

Introduction of Products

Hydro Static Transmission Forklift Models FH100/FH120/FH135/FH160-1

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Following products such as the hydro static transmission forklifts FH35/40/45/50-2, FH60/70/80-2, Komatsu has been introducing 10-16t hydro static transmission forklifts conforming to the Japanese Regulation of Emissions From Non-road Special Motor Vehicles (2014), and the European EU Stage IV emissions regulations to the Japanese, and Australian markets since 2017. In addition to our cultivated fuel consumption reduction technologies, these 10-16t hydro static transmission forklifts are featured with the latest safety and Information and Communication Technology (ICT) to promote further evolution. In this report we like to introduce the features of the new products.

Key Words: *Forklift, Emissions regulations, Environment, Safety, ICT, Electronic control hydrostatic transmission (HST), Closed center load sensing system (CLSS), Low fuel consumption*

1. Introduction

Due to the global rise in environmental consciousness and soaring crude oil prices in the recent years, the needs of fuel-efficient and environment-friendly industrial vehicles are growing. To meet these needs, we introduced the 4-5t class FH 40/45/50-1 of FH Series hydraulically driven forklifts, featuring significant improvement in fuel efficiency and operability, into the market in July 2012. Thereafter, the 3.5t and 6-8t class forklifts were made series products.

This report outlines the new 10-16t class FH100/120/135/160-1 forklifts with further improved operability, which have been introduced into the market in order to comply with the new emissions regulations and to expand the lineup to include upper class models.

To conform to the 2014 regulations of the Act on Regulation, Etc. of Emissions From Non-road Special Motor Vehicles, the machines of this series are equipped with an exhaust gas aftertreatment device that greatly reduces NOx and particulate matters (PM).



Fig. 1 Appearance of FH160-1

Table 1 Main specifications

Item		Unit	Development model FH160-1	Existing model FD160E-8
Performance and dimensions	Maximum load	kg	16000	16000
	Maximum travel speed	km/h	23.5	32
	Wheelbase	mm	3050	3100
	Vehicle weight	kg	18500	17440
Engine	Manufacturer	-	KOMATSU	KOMATSU
	Model name	-	SAA4D107E Stage 4 regulations	SAA6D107E Stage 3 regulations
	Cylinder/total piston displacement	-/cc	4/4460	6/6690
	Gross rated output	kW	110	129
Information	ICT	-	KOMTRAX	-
Fuel consumption	In-house specified course (vs. existing model)	-	70	100

2. Aims of Development

- (1) Environmental compliance
 - 1) Gained compliance with the Japanese 2014 emission standards (EU Stage IV)
 - 2) Achieved a significant reduction of fuel consumption up to 30% (vs. existing model FD160 E-8)
- (2) Improve the operability and safety
 - 1) Improved the traveling operability by adopting electric control hydrostatic transmission (HST)
 - 2) Improved the operability in non-creep travel, starting on slope, and switch-back
 - 3) Improved the fine traveling performance at cargo handling and dock work
 - 4) Reduced the burden to the operator by standard equipment of hand control levers and large armrest *
 - 5) Standard equipment of travel speed limiting function
 - 6) Optional seat belt interlock function added *

- (3) ICT
 - 1) Improved the visibility and increased functions by installing a color Liquid Crystal Display (LCD) multi monitor
 - 2) Improved the functions of KOMTRAX, a standard equipment since FH Series
 - 3) Improved the vehicle backward visibility through the optional rear view camera and monitor *
- (4) Improve the maintainability
 - 1) Adopted a large inspection cover *
 - 2) Adopted side-by-side cooling

* : Newly installed on FH100/120/135/160-1

3. Selling Points

3.1 Environment

3.1.1 Compliance to emissions regulations

These machines are compliant with the stage 4 emissions regulations of Japan and Europe. Table 2 summarizes the emissions gas regulations and the years of implementation in this class of Japan.

Table 2 Comparison between emissions regulation values (Japan)

		Development model Stage 4 regulations	Existing model Stage 3 regulations
Regulations effective since		October 2015	October 2012
Regulation value (g/kW·h)	NOx	0.4	3.6
	PM	0.02	0.2

Various new technologies, as detailed below, were incorporated into the engine in order to realize the economic performance and make it maintenance free in addition to satisfying the said emissions regulations.

