

Introduction of Product

Introduction of PC200-8 Hybrid Hydraulic Excavators

Hiroaki Inoue

A goal has been set to make a contribution to society in challenging global warming, especially to reduce the emissions of CO₂, by developing a hybrid system that drives the swing device of a hydraulic excavator by electric drive, to significantly reduce fuel consumption. Reductions in emissions of greenhouse gases are not making satisfactory progress and regulation of the construction industry is also expected to become stricter in the future. Under such circumstance, provisioning of products that promise lower fuel consumption to the customers will win customer satisfaction, leading to activation of the market.

This introduction of product explains the outline of the sales of Komatsu's PC200 hybrid hydraulic excavator series starting this spring aimed at an accomplishment of this goal.

Key Words: Hydraulic excavator, Swing device, Electrically driven, Hybrid, Fuel consumption reduction, Capacitor

1. Introduction (Trend toward Hybrid Construction Machinery)

In 1997, Toyota Motors unveiled a sedan based on an entirely new concept. This was the debut of "Prius" with a hybrid system installed, whose primary objective was environmental friendliness especially a reduction in CO₂ emissions, as against the conventional basic performance of cruising, turning and stopping. The impact Prius had on the industry was immeasurable and Komatsu immediately started studying a hybrid system embodying "motor driven actuators and a storage system for regenerative energy."

There is a wide variety of power sources for hybrid systems. For example, a hybrid forklift is in commercial use driven by batteries and capacitors, aside from an engine generator. More than 90% of CO₂ emissions of construction machinery are generated by fuel consumption during machine operation

throughout the life cycle from machine manufacturing to scrapping. Reduced fuel consumption directly leads to reduced emissions of global warming gases and thus the low fuel consumption technology in hybrid systems is more environmentally friendly than conventional systems as well as costing the customer less in fuel. In 2005, Komatsu started full scale development of a hybrid hydraulic excavator for the hydraulic excavators that are in most popular use in Japan, aimed at reducing fuel consumption.

2. Low Fuel-consumption Technology of Hydraulic Excavator

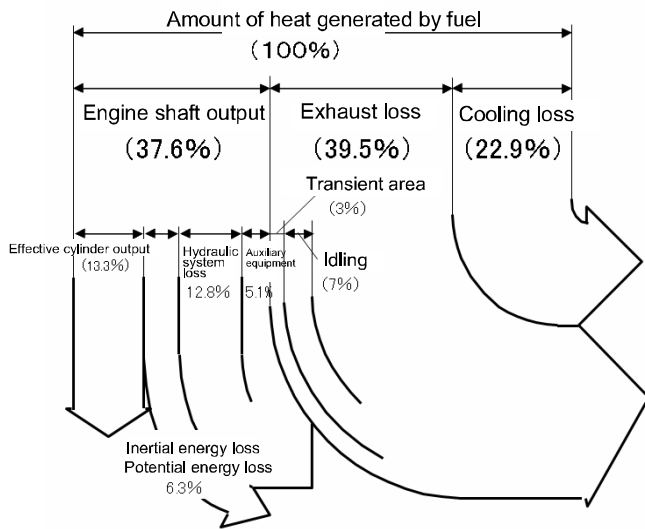


Fig. 1

The energy flow in typical work of a hydraulic excavator is illustrated in Fig. 1. According to this flow, 13.3% of energy is extracted as effective work and the rest is generally discarded as heat loss. During this process, the engine output is entirely converted into hydraulic energy in the hydraulic excavator and is distributed to each actuator. Energy conversion losses are generated between the engine and pump. Losses due to pressure loss and other losses are generated when pressurized oil is distributed. Furthermore, potential and kinetic energy of the work equipment and upper structure is converted into a meter out loss of the hydraulic system and is calculated as a loss. Compared with this, the hybrid system drives the upper structure by an electric motor, reduces energy conversion and transmission losses and regenerates kinetic energy of the upper structure. A dramatic reduction in fuel consumption reduction can be seen by optimally matching the depression effect of engine output thus obtained on an engine fuel consumption map.

3. Overview of Hybrid Hydraulic Excavator

(1) Full view of hydraulic excavator

A full view of Komatsu PC200-S Hybrid Hydraulic Excavator is shown in Fig. 2. The only difference in appearance compared with the base machine is the sticker, as the additional components required by the hybrid system are housed inside the existing space.



