heavier, and this in combination with the increasing age of the population in snow areas and the shortage of people to handle snow-clearing work has created demand for more efficient snow clearing.

In order to address these market needs, Honda has made a full model change of snow throwers in the large-

model class (body mass of over 400 kg), and developed the HSL2511 residential-use large-sized snow thrower with increased work efficiency. This model is introduced here. Figure 1 shows an external view of the HSL2511.



Fig. 1 Overview of HSL2511

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Table 1 Major specifications of HSL2511

Items	Specifications
Overall length [mm]	2,425
Overall width [mm]	1,100
Overall height [mm]	2,060
Dry mass [kg]	595
Width of snow clearance [mm]	1,100
Height of snow clearance [mm]	715
Maximum snow-throwing distance [m]	26
Engine type	Forced air cooling, 4-stroke, 2-cylinder 90deg V-type, OHV
Displacement [cm ³]	688
Net power [kW/rpm]	16.5/3600
Fuel type	Unleaded gasoline
Fuel supply system	Electronically controlled fuel injection system
Auger height adjustment system	Electro-hydraulic cylinder
Auger rolling adjustment system	Electro-hydraulic cylinder
Main equipment	Auger assist
	Auger reset
	Auger lift
	Speed guide
	Operation mode switching system

2. HSL2511 Concept and Features

The development concept was formulated as a flagship model that realizes ease of use and simple operation for tidy leveling of the snow-clearing surface. It was developed with the aim of making this a product with the appeal to make it the model that is most frequently selected by customers from among snow throwers with gasoline engines in the large model class.

The specific features are as follows.

- (1) The attitude control for the snow-clearing system (auger) has been computerized, and the snow thrower has been equipped with the world's first auger-assist function that maintains the auger at a constant inclination. This makes it relatively easy even for beginners to produce a smooth, level surface of cleared snow, or shape the cleared snow surface to the desired slope.
- (2) The adoption of an electric governor⁽²⁾ and inclusion of an operation mode-change function and speed-guide function enable the snow thrower to support a variety of different operating conditions and realize even more efficient snow clearing.
- (3) The adoption of a four-stroke V-twin engine with an electronically controlled fuel injection system (FI system) realizes simplified starting (no fuel cock or choke operation required) and improved fuel efficiency. Table 1 shows the major specifications of the product.

3. Main Equipment and Technology to Achieve Goals

3.1. Smart Auger

Smart Auger (trademark registration application filed) is the name of the auger attitude-control function in the HSL2511. It is equipped with the auger-assist function,

auger-reset function, and auger-lift function described below.

Auger-assist function: This function controls the vertical and lateral inclination of the auger electrically, and maintains the auger at a fixed inclination as desired.

Auger-reset function: Simply pressing the reset button activates this function, returning the auger to the default position (a horizontal position when initiating the auger-assist function).

Auger-lift function: When the snow thrower moves in reverse during snow-clearing work, this function automatically raises the auger to prevent dragging in the snow. When moving forward again, the function automatically returns the auger to its previous position, switching quickly from travel to clearing.

3.1.1. Aims and effectiveness

(1) Reduce frequency of operations: Use of a large-sized snow thrower requires the operator to handle many operations and devices (engine speed, snow-throwing direction and distance, height and inclination of snow clearance, movement speed and direction, etc.) while performing snow-clearing work. This work can be challenging for an operator. Figure 2 shows the controls that must be operated using the right hand while engaged in snow-clearing work.

Of those operations, the one performed most frequently is adjustment of the height and inclination of snow clearance using the auger control lever. Due to inclusion of the auger-assist function, the system constantly operates automatically to maintain the auger at the fixed inclination that has been set by the operator. Thus, the number of operations involving the auger housing has been reduced, regardless of the proficiency of the operator, and the burden of snow-clearing work has been lessened (Figs. 3 and 4).