- Aftertreatment device

The amounts of PM and NOx in the exhaust gas were greatly reduced by combining the newly developed Selective Catalytic Reduction (SCR) system and the Komatsu Diesel Oxidation Catalyst (KDOC). The SCR system decomposes NOx into nitrogen (N₂) and water (H₂O), which are both harmless. It injects AdBlue®* into the exhaust gas and causes the ammonia produced from AdBlue® react with the NOx in

the SCR catalyst, thereby decomposing it into nitrogen and water. (Fig. 2)

* AdBlue® is a registered trademark of the German Automobile Manufacturers Association (VDA).

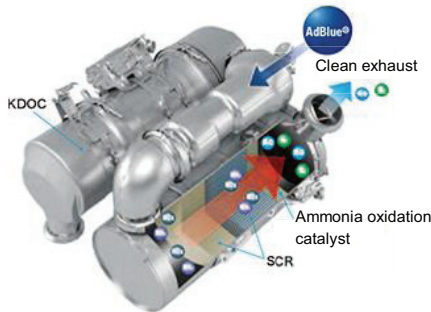


Fig. 2 Exhaust gas aftertreatment device

In addition, this device is equipped with a KDOC, which is a highly efficient oxidation catalyst, and has a simple structure without a soot filter; therefore, it does not require regeneration control or periodic maintenance for removal of soot.

▪ Electronic control system

By adopting a newly developed engine controller, the newly developed SCR system can be controlled with high accuracy, thus realizing the optimal control of the machine body. The stage 4 emissions regulations (EU Stage IV) include SCR Inducement provisions, which require the engine output to be limited when the remaining AdBlue® drops to a very low level. The function of the troubleshooting system was further advanced in order to comply with this SCR Inducement.

The engine status is shown on the multi monitor through the on-board network.

Furthermore, optimal maintenance can be implemented by managing the above information with KOMTRAX.

3.1.2 Reduced Fuel Consumption

Forklifts often operate in a narrow place and are frequently required to perform acceleration and stop (switch between forward and backward travel) or combined operation of container handling and traveling. In particular, the higher the load or operation rate at the site (e.g. land transportation, container handling), the more the above working condition becomes noticeable. Since the fuel consumption increases, the users' interest in reducing the fuel consumption will also be great. Assuming a work site where the benefit to the user by reducing the fuel consumption will be large, a model course (Fig. 3) has been specified as an in-house reference standard.

By incorporating the following technologies, we achieved fuel consumption reduction up to 30% on this course.

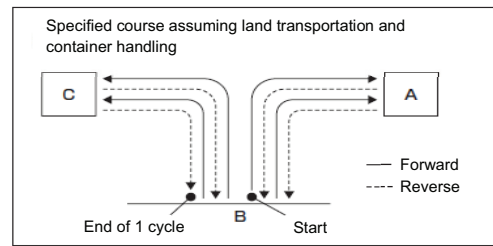


Fig. 3 Course assuming land transportation and container handling

- (1) Adopting the travel electronic control HST plus the work equipment variable pump Closed-center Load Sensing System (CLSS)

When the work equipment is operated while traveling on a conventional vehicle with a torque converter, the speed must be controlled by adjusting the clutch slip with the inching pedal. This causes losses due to clutch slip and friction heat. It also generates idle rotation loss of the fixed capacity gear pump of the work equipment at the same time. On the other hand, for electronic control HST vehicles, instead of slipping the clutch, the angle of the pump swash plate is changed to reduce the oil flow and control the travel speed. Therefore, neither heat loss nor slippage loss occurs, resulting in reduced fuel consumption. (Fig. 4)

