Introduction of Products

Electric Forklift Truck Model FE25/30-2

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We have developed an electric forklift truck FE25/30-2 that can be used both indoors and outdoors. In addition to the features of conventional model FE25/25H/30-1 released in April 2014, this product has achieved an equivalent driving performance to diesel forklift truck and has further improved safety and comfort while maintaining an environmental performance and compactness. In this report, we would like to introduce the main features of this new product.

Key Words: *FE25-2, FE30-2, Electric forklift, Fast-charging, Easy maintenance battery, Sealed wet type brake, High voltage, Stationary fast charger, Travel speed limit when turning, Slope warning, Accelerator one-pedal mode, Cab*

1. Introduction

Komatsu is considering reaching carbon neutrality in the 2050s, with the target of reducing CO_2 emissions by 50% in the 2030s (vs. FY2010) in order to reduce greenhouse gases. The FE25/25H/30-1 series has been sold as a core product of the forklift business to replace diesel vehicles. It has led the way in the Japanese market of 2.5 and 3 t class batteries in line with 2014 standard emission regulations for Japan coming into effect. However, it was not able to cover the needs of some users for long-distance or uphill driving outdoors, so the transition away from engine vehicles was not moving forward. Against this background, we have developed the FE25/30-2, which combines environmental, economic, performance, safety, and comfort features. Here is an overview.

Fig. 1 FE25/30-2 (Figure is of FE25-2)

2. Aims of development

The FE25/30-2 continues with the distinctive features of the previous model FE25/25H/30-1. These include a fast-charging system that enables long-term operation, easy maintenance battery that eliminates the troublesome filling of battery water, opening the battery hood and other charging preparation tasks, water and dust resistant structure that enables outdoor work, ICT function (Komtrax) that tracks the operating condition of the vehicle and contributes to the confidence and trust of customers. The FE25/30-2 has significantly increased product appeal by improving driving performance, safety, economy, and comfort in order to provide more value than engine vehicles.

Below are some of the distinctive structures and functions newly adopted for FE25/30-2.

(1) Improved environmental friendliness and economy
- Sealed wet type brake

(2) Performance improvement
- Travel performance and road-handling comparable to engine vehicles

(3) Improved safety
- Fast charger (high voltage compatible, improved Electromagnetic Compatibility (EMC) performance)
- Travel speed limit when turning linked to the amount of steering
- Slope warning, tipping over notification, collision detection alarm system

(4) Improved comfortableness
- Accelerator one-pedal mode
- Cab

3. Major features

3.1 Improved environmental friendliness and economy

3.1.1 Sealed wet type brake

2.5 and 3 t class forklifts are often used in the fishing industry, and the braking performance was difficult to stabilize in the operating environment where water pours onto the conventional drum brakes. To solve this problem, the FE25/30-2 is equipped with a sealed wet type multiple disc brake that has a proven track record in our FH series and WA series (**Fig. 2**).

Fig. 2 Sealed wet type multiple disc brake

(1) Waterproof and dustproof

Enclosing the brake unit inside the drive axle prevents foreign matter such as water and dust from entering the brake. This enables consistent stable braking.

(2) Environmental hygiene

Preventing brake dust from scattering outside of the drive axle contributed to the improvement of environmental hygiene at the operation site.

(3) Maintenance

Compared to the previous model, the replacement interval for worn parts has been increased by at least 5 times. This almost eliminates the need for periodic maintenance other than oil changes.

(4) Brake hydraulic system

In the new output system a reduction gear is placed between the brake and the tire output section, and the braking force is increased by the gear (**Fig. 3**). This not only made the brakes much more compact, but also eliminated the need for a booster using an oil pump or pump drive motor, making it possible to adopt a brake hydraulic system that eliminates losses such as a pump drive and accumulator. This helped to improve electricity costs and operating time.