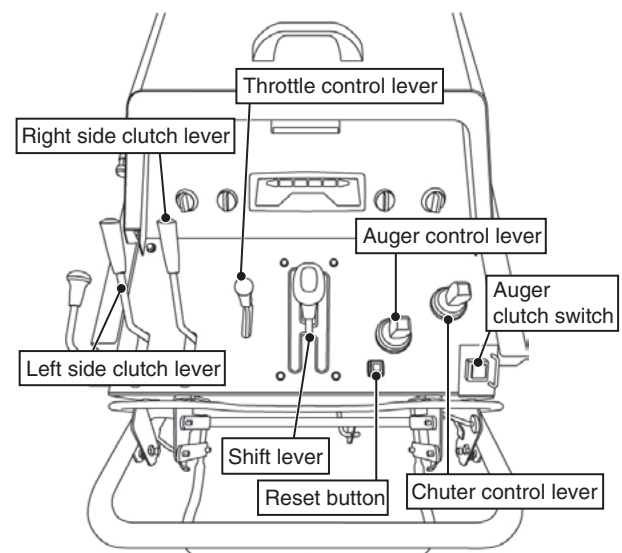


Fig. 2 Control panel view

- (2) Simplify smoothing of surface of cleared snow: The main purpose of snow-clearing work is to relocate snow to create a clear passage for people and vehicles. In other words, it is necessary to form a surface of cleared snow that is as smooth and level as practicable. When operating the auger control lever in order to form a level surface of cleared snow, however, there is a time lag before the snow thrower moves onto irregularities in the snow-clearing surface so that the resulting tilt of the snow thrower itself becomes apparent, and that lag makes the timing of this operation challenging even for experienced operators.

The auger-assist function enables the auger to be maintained at a constant inclination to deal with unevenness in the traveling surface. This allows even beginners to achieve level surfaces of cleared snow on a par with experienced operators (Figs. 3 and 4).

- (3) Simplify formation of cleared snow surfaces with the desired slope: Snow-clearing work is carried out in gardens, along the eaves of buildings, in parking areas, and numerous other kinds of locations. Parking areas in particular are commonly sloped for the purpose of drainage.

The auger-assist function enables the auger to be maintained at the desired inclination so that clearing can

proceed at the desired inclination. This enables snow-clearing to be carried out cleanly even in parking areas and other such sloped locations.

- (4) Simplify even, horizontal snow-clearing: The auger control lever is used to adjust the height and inclination of snow clearance, but since there are few objects on the snow surface to serve as objectives, operators frequently lose track of the horizontal. Since the auger-assist function and auger-reset function work together, it has become a simple matter to set a horizontal surface as the control target value for the auger assist function, so that even if the operator loses track of the horizontal, the snow thrower can form a horizontal surface automatically.

- (5) Effective overturning prevention: Since snow that has fallen and accumulated is not of consistent firmness, there may be soft patches and firm patches. When engaged in snow clearing on top of the snow, the snow thrower can sink into softer snow on one side, tilt, and tip over. With conventional snow throwers, the operator would cancel out the tilt of the machine by manually operating the auger control lever to make the auger operate toward the side away from where the snow thrower is sinking.

Adoption of the auger-assist function means that this operation can be performed automatically and with a fine degree of control. Since the snow thrower is leveled before it tilts too far, it is prevented from overturning before reaching that point.

- (6) Reduction of lost time during snow clearing: Snow-clearing work very frequently involves moving in reverse, for example when the snow is firm and the auger is not biting into the snow properly, or when moving over to clear snow along a parallel path. At such times, if the snow thrower is backed up with the auger left at the height used for clearing, the auger housing can drag in the snow and interfere with backward movement. Therefore it was necessary to perform an operation to lift the auger before starting to move in reverse, and when the snow thrower was moved forward again, the auger had to be returned to the previous position.

Adoption of the auger-lift function means that operations to lift and lower the auger can be performed automatically. This eliminates forgetting to perform the operation, and enables efficient snow clearing (Fig. 5).

3.1.2. Explanation of snow thrower movements

The operator uses the auger control lever to adjust the vertical and lateral inclination of the auger, in accordance with conventional operation. That inclination of the auger then becomes the target value, and even if the surface on which the snow thrower is moving becomes uneven so that the snow thrower tilts, the snow thrower proceeds with the auger maintained at a constant inclination while clearing.