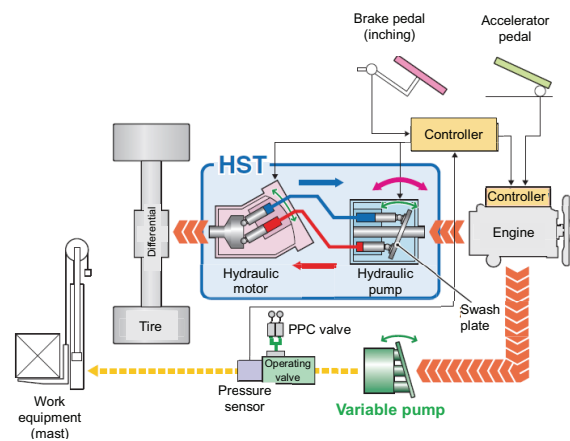


Fig. 4 Electronic control HST vehicle system configuration diagram

A work equipment variable pump CLSS is adopted to control the differential pressure between the pump discharge pressure and the load pressure of each working machine to be constant when the work equipment is operated. Since only the necessary amount of oil is supplied, the hydraulic loss is small. (Fig. 5)

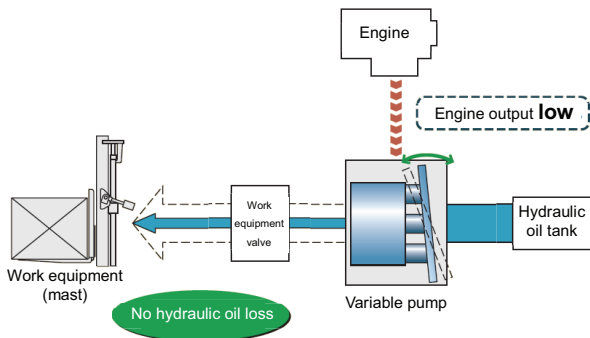


Fig. 5 Variable pump CLSS system configuration diagram

(2) Optimizing the engine rated output (from 129 to 110 kW)
 Since the electronic control HST can reduce power transmission loss, the engine output can be reduced to lessen wasteful fuel consumption. Sufficient power performance can be exhibited by controlling the engine speed and HST pump flow rate optimally. (Fig. 6 (2))

(3) Engine low-speed matching during accelerated travel
 In general, the fuel consumption ratio near the engine rotation speed at which the maximum torque can be obtained is smaller than that near the engine rated rotation speed. The matching point of the absorption torque of the hydraulic pump with respect to the engine was set closer to the maximum torque rather than the absorption torque of the torque converter. This enables using the range of small fuel consumption ratio for the longest possible time, leading to the reduction of fuel consumption during acceleration. (Fig. 6 (3))

(4) Engine output control matching the load weight
 The sensor detects the load and the engine output is automatically controlled. When the load is light, the output is switched to a lower setting to suppress wasteful fuel consumption. (Fig. 6 (4))

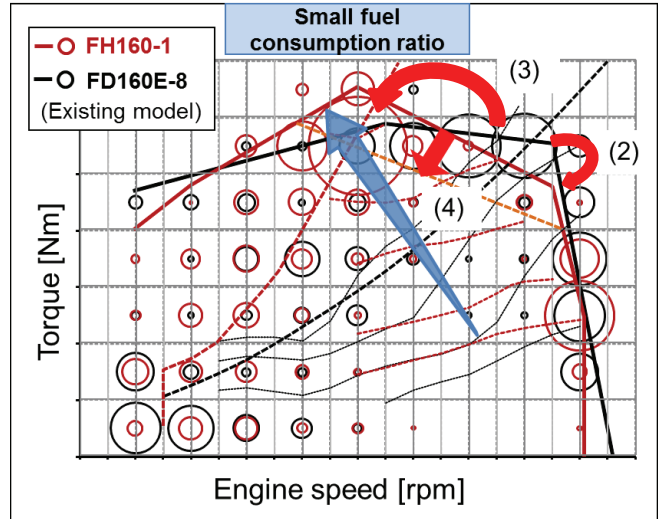


Fig. 6 Diagram of the matching with the engine

(5) Auto engine stop function
 The vehicles are equipped with an auto engine stop function as standard. If the operator forgets to stop the engine before leaving the vehicle, the engine will automatically stop when the set time has elapsed, resulting in holding the wasteful fuel consumption low. (Fig. 7)