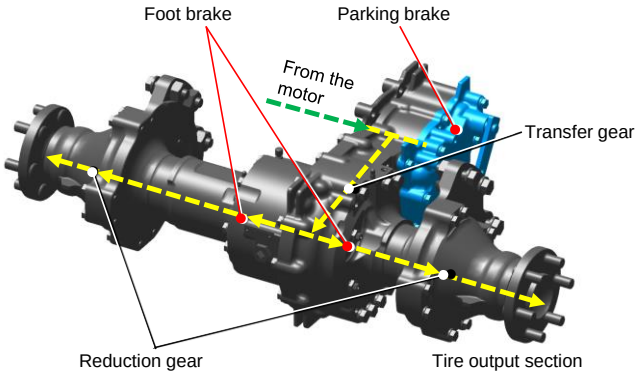

Fig. 3 Drive axle brake and gear layout

3.2 Performance improvement

3.2.1 Travel performance and road-handling comparable to engine vehicles

The FE25/30-2 has improved outdoor workability by matching the travel performance and road handling of a conventional diesel forklift.

(1) Travel performance

Conventional electric forklift have made the vehicle compact by reducing the output of the travel motor, enabling long-term operation. That makes it slow down due to a gentle drainage slope of 1 to 2° outdoors, which appears flat at first glance, the operating efficiency deteriorates when traveling a long distance, and it decelerates even on a steep slope of 9 to 12°. So it was not possible to travel uphill smoothly like a diesel forklift.

Therefore, the FE25/30-2 has a compact body size by changing the battery voltage to 108 V (FE25-2) / 120 V (FE30-2) and developing a new compact high-output motor with high voltage and high rotation. This made it possible to achieve the same power and smoothness as a diesel forklift (**Fig. 4**).

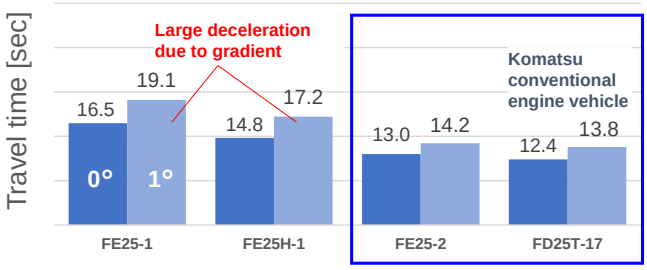

Fig. 4 Accelerating ability from standstill (0–50 m travel time under load [gradient 0°, 1°])

(2) Road handling

For uneven road surfaces outdoors, by achieving the same minimum ground clearance and rear wheel tire size as engine vehicles, the vehicle is less prone to bottoming out on road surfaces, dragging foreign objects on the road surface, and gets over steps better (**Table 1**).

Table 1 Dimensional comparison of road handling

		2.5 t			3.0 t		
		FE25-2	FE25-1	FD25-17	FE30-2	FE30-1	FD30-17
Minimum ground clearance	mm	164	115	164	195	149	191
Ramp angle	°	24	17	23	26	20	25
Rear wheel outer diameter	mm	534	469	534	588	535	588

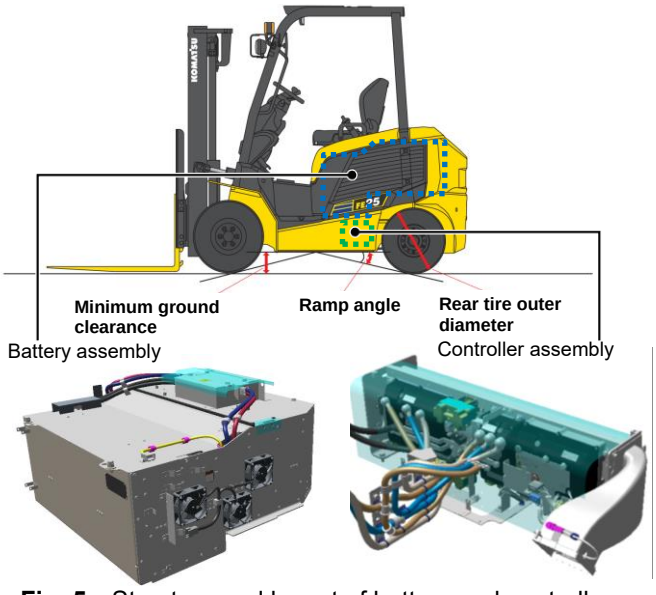

Fig. 5 Structure and layout of battery and controller

By significantly adapting the layout of the controller assembly and the shape of the battery assembly in the frame, the height of the operator's seat and the floor height were produced without changes from the previous model (**Fig. 5**).