Fig. 2

(2) Hybrid system

The hybrid hydraulic excavator consists of a swing electric motor, dynamo motor, inverter, capacitor and other components. Energy that is generated during deceleration of the swing electric motor when turning of the machine body decelerates is recovered as electric energy and stored in a condenser called a “capacitor.” This energy is reused through the inverter during turning and is also used as assist energy during engine acceleration in excavation work. As a result, the engine revolution speed can be kept low also during idling to reduce fuel consumption. One characteristic of the “Komatsu Hybrid System” is the use of a “capacitor” to instantaneously store and discharge electric energy efficiently.

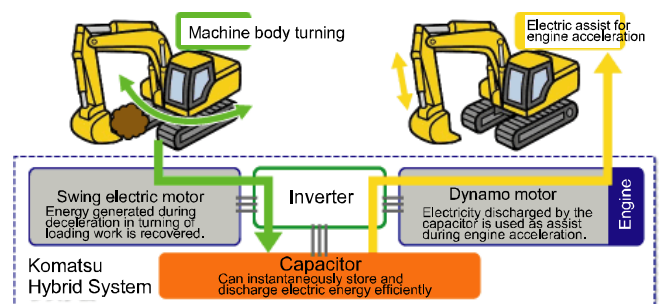


Fig. 3

(3) Hybrid components

(a) Dynamo motor

The dynamo motor is built in between the engine and hydraulic pump, to dramatically enhance the transmission efficiency to the hydraulic pump. Electricity is efficiently generated while the engine is idle and supplements storage of electricity in the capacitor.

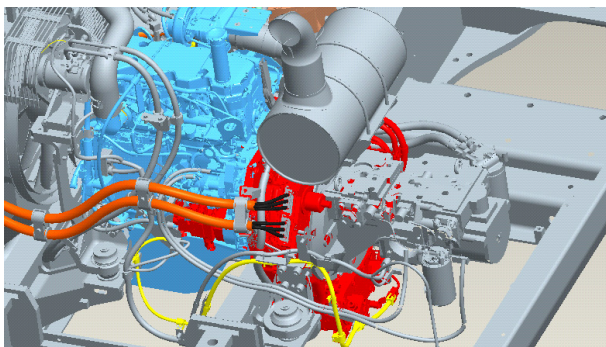


Fig. 4

(b) Swing motor

An electric motor that recovers energy during swing deceleration was developed. The efficiency of the electric motor during acceleration is higher compared with the hydraulic motor, demonstrating smooth turning performance. Circulation of lubricating oil and cooling water for the electric motor is facilitated by a special case, which was developed for the hybrid hydraulic excavator. A special decelerator was also developed to meet high-speed operation, which is characteristic of the electric motor.

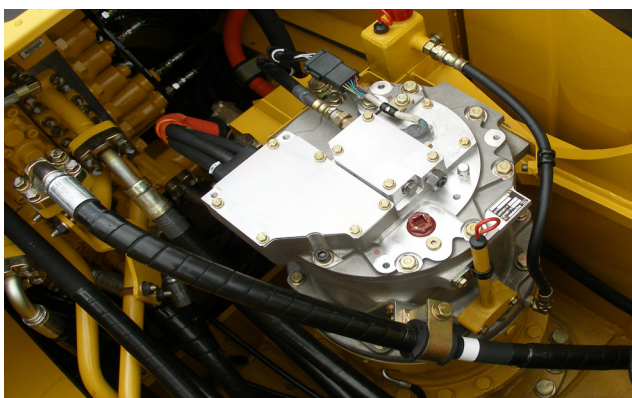


Fig. 5

(c) Inverter and capacitor

An inverter that integrates a booster, as well as a capacitor, is compactly installed on the vehicle. The reliability of each component is assured by installing a special water cooling device. A capacitor that can charge and discharge by migration of electrons and ions is installed as a condenser. Charging and discharging in a short time is therefore possible compared with batteries that require chemical reaction, enabling frequent engine speed variations of construction machinery.



Fig. 6

Theoretically, the inverter and capacitor are free of heat generation and deterioration, enabling long life and maintenance-free care.

(d) Capacitor

A capacitor was installed as a device to store the electricity of energy regenerated by turning. Automobiles with advanced hybrid technology require a large amount of electric energy during starting acceleration and then run at a relatively stable engine speed. Therefore, batteries are installed in automobiles as electricity storage equipment. Compared with automobiles, frequent engine speed variations in a short time are caused with construction machinery by such as digging work, etc. and a capacitor was installed to follow and assist in this frequent engine speed changes.