If the operator readjusts the vertical and lateral inclination of the auger, the system updates the target value

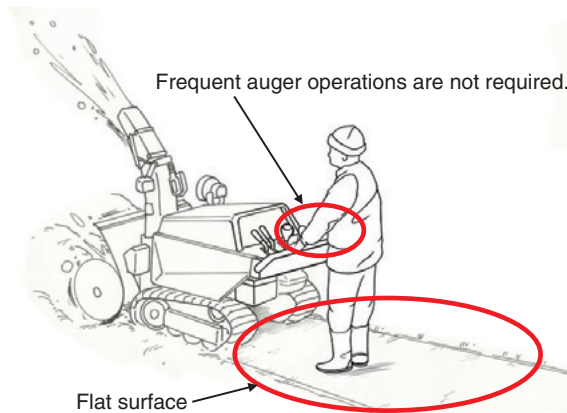


Fig. 3 Auger assist on

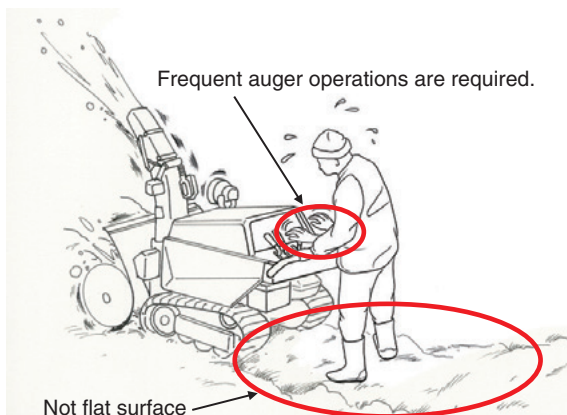


Fig. 4 Auger assist off

with the readjusted inclination.

So the inclination of the auger can be adjusted by the operator to the desired setting at any time according to the condition of the surface over which the snow thrower is moving. The system operates to maintain the auger automatically at a constant set inclination.

Figure 6 shows an example of lateral movement. (1) If the snow thrower starts tilting because the track on one side sinks into softer snow, (2) the system automatically moves the auger to the same angle by which it is tilting from the set target value on the tilting side, but in the opposite direction. (3) When the snow thrower proceeds to advance and perform snow clearing, the slope of the traveling surface comes to match the angle at which the auger has been set. (4) As the slope of the traveling surface returns toward the target value, the system returns the auger to its previous angle.

Figure 7 shows an example of movement in the vertical direction. The example shows the snow thrower forming a

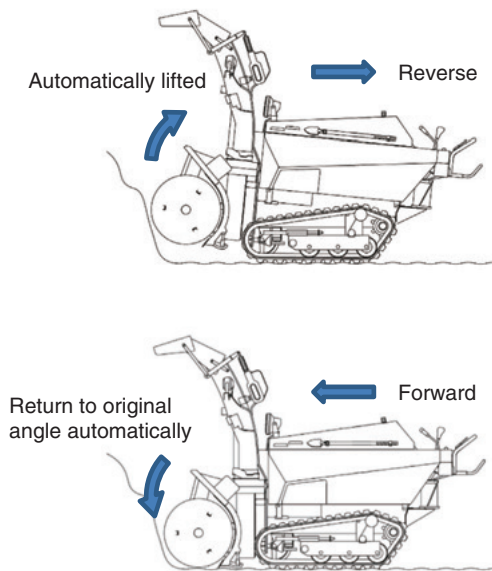


Fig. 5 Auger lift function

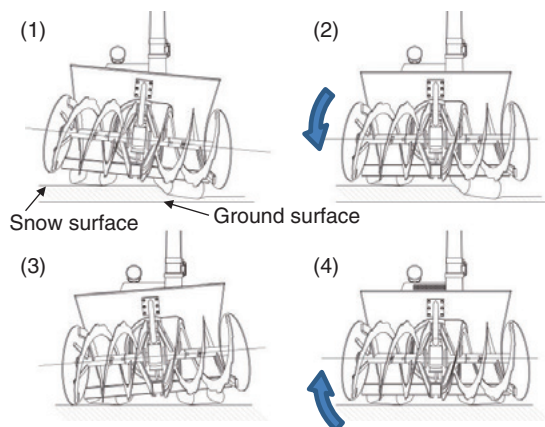


Fig. 6 Auger movement (rolling)

