

Development of Snow Thrower Control System with Engine Provided of Electronic Governor System

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ABSTRACT

An electronic control system has been developed to enhance snow removing performance, operability and fuel efficiency of medium-sized snow throwers mounting an engine provided with an electric governor. For efficient and perfect snow removal, proper control of working load and stable engine speed are required. The load control in this development uses engine throttle opening degree as a parameter of engine load detection, which enables real-time vehicle speed control which is required for load control. In a simulation of actual snow removal work, fuel economy of new system was enhanced 22% in the same area compared with that of existing hybrid snow thrower. In addition, mode control responding to usage is provided, which controls engine speed and vehicle speed automatically which was controlled manually in existing snow thrower. It has realized a user-friendly snow thrower for beginners.

1. Introduction

For those living in snowy regions, winter snow removal work is a serious issue. To ease the burden of this hard work, snow throwers have been developed for residential use.

Walk-behind snow throwers are composed of clearing parts that clear the snow and traveling parts that push the snow removal operational parts against the snow. The main components include the engine, which is the power source; an auger, which breaks up the snow; a blower, which throws the chopped snow; a chute, which guides the thrown snow; and a crawler, which moves the unit. Figure 1 shows the structure of the walk-behind snow thrower. During snow removal, the operator must carry out many operations – controlling the auger height according to the amount of snow, adjusting the chute in the direction and distance the snow is to be thrown, and controlling the traveling speed – which means that the operator must become familiar with the unit's operation.

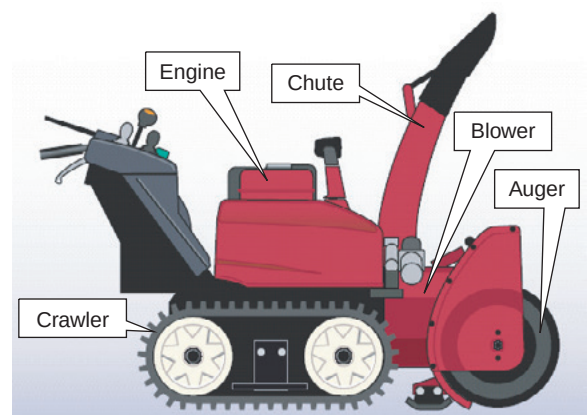


Fig. 1 Structure of walk behind snow thrower

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To make snow removal faster, simpler and more pleasant, Honda has developed the hybrid snow thrower HS1390i in 2000⁽¹⁾, adopting a series hybrid method, in which engine output is used to drive the snow removal parts and generate electricity, while the motor drives the traveling parts only, using the generated electrical power. The use of electronic controls achieves smooth start-offs and stops and smooth turning. At the same time, the engine speed that is carrying out the operation is detected, and load control automatically varies the traveling speed to the work load. When the engine speed drops in response to the work load, control is such that the traveling speed slows, reducing the amount of snow that is cleared, thereby reducing the load on the engine and minimizing the drop in engine speed.

This paper reports on the development of a control system introduced in the snow thrower HSM1590i, in which the iGX440 engine equipped with an electronic control function⁽²⁾ has been installed, and which incorporates new load and mode controls utilizing the features of an electronic governor⁽³⁾.

2. Snow Thrower Load Control

When a large amount of snow is stuck in the snow clearing parts, the engine load increases, and there are cases in which the engine speed does not just drop, but the engine actually stalls. In addition, if the snow is not completely cleared and the snow removal parts ride up onto the snow so that the body is floating, the snow removal parts can no longer be pushed against the snow, and the operator must repeat the operation after pulling the machine back. Furthermore, there are cases in which the snow removal surface is not completely cleared of snow and the snow removal procedure must be repeated. In these situations, work efficiency is poor, and it is necessary to control the amount of snow being cleared to enhance efficiency. By slowing the speed of the crawler, the amount of snow per unit time that goes into the snow removal parts can be reduced. That is to say, by controlling traveling speed in response to engine load, it is possible to operate efficiently.