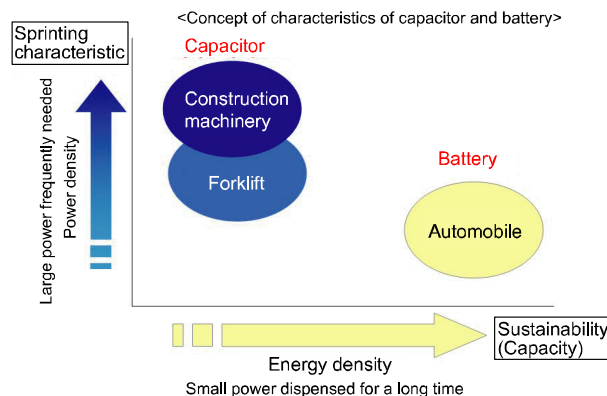


Fig. 7

The batteries installed in automobiles involve a chemical reaction and much time is required for charging and discharging. An adequate assist therefore cannot be obtained, while the capacitor efficiently recovers and stores regenerative power and instantaneously discharges electricity.

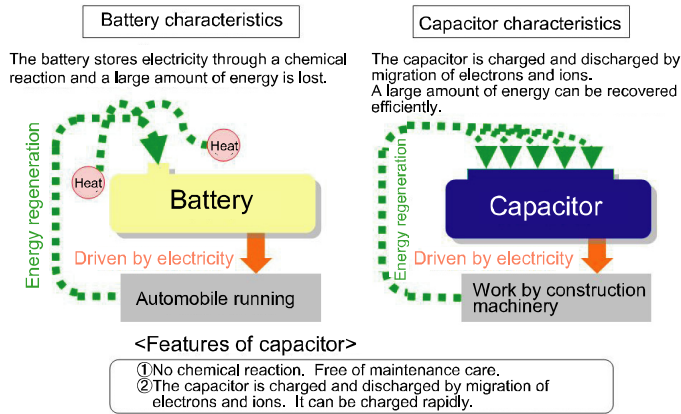


Fig. 8

(4) IT technology

The hybrid machine is installed with a “hybrid operation monitor” to assist ecological operation.

(a) Energy-saving navigation system

Fuel consumption during the most-recent five minutes is displayed by a bar graph in the center of the monitor screen installed in the operator seat, to assist and encourage eco operation by the operator. The screen can be changed to also display fuel consumption data of the most recent one hour, 12 hours, one week and one month.

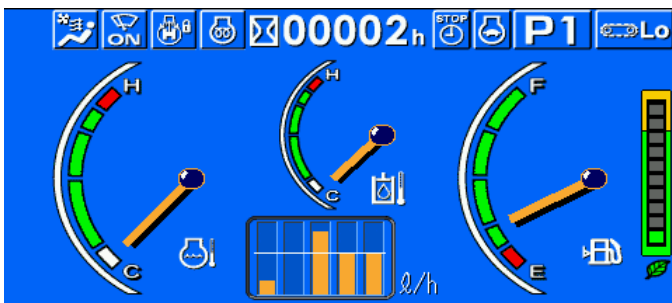


Fig. 9

(b) Energy monitor

The monitor screen can be changed to display status of capacitor charging and discharging and engine assist by the dynamo motor as an energy flow.

The components of the system and flow of energy among these components are displayed on the screen in the following color codes.

- Hydraulic drive energy
- Electric drive energy
- Regenerative energy

1) During work equipment operation + Start of swing

The work equipment is operated hydraulically by energy generated by the engine as in the conventional equipment. (Red arrows)

Swing is driven by electric energy from the capacitor and generator. (Yellow arrows)

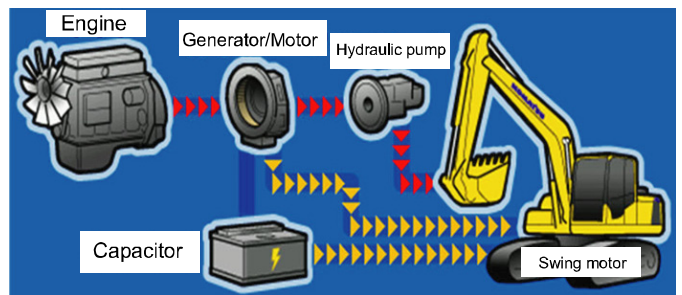


Fig. 10

2) During work equipment operation + Swing deceleration

Energy generated during swing deceleration is regenerated and is stored in the capacitor. (Green arrows) Some of the regenerated energy assists the engine through the dynamo motor and assists work equipment operation.