(3) Compatibility of travel performance and operating time

In addition to the conventional L (low), M (middle: default), and H (high) power modes which set the maximum speed and strength during travel, the FE25/30-2 has P (powerful) mode which produces travel performance equivalent to an engine vehicle (**Fig. 6**).

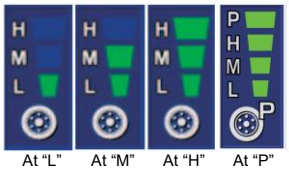

Fig. 6 Travel power mode monitor display

Reducing the power consumption as follows at the same time as increasing the output achieves the same operating time as the default M mode of the previous model even in P mode. In addition, compared to the M mode, we achieved a 10 to 20% improvement in operating time compared to the previous model in both the light load JIS course and our high load loading work course.

- Improved efficiency by increasing the motor voltage
- Vehicle weight reduction (FE25-2: -60 kg, FE30-2: -180 kg)
- Enhanced regeneration during deceleration with accelerator one-pedal mode (Explained in 3.4.1)

Furthermore, setting the new option "Automatic switching of power mode for uphill travel" that automatically switches the travel power mode to P (powerful) mode when approaching a slope achieves both improved workability and energy savings (**Fig. 7**).

Fig. 7 Automatic switching of power mode for uphill travel

3.3 Improved safety

3.3.1 Stationary fast charger

A fast charger that enables charging in a short time is required for long-term operation and high-load working conditions. Here we have developed a fast charger that can handle the higher voltage that accompanies increased vehicle body output (**Fig. 8**) (**Table 2**).

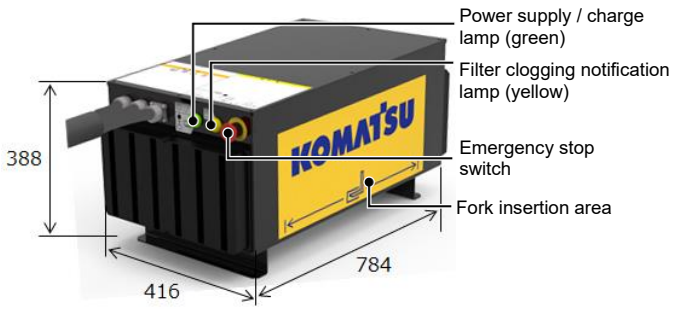

Fig. 8 Fast charger

Table 2 Main specifications of the fast charger

		FE25/30-2
Input voltage		3-phase 200 V
Output voltage		108/120 [V]
Rated horsepower		19.1 kW (fast charging)
Dimension	Size	388 × 416 × 784 [mm]
	Volume	127 L
	Weight	67 kg
Dustproof/waterproof		IP X4, with dustproof filter
EMC		Equivalent to CISPR11 Class A compliant

(1) High voltage (108/120 V)

In order to improve the travel performance of the FE series and produce travel performance comparable to that of engine vehicles, the battery voltage has been increased. The battery voltage has increased to 108 V for the FE25-2 and 120 V for the FE30-2, compared to 72 V for the previous model FE25/25H/30-1, so the fast charger also supports high voltage output (**Fig. 9**).

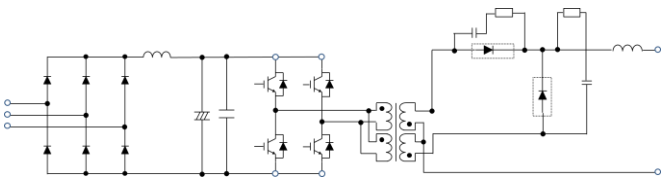

Fig. 9 Schematic circuit diagram

(2) Fast charging system

Up to 60% of the battery capacity can be recovered with a fast charge for one hour, so the operating time per day can be significantly extended.

(3) Heat balance performance

The cooling performance was optimized by separating the cooling flow line into a heat sink chamber and an electric chamber, and letting each fan handle air cooling (**Fig. 10**).

