Introduction of Products

Introduction of Hydrostatic Transmission Forklift Model FH40-1/FH45-1/FH50-1

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The 4-ton class engine powered forklift truck, FH series FH40/45/50-1, have been developed and introduced into the market as Komatsu's first forklift truck installed electronic controlled HST (Hydrostatic Transmission) and variable pump CLSS (closed-center load sensing system). New technologies and outline of the improvement for fuel efficiency in the new models are introduced.

Key Words: *Forklift, HST, Hydrostatic Transmission, CLSS, Closed Center Load Sensing System, Low Fuel Consumption, Environment, Safety, ICT*

1. Introduction

In recent years, needs for low fuel consumption and reduction in environmental loads have rapidly increased in industrial vehicles and construction machinery due to growing global environmental awareness and a rise in crude oil prices. The response to the above has become an important element in the development and manufacturing of forklifts.

Introduced below is the outline of a new hydrostatic transmission forklift model "FH Series" (**Fig. 1**, **Table 1**) which has adopted electronically-controlled HST (Hydrostatic Transmission) in place of T/C (Torque Converter) + T/M (Transmission) used for travel drive system of conventional forklifts, has realized low fuel consumption and reduction in environmental loads, has improved operability and has been introduced to the market this time.

Fig. 1 External view photo of FH50-1

Table 1 Major Specifications

Item		Unit	Developed model FH50-1	Current model FD50AT-10
Performance and dimensions	Maximum load	kg	5000	5000
	Load center	mm	600	600
	Maximum travel speed	km/h	23. 5	25
	Wheelbase	mm	2000	2000
	Tread Front/Rear	mm	1225/1120	1150/1120
	Machine mass	kg	7380	7295
Engine	Manufacturer	-	Komatsu	Komatsu
	Model name	-	SAA4D95LE	SAA4D95LE
	No. of cylinders / Total displacement	-/cc	4/3260	4/3260
	Rated output	kW/rpm	50.8/2150	59.7/2400
	Fuel tank capacity	L	105	98
Information	ICT	-	KOMTRAX	-

2. Development Objectives and Means of Achievement

(1) Reduction in fuel consumption

Reduction in power transmission loss thanks to the electronically-controlled HST

Realization of low fuel consumption in high load work by controlling engine output in accordance with cargo weight

Reduction in oil pressure loss during simultaneous operation of load handling system and travel drive system thanks to CLSS + variable pump

(2) Improvement in operability and workability

Travel operation has become easier than that of T/C forklifts due to the adoption of electronically-controlled HST.

Improvement in workability during stopping, hill starting and switch-back operation

(3) Improvement in safety

Travel speed limiting function as standard equipment

(4) ICT

Installation of “KOMTRAX” as standard for the first time in forklifts

Fig. 2 General view of FH50-1

3. Main Components

Our unique hydraulic system “electronically-controlled HST”, which has been well proven in wheel loaders and bulldozers, has been installed in the travel drive system while “variable pump and CLSS” adopted for excavators has been installed in the load handling system.

The reliability and productivity have been enhanced by developing and manufacturing main components in-house, utilizing technologies nurtured through construction machinery including commonrail electronically-controlled diesel engines and machine body controller.

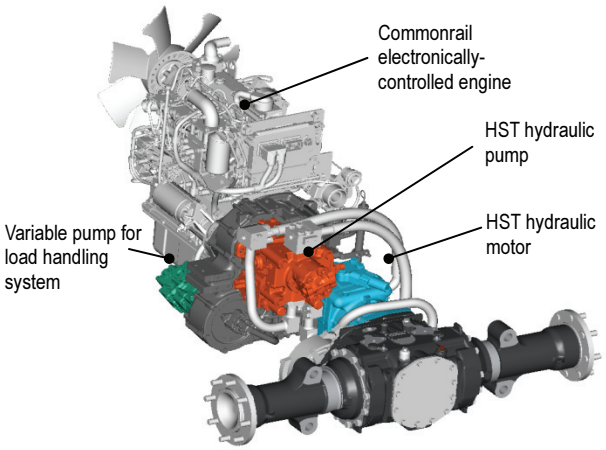

Fig. 3 Main components

4. Outline of System

4.1 Conventional forklift (with torque converter)

The structure of a general, conventional T/C forklift is shown in **Fig. 4**.