2.1. Load Adjustments by the Operator

In the case of snow throwers that change engine power in the traveling parts using gears or Hydro Static Transmission (HST), traveling speed drops proportionally to engine speed. This relationship is shown in Fig. 2. However, in cases where there is an insufficient reduction in traveling speed against engine speed drop, together with an engine speed drop feel and snow removal parts riding up, the operator oneself will need to slow the traveling speed.

2.2. Load Control by Engine Speed

With the series hybrid snow thrower HS1390i, it is possible to freely control the traveling speed with the motor, regardless of the engine speed. That is to say, if it is possible to detect the engine load, the traveling speed can be automatically adjusted.

The engine installed in the working unit has a mechanism that automatically adjusts the carburetor throttle opening, maintaining a fixed engine speed. Many of these types of systems adopt a mechanical feedback control that applies a centrifugal governor mechanism. The GX390 engine fitted in the HS1390i uses the same mechanism. However, at the same time, an engine speed difference mechanically occurs in the GX390, according to the load. Figure 3 shows the engine's Wide Open Throttle (WOT) output characteristics and centrifugal governor's partial load output characteristics.

With the HS1390i, the centrifugal governor's characteristics are utilized, and engine speed changes are used as a means of judging engine load. The ratio of the reduction in traveling speed against engine speed is shown in Fig. 4. Using this control mechanism, it is possible to reduce engine stalls due to engine speed drops, and to reduce the occurrence of clearing parts riding up. However, when 9.4 kW at the full throttle output power of 3200 rpm is needed, centrifugal governor adjustments are carried out so that the operation is 3600 rpm at no load. When operating at partial load, the engine speed is faster than 3200 rpm, but if 3200 rpm is sufficient for the operation, there is wasted engine rotation, which leads to decreased fuel economy and more noise. Moreover, the blower motor speed changes according to engine speed fluctuations, which affects the distance snow is thrown.

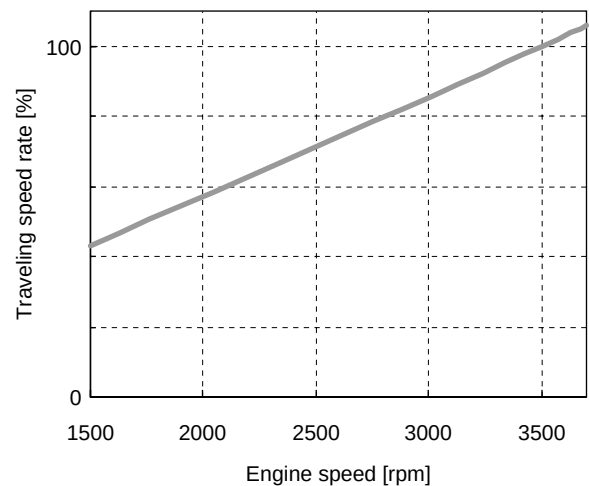


Fig. 2 Relationship between engine speed and traveling speed rate

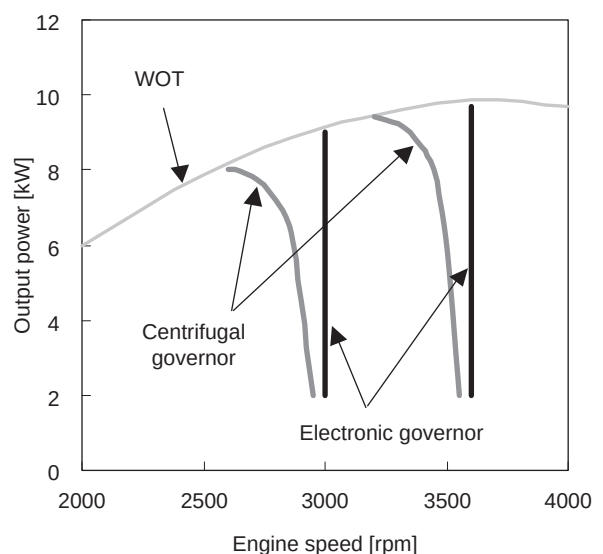


Fig. 3 GX390 engine performance

2.3. Load Control according to Engine Throttle Opening

Engines adopting the electronic governor system can operate at a fixed engine speed against target engine speed, regardless of load increases or decreases.

