

Introduction of Products

Electric Forklift Truck FE25G-2/FE30G-2

Kazuaki Ozawa

Tadashi Yamamoto

Hiroki Ito

Komatsu developed the FE25G-2 and FE30G-2 models, which inherit the truck dimensions and other features of the FE25-2 and FE30-2 models that were launched in March 2021. The new models feature high-capacity, fast-charging lithium-ion batteries and, when used with the newly-developed stationary fast chargers, expand the scope of application into the sites where extended operation with no time for recharging is needed and/or attachments are used in heavy-duty applications, a domain long reserved for engine-powered forklift trucks. This paper presents some of the key features of the new models.

Key Words: FE25G-2, FE30G-2, Electric forklift truck, Lithium-ion battery, Fast charging, Dual charger charging, Extended operation, Maintenance-free, Stationary fast charger

1. Introduction

Komatsu has been endeavoring to cut greenhouse gas emissions, having set a target of achieving a 50% reduction (over FY2010) in CO₂ emission in the 2030s and a challenging goal of reaching carbon neutrality in 2050. Komatsu has been a leading brand in the effort to increase the share of battery-powered forklift trucks in the 2.5- to 3-ton segment in Japan with its FE25 and FE30 models. These models, however, have not been able to meet the needs of some users who use heavy-duty attachments and/or perform extended operation with not time for recharging, thus failing to supersede vehicles powered by high capacity lead-acid batteries and engine-powered vehicles. In contrast to the above, Europe, driven by an ESG management approach, has witnessed high-capacity, high-output lithium-ion batteries powering more and more vehicles over the years. While there has been consistent, modest though, demand for battery-powered vehicles in the forklift truck segment, the increasing popularity of lithium-ion batteries today appears poised to push the segment further in going electric. With the above background in mind, Komatsu developed the FE25G-2 and FE30G-2 models.

Table 1 Main specifications

Item	Unit	FE25G-2	FE30G-2
Maximum load	Kg	2,500	3,000
Rated load center	mm	500	←
Battery	-	Lithium-ion	←
Battery voltage	V	115.9	←
Battery capacity	Ah	302	←



Fig. 1 FE25G-2/30G-2 models
(Picture is of FE25G-2, Source: Brochure)

2. Aims of development

Engine-powered vehicles have been used extensively in worksites where punishing, heavy-duty operation is performed and/or operation goes on for many hours with no time for recharging. In those sites, extended operation and recharging time have prevented battery-powered vehicles from being used. As for users of FE25/30 electric models, requests for further improvement have been raised, despite that those models have shortened recharging time with the fast charging feature over the conventional lead-acid batteries, a benefit especially during a busy period, as well as offering extended operating time. To satisfy all of those customers with electric versions, Komatsu developed the FE25G-2 and FE30G-2 models (Fig. 2). The new models have four key features as described below.

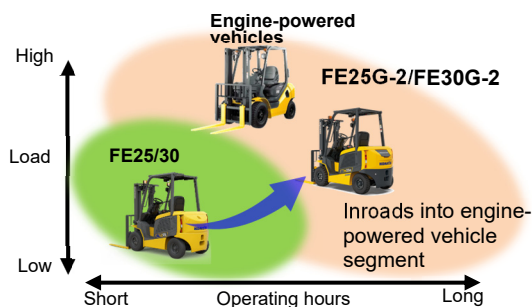


Fig. 2 Strategic evolution to meet requirements of high load and long operating hours

- (1) Long operating hours
 - Powered by lithium-ion batteries
- (2) Fast charging
 - Repeatable fast charging
 - Dual fast charger further cutting recharging time
 - Exclusive stationary fast charger
- (3) Longer battery replacement intervals
 - Long life lithium-ion battery, reducing battery cost
- (4) Maintenance-free
 - No need to replenish, can be fast charged repeatedly

3. Major features

3.1 Long operating hours

3.1.1 Powered by lithium-ion battery

The battery mounted on the FE25G-2 and FE30G-2

models have a higher capacity than that on the FE25-2/FE30-2 models to enable longer operating hours. In addition, based on the experience gained with the FE series, a range of design requirements for forklift operation have been fulfilled on the new models.

(1) Higher battery capacity

While inheriting the body dimensions of the FE25-2/FE30-2 models with lead-acid batteries, the new models use a lithium-ion battery, known for higher energy density, that also has an increased capacity (Fig. 3). Longer operating hours per charge have been achieved (Table 2).