sloping surface as it climbs. (1) The vertical inclination of the auger is adjusted to the angle of the desired slope. The dotted line indicates the present snow surface, and the solid line is the desired slope that is to be formed. (2) As the snow thrower moves forward and begins clearing snow, the snow-clearing surface is formed at the target value angle. (3) As the snow thrower inclines to the slope of the snow-clearing surface, the vertical inclination of the auger is continuously lowered. (4) The snow thrower is thus able to climb while forming a slope at the desired angle. The movements in (2) and (3) are not easy to perform continuously in a smooth manner. When performed manually, the result will tend to be a wavy surface (the two-dot chain line in (4)), but since the auger-assist function adjusts the auger position quickly and smoothly, the snow thrower is able to form a tidy, evenly sloping surface.

3.1.3. Structure and control system

A control unit with a built-in acceleration sensor is positioned on the snow thrower body in order to detect the vertical and lateral inclination of the auger in the direction of gravitational acceleration relative to the earth's axis.

Although the vertical inclination of the auger will be the same as that of the control unit mount, the lateral inclination of the auger will not be the same. An angle sensor has therefore been positioned on the connecting part that joins the auger to the snow thrower body to detect the lateral angle (Figs. 8 and 9).

The function of auger inclination adjustment was assigned to the auger control lever and auger reset button as before.

In order to allow the auger-assist action to function only during clearing, the travel motion clutch and snow-clearing clutch state is detected from the clutch switch and the auger clutch ON sensor and OFF sensor, while the forward and reverse travel state is detected by the travel speed sensor.

The functions of the actuators that change the inclination of the auger were assigned to the electro-hydraulic cylinder for height and to the rolling motor.

The vertical and lateral inclination of the snow thrower body is detected by a three-axis acceleration sensor. The acceleration sensor is influenced by vibrations from the auger, the driving system, and the engine, and its output is

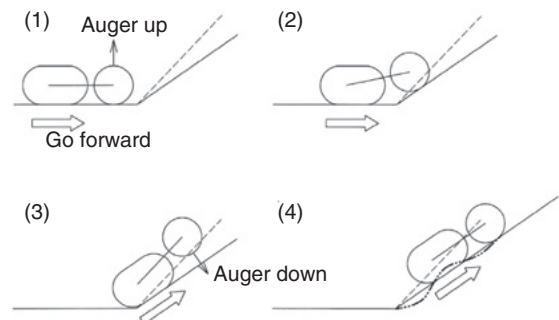


Fig. 7 Auger movement (height)

averaged. Steps are also taken to mitigate the influence of momentary acceleration due to standing starts, stopping, and height motor operation. The accuracy of auger and snow thrower inclination detection was heightened by detecting every state and filtering the sensor results.

Vertical inclination of the auger is calculated as the vertical inclination of the snow thrower body. Lateral inclination of the auger is calculated from the snow thrower body inclination and angle sensor values.

When the actual vertical and lateral inclination of the auger reach or exceed a certain deviation relative to the calculated targets for vertical and lateral auger inclination because of the state of the traveling surface, the auger starts operating.

The snow thrower can be made to operate at high speed when the deviation is a large value, and at a low speed when the deviation is a small value. This realizes speedy and finely controlled operation.

3.2. Operation Mode Change Function

3.2.1. Aims and effectiveness

A variety of conditions apply in snowfall areas, and there are some people who want to clear snow quickly while others want to throw the snow up higher. In order for a single snow thrower to meet these diverse operating conditions, however, extremely complex operations are required. These operations were found to involve