It is possible to obtain throttle opening information from the engine, when the engine installed has adopted an electronic governor controller system. According to this information, the engine load rate is controlled, and it is possible to operate at the set engine speed. This throttle opening is controlled by the electronic governor controller, and the throttle valve is driven by the stepping motor.

Figure 5 shows the relationship between the amount of snow cleared per unit time, as determined in practical use tests, and the stepping motor's step count controlling the throttle opening. When the stepping motor's step count is 102 pulses, the throttle is fully open. When the engine speed is 3600 rpm, the motor step count, in the no-load operational state where the clearing parts are only connected by the clutch, is 30 pulses. From these results, it is clear that 102 pulses is the maximum value at which engine speed changes do not occur, and 30 pulses is the state at which there is no operational load. At 3600 rpm, the motor step count with no operational load status is 30 pulses, but this value changes according to engine speed, so it is necessary to fully consider no operational load pulse counts for each engine speed.

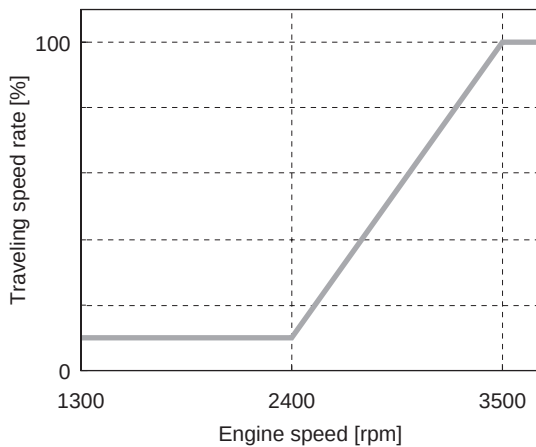


Fig. 4 Relationship between engine speed and traveling speed rate

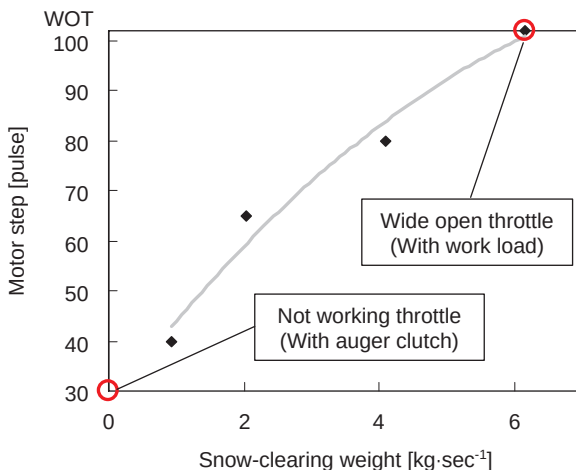


Fig. 5 Relationship between snow-clearing weight and motor step (Engine speed = 3600rpm)

Applying this to load control, step counts from 30 to 102 pulses become the range in which the throttle can follow the load. If traveling speed is controlled so that throttle opening is 30 pulses or more and 102 pulses or less, there will be no change in the engine speed. In addition, even when operational load changes occur, if the traveling speed can be varied so that the engine load, that is to say pulse count, is constant, the condition will be equivalent to rated operation. If engine load is stabilized, the engine throttle will not have to be fully opened and closed, and stable operation is possible.

In this way, by using throttle opening information, or stepping motor step count, in load control, the engine load state becomes known, traveling speed is controlled based on that load state, and load on the clearing parts is controlled before the engine speed drops enabling efficient operation.

3. Mode Control

When removing snow, the engine speed is set normally between 3000 rpm and 4000 rpm, speeds at which it is possible to obtain maximum engine power. This snow thrower is designed so that it is possible to operate at these engine speeds. When the snow thrower is not removing snow, for example when the clearing parts (auger and blower) are not operating while the unit is being moved, or when the unit is reversing during operation, little engine power is required.