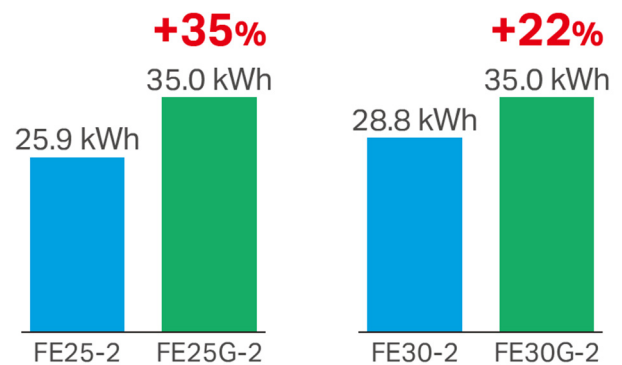


Fig. 3 Battery capacity comparison (Source: Brochure)

Table 2 Operating hours comparison (Source: Sales manuals)

		2.5 t		3.0 t	
		FE25G-2	FE25-2	FE30G-2	FE30-2
Operating pattern A *1	h	7.7	5.7	6.3	5.2
B *1	h	9.2	6.8	7.6	6.3
C *1	h	11.0	8.2	9.1	7.5

*1: Operating pattern envisioned by Komatsu
 (A: High load operation B: Normal load operation
 C: Low load operation)

(2) Water- and dust-proof battery

As lithium-ion batteries have low heat dissipation during recharging and discharging processes, a cooling fan, which is used on the FE25-2/FE30-2 models with lead-acid batteries, is discontinued on the new models. This led to the improvement in sealing performance of the battery case, achieving IP55 waterproof and dustproof rating (Fig. 4). As a result, the battery can fully withstand severe outdoor environment at worksites.

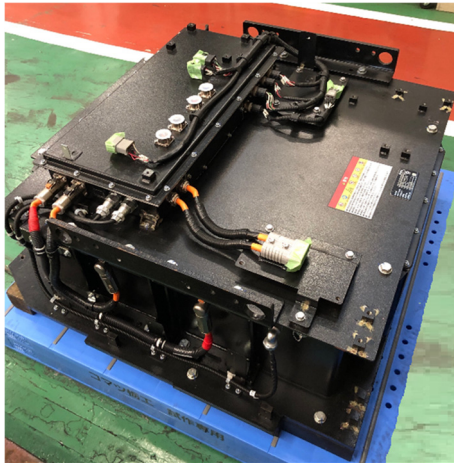


Fig. 4 Lithium-ion battery for the FE25G-2/30G-2 models

(3) Battery heater for cold weather operation

To offset the performance drop of lithium-ion batteries at low temperature, a known demerit, a battery heater was installed on the new models. The heater is housed in the battery module (**Fig. 5**) and is automatically turned on and off by the battery management system, which runs independently of the vehicle controller, as it monitors the battery temperature.

To offset the heater's power consumption, a charging cable can be left connected to a power socket on the vehicle body to continuously recharge so that the heater will not affect the vehicle operating hours at low temperature.

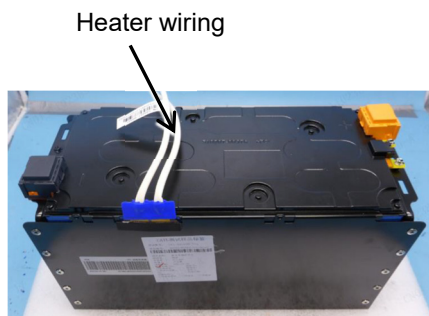


Fig. 5 Battery module and heater wiring

(4) Fast charging and safety features

To accommodate fast charging, the following items were selected: battery cells that can withstand one-hour charging current and intense power circuit parts.

In addition, to secure safe use of the lithium-ion battery, a battery management system, which runs independently of the vehicle controller, is installed in the battery. When the battery is supplying power, the system continuously

monitors the voltage of each cell, the temperature of each module, the voltage and current of the pack and other parameters. When the system detects out-of-range values, it shuts down the discharge and charge circuits. The battery management system communicates with the vehicle controller, and when it detects any abnormality, it takes appropriate actions such as limiting vehicle output in stages and displaying warning messages on the monitor panel on the vehicle to minimize operational risks (**Fig. 6**).



Fig. 6 Warning message on the monitor panel of the vehicle

(5) Lithium iron phosphate battery

As the lithium-ion battery for the new models, a lithium iron phosphate battery was selected as this type of battery is extremely safe and has high cycle performance. While lithium iron phosphate batteries have lower energy density than Li(NiMnCo)O₂ lithium-ion batteries typically used on electric automobiles, more important than that are their extreme safety (against explosion and fire) and long service life (**Table 3**).