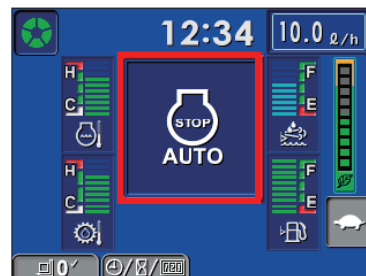


Fig. 7 Auto Engine Stop Operation screen

3.2 Operability and Safety

3.2.1 Improved traveling operability by adopting electronic control HST

(1) Improved the operability in non-creep travel, starting on slope, and switch-back
 Like the conventional FH Series models, the electronic control HST can control the swash plate angle continuously enabling the driver to switch the traveling direction with no shock without operating the brake even when the accelerator pedal is depressed. The braking effect obtained when the swash plate is in its neutral position, which is a feature of the system, reduces rolling down of the vehicle on a slope, and reduces the fatigue of the operator. It can be expected that the vehicles will get a good reputation.

(2) Improved the fine traveling performance at dock work and cargo handling

When gaining access to and stopping before load, shelves, etc., the speed can be smoothly controlled by accelerator pedal operation only. The less need of inching operations reduces the fatigue of the operator. Since the HST decreases the oil flow to the motor to slow down the vehicle when the accelerator pedal is released, the speed can be controlled without doing a lot of inching (braking). (Fig. 8)

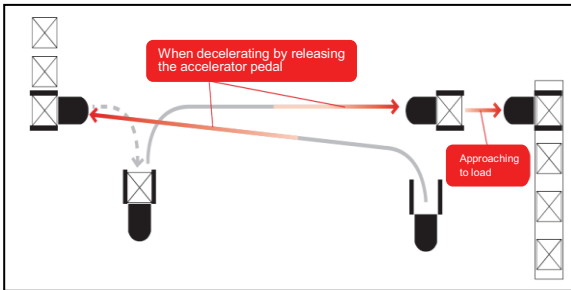


Fig. 8 Work requiring fewer inching operations

In this development, deceleration control by releasing the accelerator pedal has been improved, and the vehicles have been made possible to gain access to or stop in front of load or shelves more smoothly.

3.2.2 Reduced the burden to the operator by standard equipment of hand control levers and large armrest *

The easy-to-operate, fatigue-reducing levers for controlling the work equipment at the hand position together with the large arm rest can minimize the operator's fatigue. (Fig. 9)



Fig. 9 Levers and large arm rest for controlling the work equipment at the hand position

3.2.3 Standard equipment of travel speed limiting function

With the travel speed limiting function equipped as standard, the travel speed can be held low for working in a narrow space, and the maximum speed can be set to one of four steps according to the speed limit specified in the plant. (Fig. 10)



Fig. 10 Travel speed limit setting screen

3.2.4 Optional seat belt interlock function added

Many forklift operators feel that wearing the seatbelt is troublesome because they have to get on and off the vehicle frequently. However, tipping over accidents often occur. To ensure that the operator wears the seat belt, an optional interlock is provided to prevent traveling and container handling unless the operator sits in the seat correctly (Fig. 11 (1)) and wears the belt properly (Fig. 11 (2)).

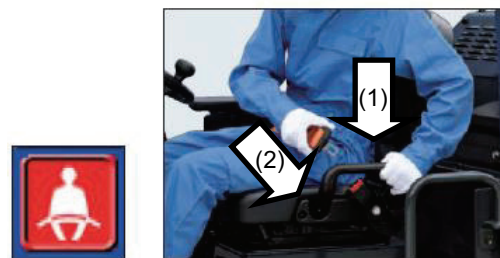


Fig. 11 Interlock function

If the seat belt is removed during machine operation, the machine stops traveling and container handling. Since this ensures that the operator wears the seat belt when getting on the vehicle, serious accidents will be prevented when the machine tips over.

3.3 ICT

3.3.1 Improved visibility and increased functions by installing a color LCD multi monitor

With a color LCD multi monitor installed, the visibility of vehicle information has been greatly improved.

- Speedometer/load meter

Some improvements are incorporated: for example, the speedometer and load meter, which were options in the conventional models, are equipped as standard.