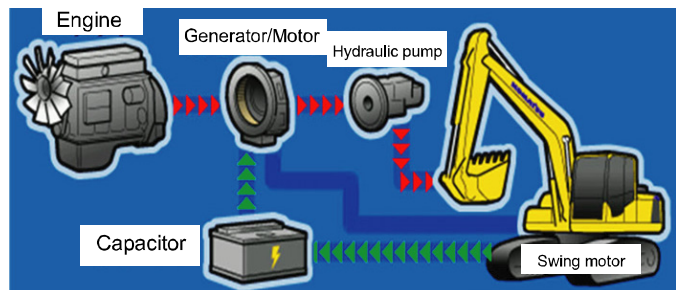


Fig. 11

(5) Effect of low fuel consumption

Compared with the conventional machine “PC200-8,” the hybrid version saves about 25% of fuel on average*. In a user test, a fuel consumption reduction of 41% maximum was registered at a work site at which the frequency of swing operations was high. This is because this system regenerates swing energy so that the effects of fuel consumption reduction vary depending on the load during turning, on the swing angle and on the frequency of swing operations. In work in which the swing angle is large, a reduction effect in excess of a nominal value of 25% can be obtained.

* The market average is a trial calculation based on an in-house standard for average usage of construction machinery.

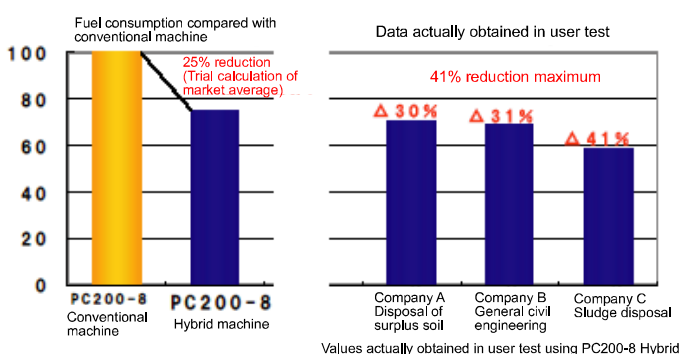


Fig. 12

(6) Trial calculation of CO₂ reduction effect

One-hour operation of a hybrid machine produces 10kg less of CO₂ compared with a conventional machine. Assuming that all Komatsu hydraulic excavators operating in Japan are replaced by hybrid machines, about 370,000 tons less CO₂ will be produced each year as a trial calculation, equal to about 153 Tokyo Dome baseball stadiums in volume.

About 10kg less CO₂ produced when one PC200-8 Hybrid works for one hour



If all Komatsu hydraulic excavators operating in Japan are replaced by hybrid machines...

CO₂ emission reduction is equal to about 153 Tokyo Dome baseball stadiums in volume

About 370,000 tons of CO₂ are reduced each year = Tokyo Dome baseball stadium × About 153

Note 1 Note 2

Note 1: The numbers of hydraulic excavators in operation and CO₂ emissions are of the end of 2006. Utility machines (mini construction machines) not included.
 Note 2: Trial calculation based on the volume of Tokyo Dome baseball stadium (1,240,000m³).

Fig. 13

4. Summary

The conventional hydraulic excavator system converts the engine output entirely into hydraulic energy and drives each actuator. Compared with this, in the hybrid system, the upper structure is driven by an electric motor, reducing energy conversion and transmission losses and regenerating the kinetic energy of the upper structure. The depression effect of engine output thus obtained is combined with engine fuel consumption matching, resulting in dramatic fuel consumption reduction effect. At the same time, the following technologies were established.

(1) Motor powering technology of swing device

The upper structure is driven by an electric motor replacing the hydraulic motor in the conventional hydraulic excavators. Motor control technology in machine operability, especially combined operations with other work equipment was established.

(2) Technology that regenerates swing kinetic energy

The voltage control technology of the storage battery was established for energy regeneration during deceleration of the swing electric motor.

(3) Total energy management technology for the engine, hydraulic pressure and electricity.

Power distribution individually for the engine, hydraulic pump and dynamo motor was decided and total control technology to achieve optimum fuel consumption operation was established.

(4) Hybrid component development technology

A motor, inverter and capacitor were developed as components to deal with large loads of construction machinery. (Capacitor cells were purchased)

5. Conclusion

The history of hybrid construction machinery has just started. However, hybrid construction machinery is expected to be sold by the manufacturers of construction machinery as part of the measures against global warming and resource depletion, occupying a certain market share. The key point for spreading of hybrid construction machinery is cost reduction. Expectations are placed on the support of central and local governments as in a bidding system based on comprehensive evaluation of machines.

Technically, energy saving techniques by hybrid systems will be extremely effective for construction machinery, which has a wide variety of applications. Efforts on the further development of hybrid construction machinery will be continued.

Introduction to the writers



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[A few words from the writers]

Global warming is dramatically reducing the amount of ice in the Arctic Ocean and the development of submarine oil fields is reported to be active as a result of this phenomenon. Regrettably, habitats of polar bears continue to be reduced.