Table 3 Types and characteristics of lithium-ion batteries

Cell material	Iron phosphate	Li(NiMnCo)O ₂
Cathode	LFP (Fe, P)	NMC (Ni, Mn, Co)
Anode	Graphite (C)	Graphite (C)
Q Voltage (V)	3.2	3.7
Cell energy density	○	◎
Power density	○	○
Service life (State of health 80%)	◎	○
Safety	◎	△
C Cost	◎	△
D Material availability (Rare earth)	◎	△ (Ni, Co)
Major applications	Cars, buses, trucks	Cars

◎ Excellent
○ Good
△ Poor

3.2 Fast charging

3.2.1 Repeatably fast charging

The combination of the repeatedly rechargeable lithium-ion battery and the fast charger enables fast replenishment of the battery that can be done typically during breaks, contributing to downtime minimization. For worksites of extended operation that use vehicles with high-capacity lead-acid batteries, which still necessitates battery and vehicle replacement, the above combination, if adopted, offers the possibility of using only one vehicle with a fast battery replenishment feature (Fig. 7).

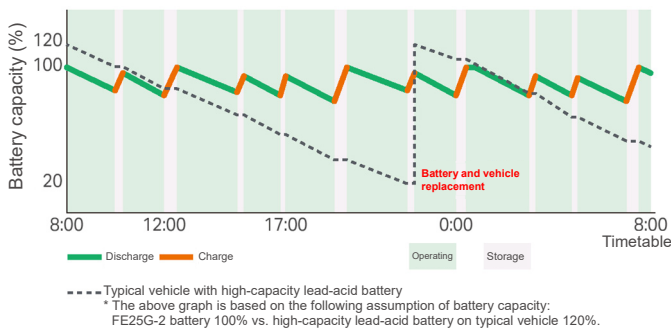


Fig. 7 FE25G-2 continuous operation with a fast charger (Source: Brochure)

3.2.2 Dual fast charger further cutting recharging time

For worksites of extended operation facing difficulty in securing time for recharging, the dual fast charger (Fig. 8) further cuts recharging time (Fig. 9). For worksites of heavy-duty operation requiring lead-acid battery and vehicle replacement and/or when additional work pops up during a busy period, the fast charging capability offers a solution (Fig. 10).



Fig. 8 FE25G-2 fast charging with a dual fast charger (Source: Brochure)

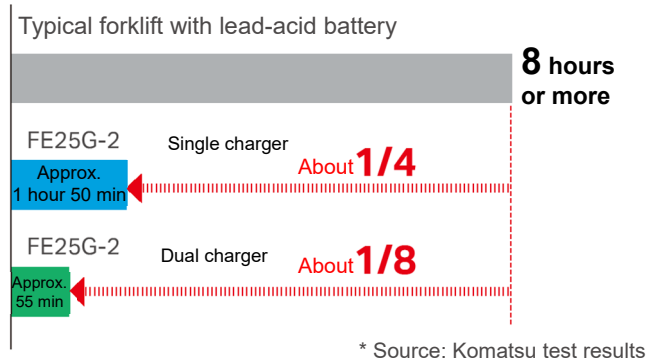


Fig. 9 Charging time from state of charge 20% to 100% (Source: Brochure)

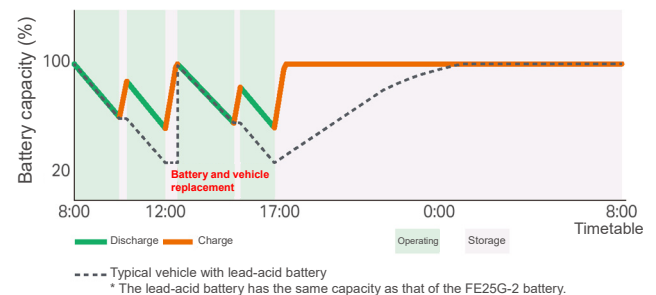


Fig. 10 FE25G-2 high-load operation with dual charger battery replenishment (Source: Brochure)

(1) Charge ports for dual charger

On the new models, two charge ports for the dual charger are provided above the rear counterweight of the vehicle, relocated from the front right-hand side of the vehicle on the FE25-2/FE30-2 models. For ease of operation, provided between the charge ports are the battery ON/OFF button and the power lamp, which indicates battery power supply and charge statuses (Fig. 11).