The clutch is attached to the output shaft of the transmission and when the inching pedal is depressed, power is shut off. If you want to travel forward slowly while operating the load handling system fast (simultaneous operation of load handling and travel), depress the accelerator pedal to increase engine speed and adjust clutch slip with the inching pedal to control the travel speed.

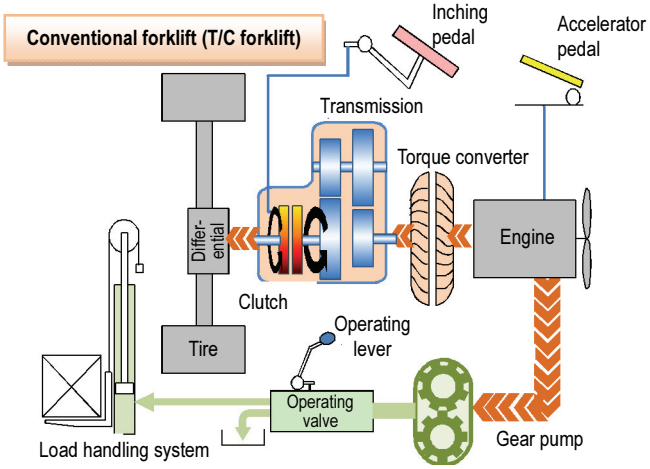

Fig. 4 System structure chart of general conventional forklift (T/C forklift)

In general, a gear pump is used for the hydraulic system of the load handling system, and because it is a fixed capacity type pump, a constant oil quantity is supplied according to engine speed regardless of the operation of load handling system.

4.2 New FH Series forklift (with HST)

The system structure of the new “FH Series” HST forklift is shown in **Fig. 5**.

The engine rotates the pump to produce oil pressure, which is converted again to turning force with the motor. A flow rate of hydraulic oil is continuously increased or decreased by changing the angle of the swash plate connected to the pistons to change the piston stroke. This swash plate angle control realizes the stepless speed control from forward travel, stop to reversing. When the swash plate is moved to the neutral position, the piston stroke stops, producing the same effect as the application of the brake.

When the inching pedal is depressed, the HST pump swash plate moves to the neutral position and the machine stops. During simultaneous operation of load handling and travel, depress the accelerator pedal to increase engine speed, change a HST pump capacity control signal from the controller with the inching pedal and adjust the swash plate angle (oil quantity) to control the travel speed.

A variable pump is used also for the hydraulic system of load handling system and supplies only a necessary quantity of oil with a signal from the operating valve.

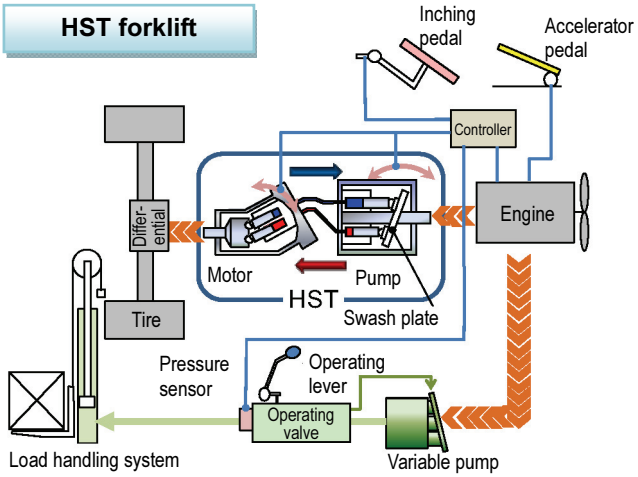

Fig. 5 System structure chart of HST forklift

5. Reduced Fuel Consumption

5.1 Usage of forklift

Forklifts are often operated in a limited place, and acceleration and stop (with change in travel direction, forward and backward), and simultaneous operation of load handling and travel are frequently performed. This type of usage is more remarkable in a worksite with higher load and higher rate of operation. As such condition also makes the fuel consumption larger, users have a keen interest in fuel consumption reduction. In consideration of such worksites

where fuel consumption reduction has a large merit to customers, the following fuel consumption reduction technologies have been incorporated.