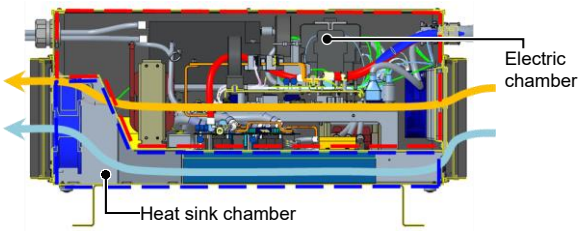

Fig. 10 Cooling flow line separation

(4) Improved EMC performance (equivalent to electromagnetic compatibility CISPR11 Class A compliant)

A high-performance EMC filter is used and the DC/AC line is separated so that the switching noise generated by the power semiconductor cannot be loaded on the commercial power circuit.

(5) Improved waterproof performance

A newly developed plastic louver with a labyrinth structure makes it waterproof from all directions (**Fig. 11**).

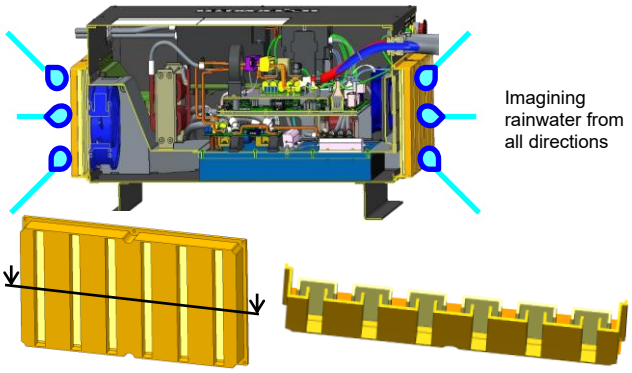

Fig. 11 Labyrinth louver

(6) Filter clogging notification lamp

A function has been added to detect and notify the user that the intake or exhaust filter is clogged, the cooling flow rate is reduced, and the temperature of internal parts is rising (**Fig. 12**).

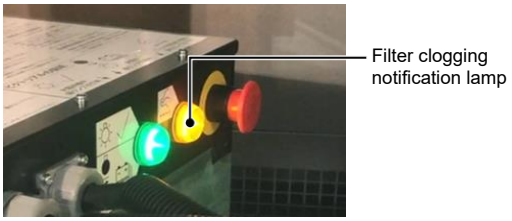

Fig. 12 Filter clogging notification lamp

(7) New charging plug

Operability is improved by reducing the operating effort by approx. 30%. In addition, by adopting an alignment structure connector (power terminal, signal terminal), the terminals at the time of fitting are aligned to ensure a secure connection and improve reliability.

3.3.2 Travel speed limit when turning linked to the amount of steering

In order to reduce the speed when turning and prevent the vehicle from rolling over when turning, it is equipped with a speed limiting function linked to the steering angle. Specifically, by constantly monitoring the steering angle, calculating the swing radius of the vehicle, and automatically adjusting the speed limit of the vehicle according to the magnitude of the swing radius, lateral stability is increased while maintaining the vehicle speed during operation (**Fig. 13**).

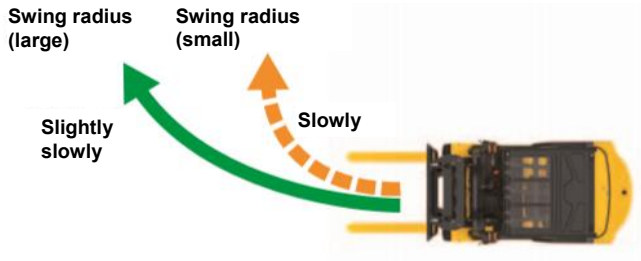

Fig. 13 Speed limit when turning

3.3.3 Slope warning, tipping over notification, collision detection alarm system

Safety awareness at the forklift operation site is increasing year by year, and the number of misfortunes decreasing, but many serious misfortunes have occurred even in recent years. Most of the misfortunes are caused by contact accidents such as getting sandwiched, getting caught, and collisions, as well as tipping over accidents. In response to these, Komatsu will add a new optional safety assistance function to help users work safely and contribute to raising safe operation awareness for administrators and operators.