For snow throwers that change speeds mechanically using gears or HST and use engine power to drive the traveling parts, even when no snow is being removed and there is little need for engine output, it is necessary to increase the engine speed to increase the traveling speed.

Snow throwers that adopt a series hybrid method have travel powered by the motor only, using generated electricity, so it is not necessary to have high engine speed to obtain fast traveling speed. Changing the set engine speed in response to the operational state, so that there are no unnecessarily high engine speeds, works to enhance fuel economy and to make the unit quieter.

With the HS1390i, fitted with the GX390 engine, by changing the governor spring load using wires, the engine target speed is set, and so to change the engine speed settings, it was necessary for the operator to carry out each operation.

With the newly developed control system, the use of the iGX440 engine fitted with an electronic control function that has adopted the electronic governor control system makes it possible to set the target engine speed, from the Electronic Control Unit (ECU) that controls the snow thrower system as a whole. Three operational modes are available as follows, adjustable to the way the snow thrower is used by the operator: Auto Mode, which automatically controls the traveling speed and engine speed to minimize operational procedures by the operator; Power Mode, which automatically selects the engine speed during operation, allowing more powerful snow removal; and Manual Mode, which allows the operator to control operations at will, with almost no automatic controls. In these modes, not only the target engine speed, but also the previously mentioned load control and other functions are switched.

3.1. Setting Engine Speed by Mode

The newly developed control system adopts a method wherein the operational state is recognized by the ECU, and the target engine speeds are adjusted automatically. The relationship between each mode and target engine speed is shown in Table 1.

Table 1 Operation models

Mode		Auto	Power	Manual
On working	Forward and auger on	Auto set 3000 [rpm]	Speed set by user 2000 - 4000 [rpm]	Speed set by user 2000 - 4000 [rpm]
	Reverse and auger on	Auto set 2000 [rpm]	Speed set by user 2000 - 4000 [rpm]	Speed set by user 2000 - 4000 [rpm]
Off working	Forward and auger off	Auto set 2000 [rpm]	Auto set 2000 [rpm]	Speed set by user 2000 - 4000 [rpm]
	Reverse and auger off	Auto set 2000 [rpm]	Auto set 2000 [rpm]	Speed set by user 2000 - 4000 [rpm]

3.2. Load Control by Mode

Load control when Auto Mode and Power Mode are selected reduces traveling speed based on throttle opening. However, when Manual Mode is selected, deceleration occurs only in proportion to the engine speeds shown in Fig. 2, so there is no feeling of the ECU arbitrarily reducing speed with respect to the traveling speed set by the operator. Figure 6 shows the traveling speed deceleration rate against the stepping motor step count of the engine throttle valve when Auto Mode is selected and when Power Mode is selected.

With the iGX440 engine, when the stepping motor's step count is 92 steps, the throttle is fully open.

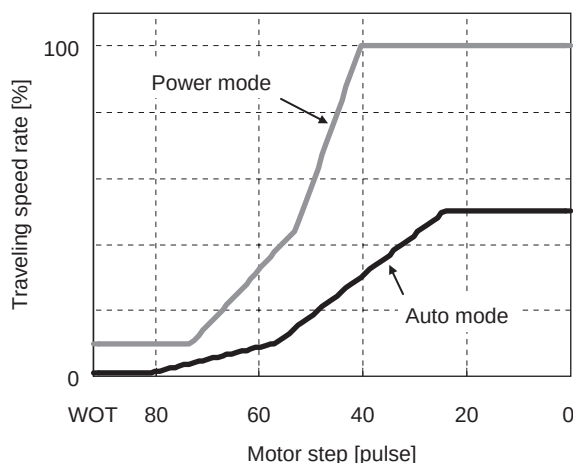


Fig. 6 Relationship between motor step and traveling speed rate

3.3. Auto Mode

In Auto Mode, by reducing traveling speed, clearing part ride-up is reduced and the engine speed, too, is kept at 3000 rpm, as shown in Table 1. The settings are such that quiet snow clearing is possible without traveling speed or engine speed adjustments.