5.2 Technology to reduce fuel consumption

(1) Reduction in heating loss and slip loss by HST

In simultaneous operation of load handling and travel of a T/C forklift, clutch slip loss and heating loss are produced because speed control is performed by controlling the clutch slip with the inching pedal. (**Fig. 4**)

On the other hand, on a HST forklift, the travel speed is controlled by changing the pump swash plate angle to reduce the oil flow rate instead of slipping the clutch. Therefore, heating loss and slip loss are not produced, resulting in fuel consumption reduction. (**Fig. 5**)

(2) High efficiency in low travel speed zone

In a torque converter (3 elements, 1 stage, dual phase type) used generally for forklifts, efficiency in the high travel speed zone is high due to a free wheel, but efficiency is worse than that of HST in the low travel speed zone due to large churning loss. (**Fig. 6**)

Therefore, on a HST forklift, control is performed to suppress the rev-up of engine while improving the acceleration performance, reducing fuel consumption during acceleration without changing traveling performance.

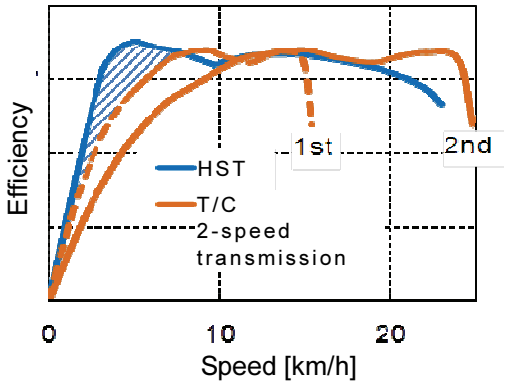

Fig. 6 Travel efficiency

(3) Optimization of engine output

From the above (1) and (2), the engine maximum output can be reduced by approximately 15% compared to that of the conventional T/C forklift with almost no loss of workability, which results in reduction in fuel consumption. ((3) in **Fig. 7**)

(4) Low-speed matching

In general, the fuel consumption rate near engine speed where the maximum torque can be obtained is smaller than that near engine rated speed.

The matching point of HST pump absorption torque with respect to the engine has been set near the maximum torque as compared with that for the torque converter. This allows for long use of the range where the fuel consumption rate is small to the extent possible during acceleration, leading to fuel consumption reduction. ((4) in **Fig. 7**)

(5) Switching of engine torque curve under no load

On a forklift, the machine body weight difference is large between when it has a load (under load) and when it does not have a load (under no load). To suppress needless acceleration under no load, a sensor detects weight of a load and when the load is light, engine output is suppressed, which leads to fuel consumption reduction. ((5) in **Fig. 7**)

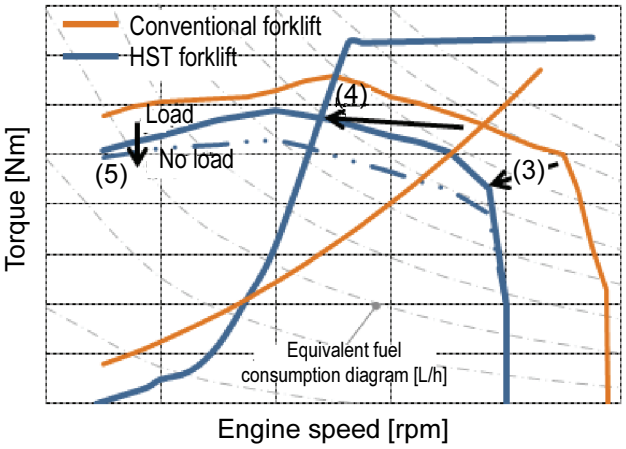

Fig. 7 Matching diagram with engine

(6) CLSS (Closed-center Load Sensing System) + variable pump system

The CLSS + variable pump system has been installed in our conventional machines and has contributed to reduction in fuel consumption.