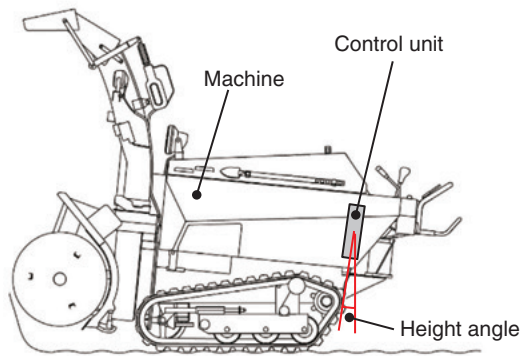


Fig. 8 Control unit location

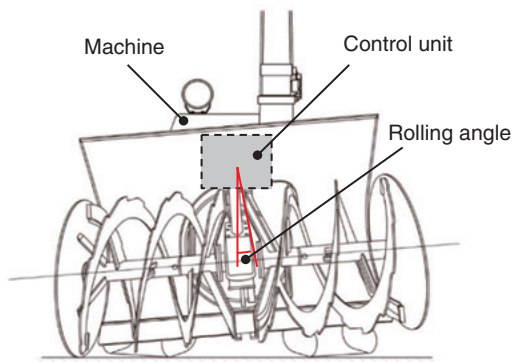


Fig. 9 Rolling angle

considerable difficulty for beginners.

The HSL2511 is equipped with an operation mode-change function that can toggle between standard mode and throwing distance mode by means of a single switch. This enables even beginners to meet a variety of different operating conditions without performing complex operations (Fig. 10).

3.2.2. Explanation of function

The operation mode-change function changes the output power characteristics by changing the maximum engine throttle position and the engine speed-setting range in accordance with conditions. Figure 11 shows the torque characteristics in each mode.

In standard mode, the engine speed-setting range is 2000-3500 rpm, which can achieve work equal to a conventional snow thrower. This mode also regulates the maximum degree of governor open throttle for each engine speed, in this way changing the engine characteristics. On the low-engine-speed side, the snow thrower is operated with the degree of governor open throttle ranging from completely closed to wide open. As the engine speed increases, however, the maximum throttle position is stepped down in stages. This reduces the maximum output power on the high-engine-speed side. This allows a larger torque increase to accompany the reduction in engine speed.

When the snow thrower travel speed is set higher because the operator wishes to quickly clear large amounts of snow, the load from the snow is increased and the engine torque cannot keep up. Then, (1) the engine speed

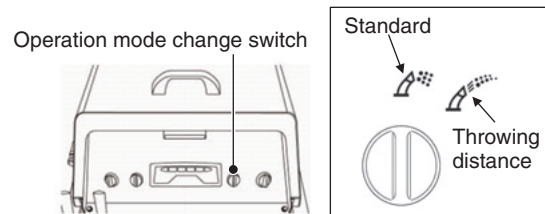


Fig. 10 Operation mode change switch

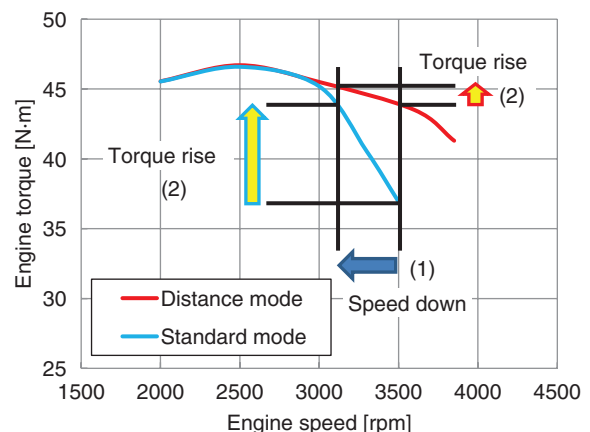


Fig. 11 Torque characteristics in each mode

decreases until the load and torque are balanced. When this happens, (2) in standard mode the torque rise is larger than in throwing distance mode, and the load from the snow and the engine torque quickly become balanced. This reduces the operator frequency of fine adjustments to travel speed, making the snow thrower easier to handle.

The operator can readily sense when the engine has reserves of power available because the rate of torque rise is large relative to the rate of engine speed decrease.

In throwing distance mode, the engine speed-setting range is 2000-3850 rpm, which is a wider range than in standard mode. A maximum throttle opening limit is not set, and the engine is operated throughout the entire range from completely closed to wide open. The engine characteristics here (the wide-open curve) are identical to those of the engine itself.

The maximum output power of the engine is greater than in standard mode, and the set engine speed is also higher. This means that the snow thrower can throw snow at higher engine speeds, and the operator can throw snow higher and farther.