Figure 7 shows data on engine speed, motor step count and traveling speed when clearing snow in Auto Mode. Engine speed is controlled at a fixed 3000 rpm by automatically reducing traveling speed as the motor step count, which expresses the engine load state, rises.

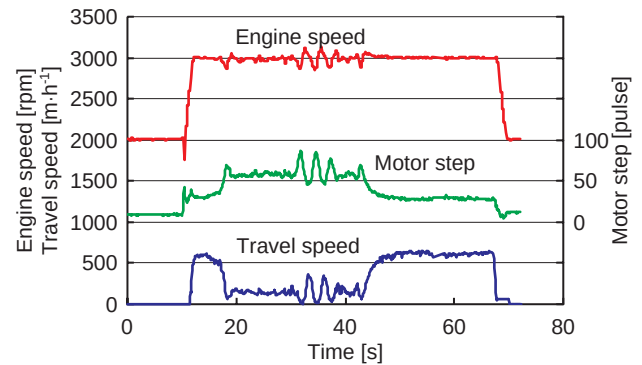


Fig. 7 Clearing snow in auto mode

3.4. Power Mode

In Power Mode, traveling speed is automatically adjusted to maintain engine output near its maximum. The operator can select engine speed at will, such as 4000 rpm, providing a maximum snow throwing distance; 3600 rpm, providing maximum engine output; or 2000 rpm, when quiet operation is desired.

Figure 8 shows data on engine speed, motor step count and traveling speed when clearing snow at an engine speed of 4000 rpm in Power Mode. Engine speed is controlled at a fixed 4000 rpm by automatically reducing traveling speed as the motor step count, which expresses the engine load state, rises.

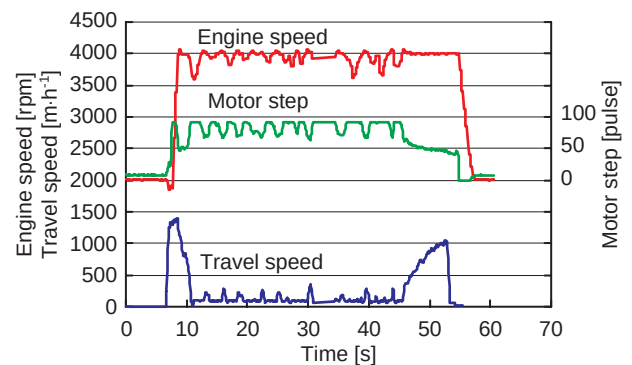


Fig. 8 Clearing snow in power mode

4. Fuel Economy Enhancement Effect

The system configuration is like that of the HS1390i snow thrower. Engine output drives the auger and blower, which clear the snow, while only the motor drives the crawler, which moves the snow blower, when a series hybrid method is used. In addition, there is data communication between the ECU, which carries out system control, and the iGX440 electronic governor control system. Figure 9 shows the system's schematic diagram.

In the newly developed system controls, there is an Auto Mode that automatically lowers engine speed when it is unnecessarily high by controlling the engine speed settings by mode. In addition, the HSM1590i snow thrower has better fuel economy than the HS1390i snow thrower, due to its better snow clearing efficiency. The benefits, with the same area and the same load rate, are outlined below.

Working conditions

- (1) Snow Clearing Surface Area: 128 m²
- (2) Load Rate: 80%
- (3) Deposited Snow: 0.4 m
- (4) Specific Gravity of Snow: 0.1
- (5) Actual Snow Clearing Width: 0.7 m
- (6) Engine Speed (HS1390i snow thrower): 3000 rpm
(HSM1590i snow thrower): Auto Mode