As a gear pump (fixed capacity) is mainly used for the hydraulic system of the load handling system for general forklifts, an oil quantity more than necessary is supplied, which produced large loss.

The CLSS + variable pump system has been adopted for HST forklifts as with our conventional forklifts. Oil pressure loss is small because only a necessary quantity of oil is supplied by performing control so that differential pressure between pump discharge pressure and load pressure of each load handling system is constant when the load handling system is operated. (**Fig. 8**)

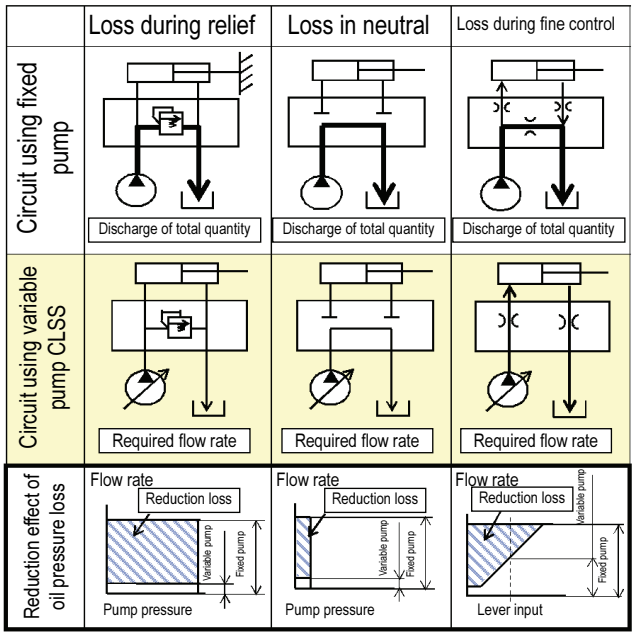

Fig. 8 Reduction effect of oil pressure loss of load handling system

6. Result

6.1 Reduction in fuel consumption

Fig. 9 shows the fuel consumption reduction effect at in-house measurement courses.

The fuel reduction effect was obtained in any course. In particular, the effect of no less than 29% was obtained at a high load course (Course A) where there is a lot of switch back in a short distance assuming loading work to a truck.

Fig. 11 shows the frequency distribution of engine speed and torque at the high load course (Course A). This shows that as a circle is larger, the frequency is higher. It can be seen that large circles move to the small fuel consumption side as compared with those for the conventional forklift. In particular, HST forklift used the range where there was little change in engine speed during acceleration and fuel consumption was small for a long time. Therefore, the result as intended was obtained.

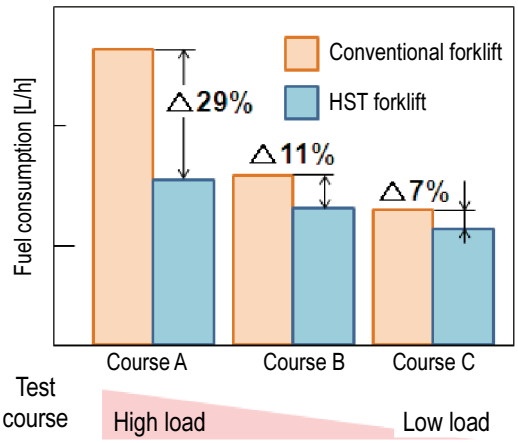

Fig. 9 Result of fuel consumption reduction at in-house courses

According to high load user data at a paper mill where HST forklifts were introduced on a trial basis, a maximum of 30% fuel consumption reduction compared to our conventional forklifts was accomplished. (**Fig. 10**)