(1) Slope warning and tipping over notification

This is a safety assistance function for tipping over accidents, which are a problem specific to the outdoors. The operator is alerted by sound when approaching a slope above the set angle, handling loads on a slope, turning, or other dangerous work. At the same time, Komtrax also notifies the administrator, which contributes not only to raising safe operation awareness but also to safety management by tracking dangerous work and dangerous places.

In addition, in the unlikely event that the vehicle tips over, the horn will sound to notify anyone in your surroundings, and at the same time, Komtrax will notify the administrator, which contributes to the early detection of the accident (**Fig. 14**).

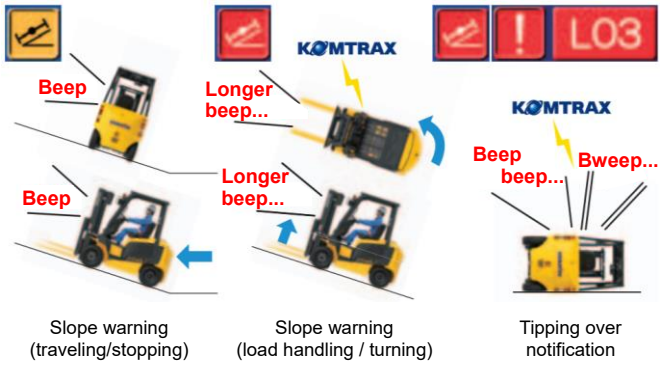

Fig. 14 Slope warning and tipping over notification

(2) Collision detection alarm system

This is a safety assistance function for contact accidents caused by overlooking blind spots or lack of safety confirmation when traveling backward. It supports the operator during rear safety confirmation with lights and sounds. The direction of travel is predicted from the steering angle (tire turning angle) when traveling backward, and an alarm is generated when there is a risk of collision in that direction. Unnecessary alarms are reduced for people, luggage, etc. outside the direction of travel of the vehicle. In addition, depending on the degree of danger of collision, two levels of caution range and warning range are set, and the operator is alerted by the difference between the number of blinks of the alarm lamp and the intermittent sounds of the alarm buzzer (**Fig. 15**). (Refer to the separate Komatsu Technical Report for details)

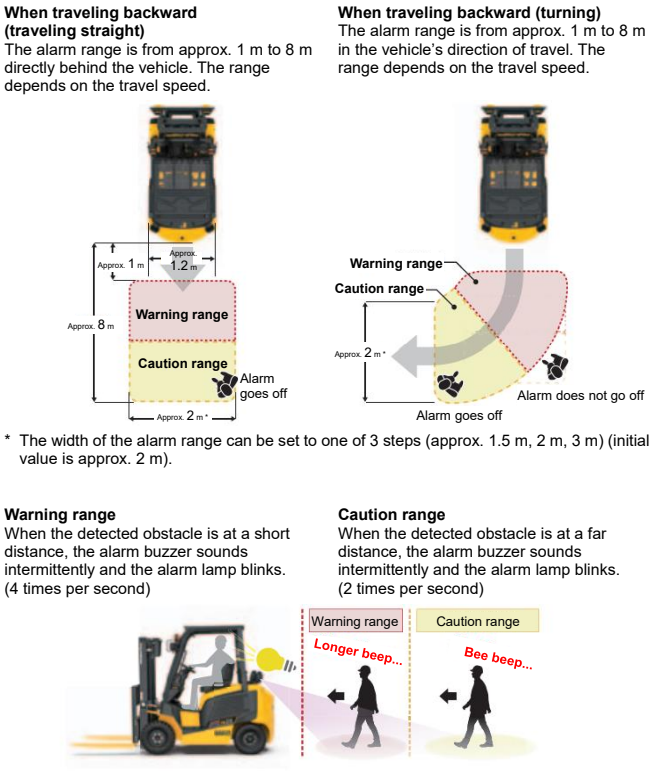

Fig. 15 Overview of collision detection alarm system

3.4 Improved comfortableness

3.4.1 Accelerator one-pedal mode

In a previous model, when approaching a load, it was necessary to frequently switch between the accelerator pedal and the brake pedal to adjust the speed, stop, and start moving. For the purpose of reducing such frequent pedal control and reducing the strain on the operator, we installed the accelerator one-pedal mode that allows the operator to accelerate, decelerate, and stop the vehicle using only the accelerator pedal (**Fig. 16**).