- Rear wheel tire steer angle indication

On large forklifts, it is difficult for the operator to check whether the rear wheel tires are faced in the straight direction while sitting in the operator's seat. For the new models, the rear wheel tire angle is shown on the monitor to enable the operator to see that the steering wheel has been turned to the desired direction and to improve the safety for moving the vehicle. (Fig. 12 (1))

- ECO gauge / average fuel consumption

The new modes are equipped with a fuel consumption meter that indicates the ECO gauge and average fuel consumption at all times on the monitor screen. In addition, more fuel-efficient driving can be supported by optionally setting the fuel efficiency target value (in the range of green display). (Fig. 12 (2))

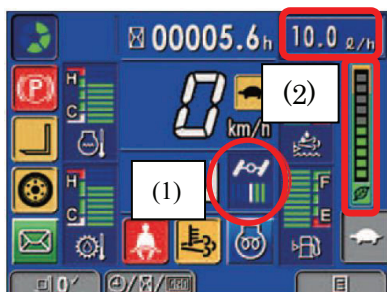


Fig. 12 Color LCD multi monitor

3.3.2 Functional Improvement of KOMTRAX

The KOMTRAX allows the customer to know the operating status of the vehicle. In addition to vehicle information such as position information, operating status, and fuel consumption, it is now made possible to know the consumption amount of AdBlue® KOMTRAX, to control the consumption of AdBlue® which is required for the exhaust gas aftertreatment device newly adopted in this development.

3.3.3 Improved vehicle backward visibility with the optional rear view camera and monitor

A viewing camera is equipped at the rear of the machine body (Fig. 13), and the backward view from the vehicle can be clearly viewed on a 7-inch LCD monitor (Fig. 14). This function allows the operator to check the situation behind the vehicle (at a glance) which cannot be checked in a direct view. The operator's burden of safety check can be reduced.

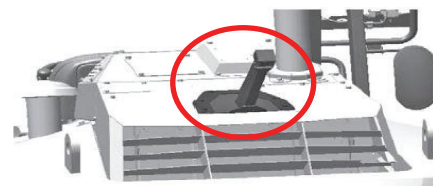


Fig. 13 Rear view camera



Fig. 14 Rear view monitor

3.4 Improved Maintainability

3.4.1 Adopted a large inspection cover

Aiming at improving the maintainability, the necessity of climbing to high places have been eliminated, and the daily maintenance (start-up inspection) items have been gathered under the side covers on the left and right of the machine body, which are accessible from the ground. Each side cover can be opened and closed easily without any tool, and inspection steps are provided so that the inspector's can easily reach inside the cover. (Fig. 15)



Fig. 15 Large inspection cover

3.4.2 Adopted side-by-side cooling

The radiator, air cooling aftercooler and the hydraulic oil cooler are arranged in a row horizontally for side-by-side cooling. They can be easily cleaned by blowing air or steam from the counterweight part at the rear of the machine body. (Fig. 16)

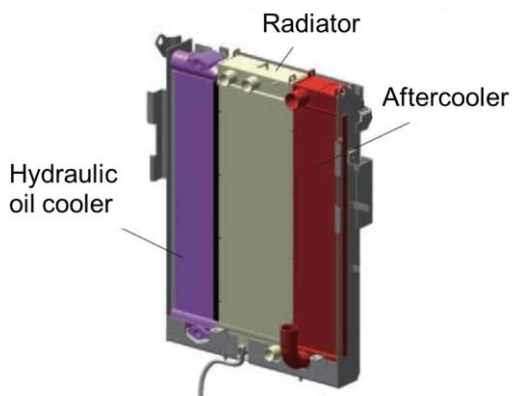


Fig. 16 Side-by-side cooling

4. Conclusion

Since the launch of FH35/40/45/50-1 that were equipped with the electronic control HST plus variable pump CLSS and became Komatsu's DANTOTSU products, we have incorporated market needs and various new functions into the further developed FH100/120/135/160-1 models that have been realized as products. This has completed the FH Series from 3.5t-6t. By continuing to evolve and grow the FH Series from now on, we would like to offer attractive products that will make our customers more satisfied.

Introduction of the authors



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[A comment from the authors]

Though the development schedule was tight, we succeeded in implementing a full model change for the first time in ten years as well as gaining compliance with the Tier 4 Final regulation. This is the first series of forklift models equipped with the SCR, and we believe that these products can be said to be the culmination incorporating various features of the FH Series.

We would like to express our gratitude to everyone who contributed to this development.