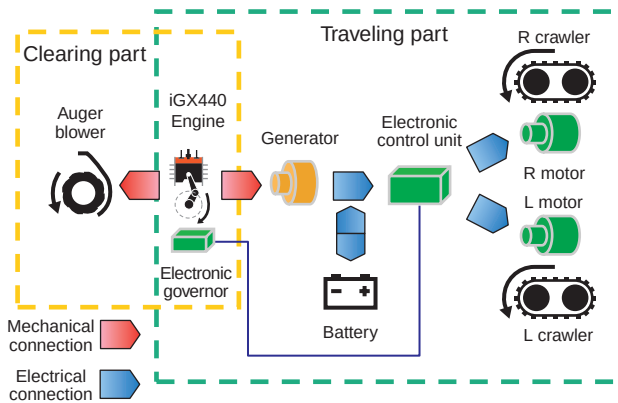


Fig. 9 System configuration

Maximum snow clearing capability at an engine speed of 3000 rpm is 79 ton/h and 92 ton/h, respectively. Snow removal operation speeds with an 80% load rate are 0.155 m/s and 0.18 m/s, respectively.

Tables 2 and 3 show fuel consumption when reverse speed for both is 0.5 m/s, a direction correction count is 56, and the time required to make the turns is 10s and 5s, respectively.

As a result, the fuel economy when clearing snow over the same surface area by the HSM1590i is enhanced 22% than that of the HS1390i. In addition, during actual snow removal, when operation loads are inconsistent, it is necessary to familiarize oneself with the unit's operation, in terms of the optimal traveling speed that allows maximum snow clearing capability. However, with the newly developed HSM1590i incorporating the control system, load control is carried out using the throttle opening, so the ECU automatically reduces traveling speed so that the load does not exceed the maximum snow clearing capability, meaning that even novice operators can remove the same amount of snow as an experienced operator.

Table 2 Fuel used by HS1390i

Mode	Time required [min]	Engine speed [rpm]	Fuel efficiency [L·h ⁻¹]	Fuel [L]
Clearing snow	19.7	3000	3.30	1.08
Reverse	4.0	3000	1.32	0.09
Turning	9.3	3000	1.32	0.21
Total	33.0			1.37

Table 3 Fuel used by HSM1590i

Mode	Time required [min]	Engine speed [rpm]	Fuel efficiency [L·h ⁻¹]	Fuel [L]
Clearing snow	16.9	3000	3.20	0.90
Reverse	4.0	2000	1.16	0.08
Turning	4.7	2000	1.16	0.09
Total	25.6			1.07

Figure 10 shows an external view of the HSM1590i snow thrower, fitted with the newly developed control system.



Fig. 10 External view of HSM1590i

5. Conclusion

The following advantages were achieved with the snow thrower incorporating the control system that utilizes the electronic governor controller features.

- (1) Stable snow throwing distances were achieved because constant engine speeds could be maintained, even with increases and decreases in load.
- (2) It was possible to detect load increases before the engine speed dropped, reducing instances of snow thrower ride-up and traveling speed adjustment operations by the operator.
- (3) Engine speed settings were automatically adjusted, and reduction of engine speed when high engine speeds were unnecessary resulted in a 22% enhancement in fuel economy and quieter operation.

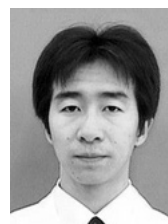
References

- (1) Hanafusa, J., Wakitani, T., Yamamoto, T., Inui, T.: Development of Hybrid HS1390i Snow Thrower, Honda R&D Technical Review, Vol. 14, No. 1, p. 31-38
- (2) Ito, K., Honda, S., Saito, T., Kurata, M., Naoe, G.: Development of Electronically Controlled Multi-purpose Engine iGX440, Honda R&D Technical Review, Vol. 17, No. 2, p. 44-51
- (3) Fukushima, T., Matsuda, H., Shinogi, Y., Taniguchi, Y.: Governor System for General Purpose Engine Using Adaptive Control Theory, Honda R&D Technical Review, Vol. 17, No. 2, p. 58-64

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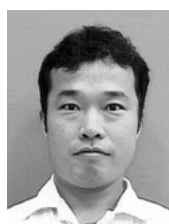
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