3.2.3. Structure and control system

In order to change the maximum throttle opening in accordance with conditions, this model does not use a mechanical governor of the type widely employed in conventional snow throwers, but rather an electric governor as used in the HSM1590i⁽³⁾ and other medium-sized hybrid snow throwers. An electric governor is a device that maintains the set engine speed regardless of changes in load by using a motor to drive the throttle to the target degree of governor open throttle calculated by the electronic control unit (ECU). For that purpose, the ECU is always capable of recognizing the degree of governor open throttle, and it has also gained the ability to change it freely. This snow thrower makes good use of that advantage by realizing the mode-switching function.

In specific terms, standard mode uses the following throttle opening limit (Fig. 12).

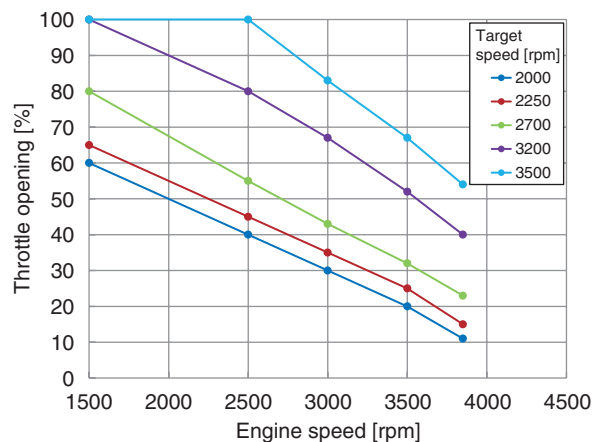


Fig. 12 Throttle opening limit

Table 2 Speed guide indicator lighting

Indication	Status	Operation
Light-off	Engine is not fully loaded	Can accelerate
Light-on	Optimal speed	Maintain speed
Blinking	Overloaded	Decelerate

3.3. Speed-Guide Function

3.3.1. Aims and effectiveness

Efficient snow clearing requires maintaining the engine at a constant speed. This is because operating efficiency and snow-throwing distance are in proportion to engine speed.

In order to maintain the engine at a constant speed, the load on the engine has to be maintained at a constant level. The load on the engine is determined by the operating volume, i.e., the snow-clearing volume (t/h). Since the snow-clearing volume is in proportion to the snow thrower travel speed, efficient snow clearing needs to make fine adjustments of the speed in accordance with the quality of the snow (snowdrift height, firmness, dampness, etc.).

However, the height, depth, and firmness of accumulated snow are not constant, and since the operator cannot readily grasp those variations in advance, it becomes challenging to maintain the optimal speed.

Adoption of the speed-guide function enables operators to easily determine whether they should accelerate or decelerate. They are able to operate the shift lever to perform snow clearing at the optimal speed, significantly reducing working hours.

3.3.2. Explanation of function

The speed-guide function guides the operator to the optimal travel speed by the status of the indicator light (Table 2).

The HSL2511 has two operation modes that change the optimal travel speed according to the respective operating conditions.

In standard mode, the function guides travel speed adjustment to the vicinity of the torque peak (2500 rpm), where operation is efficient and maximum snow-clearing volume can be obtained. In throwing distance mode, the function guides travel speed adjustment to the vicinity of the output power peak (3850 rpm), where snow can be thrown higher and farther and maximum snow-throwing distance can be obtained (Figs. 13 and 14).

3.3.3. Structure and control system

Even if snow clearing is being performed at the same travel speed, the condition of the snow will vary so that the load on the engine changes. It is necessary, therefore, to monitor the amount of load on the engine. One means of doing this is to use the degree of governor open throttle of the electric governor described in section 3.2.3. The engine speed and degree of governor open throttle at a particular

point are used to estimate the load, and the result is used to control the indicator lights. Specific details of indicator lighting are shown in Figs. 15 and 16.

When work is started in standard mode with the initial engine speed set at 3500 rpm (black arrows in Fig. 15), as the load increases the degree of governor open throttle increases as well. (1) When the degree of governor open throttle reaches 45%, the system determines that the load is optimal and turns on the indicator light. (2) When the load continues to increase and reaches 67%, the throttle-opening limit is activated so that the throttle does not open any farther and the engine speed starts to drop. (3) At the same time, the limit value for the degree of governor open throttle also rises and the torque increases. (4) When the engine speed drops below 3100 rpm, the system determines that overload is occurring and causes the indicator light to blink.