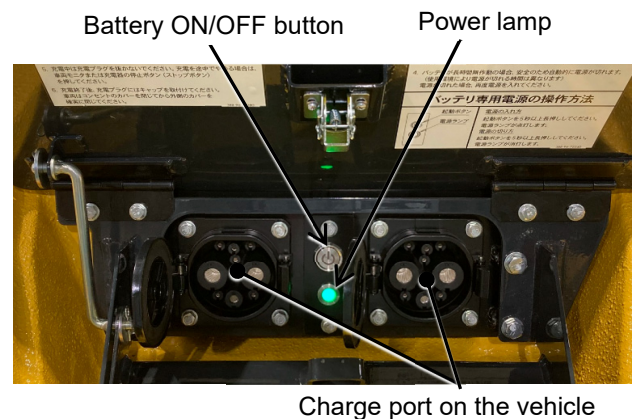


Fig. 11 Charge ports

(2) Automatic start of fast charging

On the FE25-2/FE30-2 models with lead-acid batteries, the operator must choose from among several charge modes available (Normal, Fast replenish, etc.) on the charge mode selection screen of the vehicle monitor panel after inserting the charger plug. On the FE25G-2/FE30G-2 models, to facilitate frequent replenishing, fast charging automatically starts when the charger plug is inserted (**Fig. 12**). Fast charging also starts automatically when both charger plugs are inserted for dual charger charging for ease of operation.



Fig. 12 Automatic charge start display on the vehicle monitor panel

3.2.3 Exclusive stationary fast charger

The stationary fast charger must meet the fire prevention ordinance for high-output dual charging application, and was designed exclusively for use on the FE25G-2/FE30G-2 models. For enhanced ease of operation, a number of items were added, including indicator lamps and a liquid crystal panel. The charger was further refined to retain the ease of operation even when used as a dual charger.

(1) Safe design for compliance with the fire prevention ordinance

To prevent inadvertent removal of the charger plug during a charging process, a plug with an electromagnetic locking device was selected for the fast charger (**Fig. 13**).

The plug is electromagnetically locked and cannot be pulled off while charging is in progress.



Fig. 13 Locking device on the plug

The charger is equipped with the capability to detect earth fault on the charger itself, battery and vehicle body before and during a charging process. Those safety features made the fast charger compliant with the fire prevention ordinance on high-powered dual charger charging.

(2) Indicator lamps, liquid crystal panel, switches

For enhanced ease of operation, the charger is equipped with indicator lamps and a liquid crystal panel for the operator to be able to monitor the charge status. Charge stop and start switches are also provided on the charger. Using those switches, the operator can stop and restart the charging process from the charger (**Fig. 14**). Charge progress status monitoring, charge stop and restart operation and other actions, which until now are only possible on the vehicle monitor, can now be performed from the charger (**Fig. 15**).

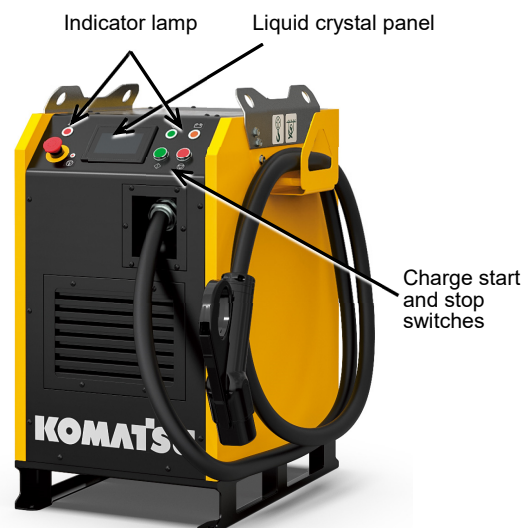


Fig. 14 Indicator lamps, liquid crystal panel and switches on the charger (Source: Brochure)

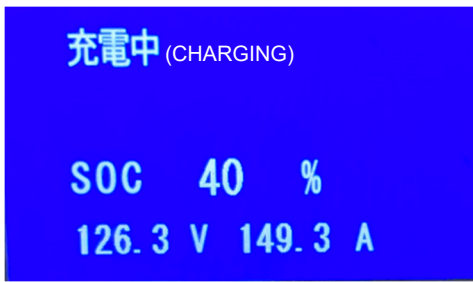


Fig. 15 Liquid crystal panel display on the charger during the charging process

(3) Dual charger charging

The stationary fast charger ensures ease of operation even when it is used as a dual charger, by offering useful facilities. When charging the battery with two fast chargers connected to the vehicle, pressing either the stop switch or the emergency stop switch on either of the chargers stops both chargers. Likewise, pressing the start switch on either of the chargers starts both chargers. As a result, starting and stopping two chargers at the same time is as easy as starting and stopping one charger.