Fig. 16 Accelerator one-pedal mode

The accelerator one-pedal mode has a new type of motor control with a higher regenerative braking ratio to the operator's pedal control than the previous model. This improves the controllability of the vehicle speed by pedal work and helps extend the operating time by efficiently recovering the braking energy.

In addition, installing the accelerator one-pedal mode has reduced the required number of pedal switches in many situations, and improved operability. For example, when traveling on a slope, the accelerator pedal controls the vehicle when moving backward, as well as reducing the amount of slide from switching the pedal when moving forward by 80% compared to the previous model. This allows the vehicle to start smoothly and to be operated more safely (**Fig. 17**).

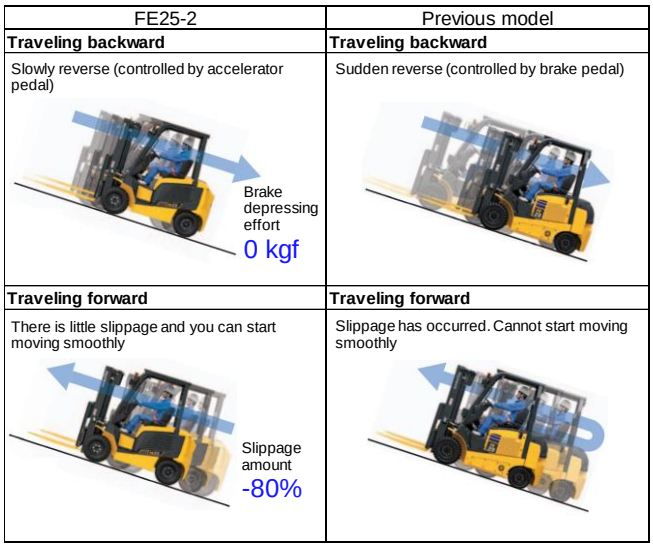

Fig. 17 Traveling on slope

3.4.2 Cab

The newly designed cab continues with the good upward visibility of the popular skylight glass from the previous model, the wiper motor position has been adapted, the length of the wiper blade and arm has been extended, the wiping position has been improved and the wiping range has been widened (80% improvement). These changes make it easier to see what you want to see and improve safety. In addition, adapting the position of the side mirrors reduces the movement of the eyes, improves safety, and reduces fatigue. Furthermore, by installing slide sashes on the left and right doors and using a flip-up window for the rear, the ventilation was significantly improved and it was made more comfortable for the summer. Even for winter, changing the heater fan reduced heater noise (16 dB improvement) and improved comfort. The interior light has been changed to LED, making it easier to read documents. The charging port is located outside the room, making it possible to charge with the door closed, eliminating indoor wetness from rain (**Fig. 18**).

Fig. 18 FE25/30-2 with cab (Figure is of FE25-2)

4. Conclusion

Komatsu turned to electrification and in 2014 introduced the previous model FE25-1 to the 2–3 t market, which accounts for half of the demand for forklifts for Japan. It was a very big hurdle for Komatsu, which had relied on the sale of engine vehicles. However, getting over that hurdle is what showed Komatsu the way to the next hurdle. The new model FE25/30-2 was able to incorporate a large number of improvements and market demands that could not be incorporated in the previous model, as well as new structures and functions to appeal to the emerging customer values. The FE25/30-2 has been mass-produced and introduced to the market.

Being electric is an element of this forklift. We take pride in the fact that it can provide more value than engine-powered forklifts. We would like to follow up on this product so that we can further improve our users' worksites by embracing the next emerging hurdle.

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[A comment from the authors]

During development, we received a great deal of cooperation from the product planning department, sales department, production department, service department, subcontractors, etc., from the market research and business discussion stage to mass production. In addition, this product was created with the cooperation of many people in the development department, above all those involved in the production of this report. We would like to express our gratitude to everyone who contributed to this development.

It took time to introduce the product to the market due to unexpected difficulties near the completion of quality evaluation. We will continue to pursue and create the necessary value for your worksites.