In throwing distance mode, when the engine speed is 3300 rpm or higher and the degree of governor open throttle is 70% or more, the system determines that the load is optimal and turns on the indicator light. When the engine speed is 3300 rpm or less and the degree of governor open throttle is 70% or more, the system determines that overload is occurring and causes the indicator light to blink. Otherwise, the indicator light is turned off.

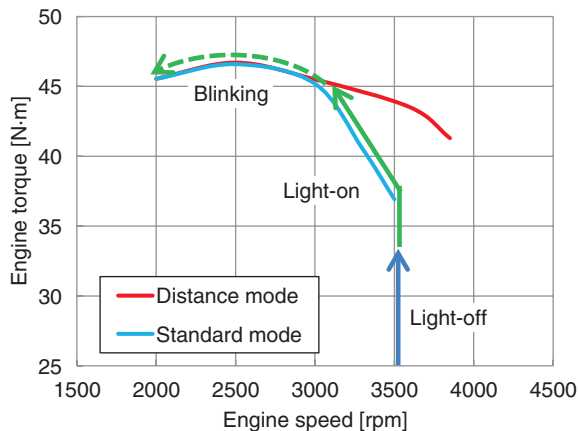


Fig. 13 Speed guide (standard mode)

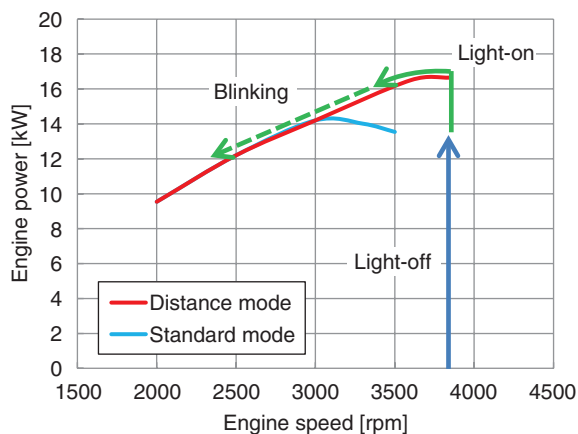


Fig. 14 Speed guide (distance mode)

3.4. New Model Engine with FI System

3.4.1. Aims and effectiveness

- (1) Simplified starting and heightened workability: Adoption of a four-stroke V-twin engine equipped with an FI system enables simplified starting. Unlike an engine with a carburetor, the starting operations of opening the fuel cock, pulling out the choke lever, and setting the engine speed adjustment lever to the starting position are not required.
- (2) Practical fuel efficiency improvement: Use of a four-stroke V-twin engine with an electric governor and FI system enables automatic and finely detailed adjustment of the fuel injection amount, heightens the working efficiency of each function, and, in combination with the adoption of a new model chuter, supports the EU Stage 2⁽⁴⁾ emission regulations. The new model's fuel efficiency, however, is still improved relative to the conventional model HS2411Z that predates the model change.

Table 3 shows the results of a comparison under the same conditions of throwing distance and efficiency. The HSL2511 can perform the same work as the HS2411Z at lower engine speed and load factor, consequently achieving

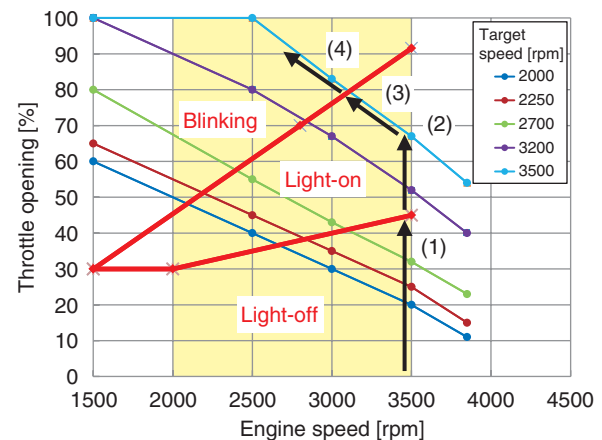


Fig. 15 Indicator lighting (standard mode)