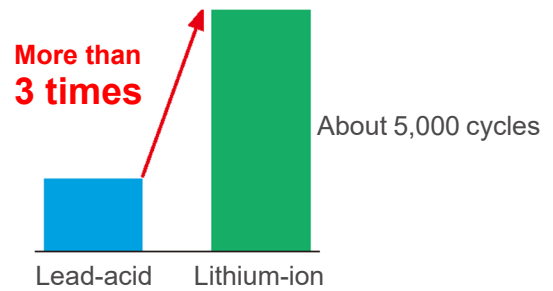
(4) Flexibility to meet the capacity of worksite circuit breaker

To meet various capacities of worksite circuit breakers, the current limit on the stationary fast charger can be selected from among 30 A, 60 A and 75 A. (The current limit selection and setting can only be performed by Komatsu dealers.)

3.3 Longer battery replacement intervals

3.3.1 Long life lithium-ion battery, reducing battery cost

Lithium-ion batteries have longer service life than the widely-used lead-acid batteries. Among the lithium-ion batteries, lithium iron phosphate batteries are used on the new models. This type of battery has high cycle life performance, lasting more than about three times longer than lead-acid batteries (**Fig. 16**). Worksites that need to replace batteries frequently can expect longer battery replacement intervals and lower life cycle cost with the lithium iron phosphate battery.



* Source: Komatsu test results on the number of discharge/charge cycles (One cycle refers to full discharge of a fully charged battery with subsequent full recharge.) The figure does not reflect actual battery life.

Fig. 16 Comparison of charge/discharge cycles (Source: Brochure)

3.4 Maintenance-free

Unlike ordinary lead-acid batteries, lithium-ion batteries do not need to be replenished ^{*2} and therefore do not generate related cost. Nor do lithium-ion batteries require regular, time-consuming full charge ^{*3}, relieving the operator of the chore of charge state management. As the battery can be charged fast and repeatedly, it is expected it will help extend worksite operating hours.

*2: Ordinary lead-acid batteries require regular replenishment as part of the electrolyte evaporates through chemical reaction during charging.

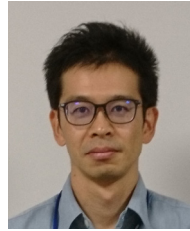
*3: Lead-acid batteries require regular full charge to remove the lead sulfate crystals that form as they discharge.

4. Conclusion

CO₂ emissions have been highlighted as a global issue in recent years, prompting everyday discussions on how to achieve carbon neutrality. For consumers in general, an associated, familiar phenomenon is the increasing popularity of battery-powered cars (EVs). In line with this trend, Komatsu started to develop forklift trucks powered by lithium-ion batteries to make further progress in the EV field. The existing lead-acid battery-powered FE25-2/FE30-2 models already featured fast charging capability, a major benefit. Under the development program, new models powered by lithium-ion batteries would be based on and surpass the existing models in performance. After an extensive trial and error process for the best fast charging method, a high-powered dual fast charger was chosen.

Since completion, the new models featuring the fast charging capability are drawing huge attention, as highlighted at Logis-Tech Tokyo in September 2022 where the new models were presented. Thus, Komatsu can state with confidence that the fast charging as well as other concepts of the new models help customers improve productivity. Going forward, Komatsu, harnessing the knowledge gained through the development program, will strive further for the electrification of forklifts and to achieve carbon neutrality, a challenging goal.

Introduction of the authors



Kazuaki Ozawa

Joined Komatsu in 2000.
Vehicle Development Center 4,
Development Division



Tadashi Yamamoto

Joined Komatsu Ltd. in 2008.
Electrification Development Center,
Development Division



Hiroki Ito

Joined Komatsu Ltd. in 2010.
Electrification Development Center,
Development Division

[A comment from the authors]

From its initial planning stage, the development program discussed in this paper was blessed with huge cooperation from those including in the product planning, sales and production departments and at suppliers. It cannot be emphasized enough the leading role played in the development of lithium-ion battery-powered forklifts, a novel product, by those from the Electrification Development Center, which was launched in 2020, and the suppliers of the battery and charger. We would like to thank all those mentioned above for their dedication to overcoming a series of challenges during the development and bringing about commercial production of the new models. Customers who receive our products will be followed up on for their precious feedback, which Komatsu will then utilize to develop new products that customers find valuable in helping to improve their worksite productivity.