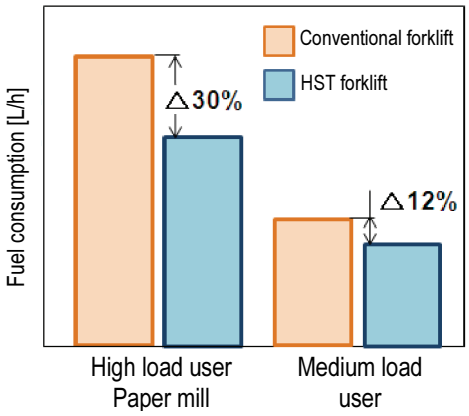

Fig. 10 Result of fuel consumption reduction at user's worksites

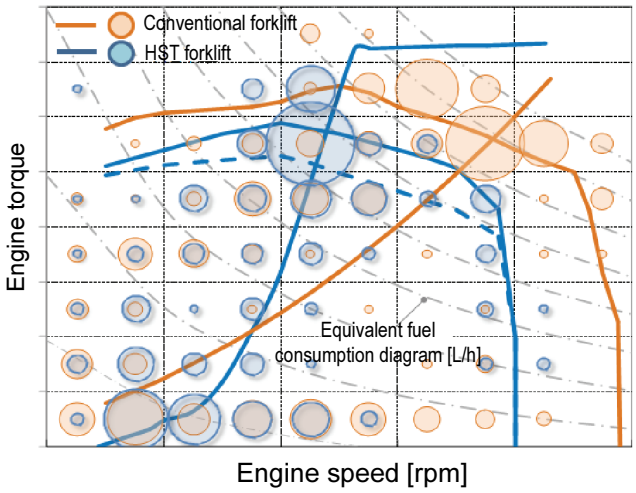

Fig. 11 Frequency distribution and fuel consumption map at high load course

Type of business in which HST forklift is effective for decreasing fuel consumption (**Fig. 12**)

Handling business of recycled resources (wastepaper)

Bale clamp

Handling business of timber and woodwork

Hinged fork

Handling business of recycled resources (general)

Hinged bucket

Handling business of concrete secondary product

Hinged fork

Fig. 12 Example of type of business where forklifts are used

6.2 Improvement in operability and workability

On the electronically-controlled HST, the swash plate is controlled continuously at the time of change between forward travel and backward travel so that the change can be performed without a shock without stopping once and with the accelerator pedal kept depressed. Thus, the brake operation like conventional forklifts is not required.

In addition, the braking by setting the swash plate in the neutral position, a characteristic of HST, reduces rolling down of the machine on a slope, contributing to the reduction of fatigue of an operator.

6.3 Safety

The travel speed limiting function is equipped as standard. The maximum speed can be set to four stages with respect to the speed control in a limited space, speed limit specified in a plant, and so on.

6.4 ICT (Information and Communication Technology)

The machine remote monitoring system “KOMTRAX” has been installed as standard in forklifts for the first time. “Visualization” of machine information such as the location, operating condition and fuel consumption has allowed to support the fleet management with meticulous attention.

7. Conclusion

In cooperation with Power Train Development Center and Hydraulic Equipment Technical Center, we have realized commercialization of forklifts installed with electronically-controlled HST and CLSS hydraulic system for the first time as Komatsu.

We will continue to make efforts to expand the model lineup installed with HST and CLSS in the future and at the same time to aim at further technological leaps to develop these models to be more attractive to customers.

Introduction of the writers

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[A few words from writers]

We think we have completed the competitive forklifts by concentrating the Komatsu technologies thanks to the merger of the utility equipment businesses in 2011.

We would like to express our deep gratitude to IPA, Hydraulic Equipment Technical Center, Power Train Development Center, System Development Center, Test Engineering Center, and Tochigi Plant and other production departments, not to mention the customers and distributors who helped our researches.