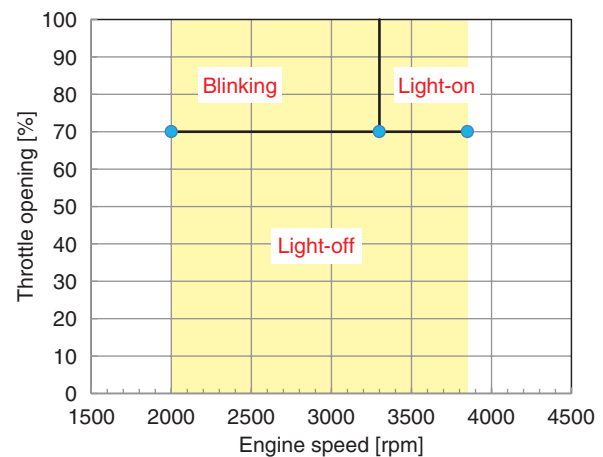


Fig. 16 Indicator lighting (distance mode)

Table 3 Fuel efficiency

	HSL2511	HS2411Z
Throwing distance [m]	18	
Clearing volume [t/h]	50	
Engine speed [rpm]	3100	3400
Engine load [%]	80	100
Fuel consumption [L/h]	6.9	8.3

a 16% improvement in fuel efficiency (using the HSL2511 in standard mode).

3.4.2. Structure and control system

Figure 17 shows the FI structure.

In this system, the intake manifold pressure sensor detects the atmospheric pressure. Unlike an engine with a carburetor, this means it is unnecessary to change settings for operation at higher elevations.

The starting operation involves turning the key switch over to the starting position. It then returns automatically to the ON position, and the starter motor operates continuously for a maximum of five seconds to start the engine. With a system able to start in this way, it is no longer necessary to turn the key switch and hold it in the starting position.

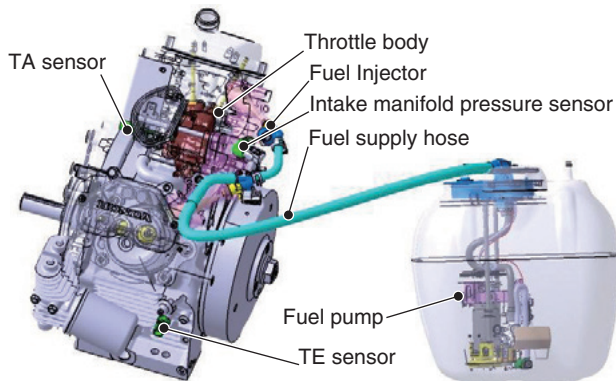


Fig. 17 FI system structure

4. Conclusion

Development of the HSL2511 large-sized snow thrower with a four-stroke V-twin engine and equipped with a smart auger, electric governor, and electronically controlled fuel injection system has achieved the following:

- (1) An auger height and rolling motor moves the snow-clearing system vertically and laterally using a control unit with built-in acceleration sensor to compute the inclination. This is also the first snow thrower in the world to be equipped with an auger-assist function that maintains the snow-clearing system at a constant inclination while in operation. This makes it easier even for beginners to form a smooth, level surface of cleared snow or a cleared surface with the desired slope. This has also reduced the frequency with which the

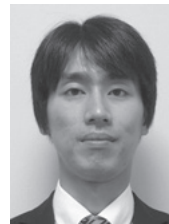
operator needs to operate the controls, and has improved workability.

- (2) With the adoption of an electric governor and an operation mode-change function that switches to different engine power curves according to various operating conditions, complex operations have become unnecessary and workability has been increased. The system also includes a speed-guide function that guides the operator to the optimal working speed. The operator thus becomes able to use the optimal speed to realize efficient snow clearing.
- (3) Installing a four-stroke V-twin engine equipped with an FI system has achieved a simplified starting procedure (fuel cock and choke operations are eliminated), reducing the burden on the operator. Furthermore, the increased working efficiency achieved by the various functions and the adoption of the new model chuter have together realized a 16% improvement in fuel efficiency.

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