Environmentally Conscious Green Mobility

Tomohiko Yasuda
Takashi Kamei
Masakatsu Fujishita
Kazuhiro Umekita

OVERVIEW: Hitachi develops transport systems ("green mobility") that reduce the burden on the environment. In the field of construction machinery, it has developed highly efficient dump trucks for the mining industry through measures that include using lighter body structure and adopting electric drive. To encourage the wider adoption of railway systems which emit less CO_2 per unit of load carried, Hitachi has also used computational fluid dynamics to develop and deploy environmentally conscious technologies that minimize noise and pressure fluctuations as well as maintenance technologies essential for reliable rail transport. For automotive systems, Hitachi has developed direct injection systems to improve the efficiency of vehicles powered by internal combustion engines, and electrodynamic brakes and other components to improve the efficiency of hybrid and electric vehicles. Through the development of green mobility, Hitachi is responding to the growing need to conserve energy throughout society which has been highlighted by the aftereffects of the recent earthquake in eastern Japan.

INTRODUCTION

HITACHI develops and supplies transport systems such as railway and automotive systems and also construction machinery. With these systems believed to be responsible for around 20% of all CO_2 (carbon dioxide) emissions, cutting these emissions has an important part to play in reducing the burden on the environment[(1)].

Ways of reducing the CO_2 emitted by these transport systems include the adoption of electric drive and engine efficiency improvements, lighter body structures, and the utilization of regenerative energy. Hitachi is also working to reduce the burden on the environment by improving maintenance technology to achieve more reliable operation and by considering the effects, such as noise and pressure fluctuation, that operating these transport systems has on the surrounding environment.

The general term for transport systems designed to reduce the burden on environment is "green mobility."

This article describes the environmental technologies used in the construction machinery, railway systems, automotive systems, and other types of green mobility being developed and supplied by Hitachi.

CONSTRUCTION MACHINERY

In addition to demands for improvements in production efficiency, the need to reduce the burden placed on the environment by construction machinery has strengthened in recent years. This includes cutting CO_2 and exhaust gas emissions and reducing noise. To respond to these demands, it is necessary to increase efficiency in terms of the energy consumed per unit of work done.

To improve the efficiency of the large dump trucks used in opencast mining, Hitachi is adopting electric operation whereby electricity from a generator is used to drive electric motors and provide motive power. To improve carrying efficiency, Hitachi is also making progress on reducing chassis weight to increase vehicle capacity. The following sections describe the adoption of electric drive and the reduction of chassis weight in these mining dump trucks.

Fig. 1—EH4000ACII Mining Dump Truck.
The EH4000ACII electric drive dump truck has a 220-t-class capacity.

Adoption of Electric Drive

The two drive methods used on large dump trucks are mechanical drive and electric drive. The former uses a gearbox to convert the rotation of the engine to a lower speed which can be used to drive the wheels. Electric drive, in contrast, uses the engine to turn a generator and produce electricity which powers the electric motors that drive the truck. In 2008, Hitachi released the 190-t EH3500ACII AC (alternating current) electric dump truck which uses an inverter with high-voltage, heavy-duty IGBTs (insulated gate bipolar transistors)(2). This was followed in November 2010 by the 220-t EH4000ACII, the next model in the series (see Fig. 1).

Because the adoption of electric drive eliminates the need for parts such as a gearbox and differential gear, it reduces maintenance costs as well as providing a high level of power transmission efficiency. The dump trucks can also change speed quickly and smoothly thanks to the precise control of the drive motors provided by the highly responsive IGBT inverter. Meanwhile the high-capacity electric brake gives the dump trucks stable deceleration performance even when traveling downhill. These features speed up the transport cycle and achieve high work efficiency.

Hitachi is also developing trolley dump trucks in which the drive motors can be powered by an external power supply with low CO_2 emissions.

Body Weight Reduction

Increasing the carrying capacity of a dump truck is desired because it improves mining production efficiency. Because the total weight of the dump truck is limited by the load-bearing capacity of the tires, increasing carrying capacity requires that the body weight be reduced without compromising strength. To achieve this, Hitachi has developed an analysis technique for evaluating dump truck tray strength and used it to produce a lightweight tray.

The strength evaluation technique uses an analysis of the behavior of granular material such as earth and sand to estimate and model the pressure distribution on the sides of the tray resulting from the material being carried. It uses acceleration data from when the vehicle is in motion to calculate dynamic changes in pressure and a structural analysis to obtain the stresses in the tray.

This strength evaluation technique was used in the development of the tray for the EH4000ACII dump truck. The weight of the tray was reduced by 13% while maintaining strength by using thinner materials and repositioning the strengthening ribs in such a way that fewer ribs were needed (see Fig. 2).

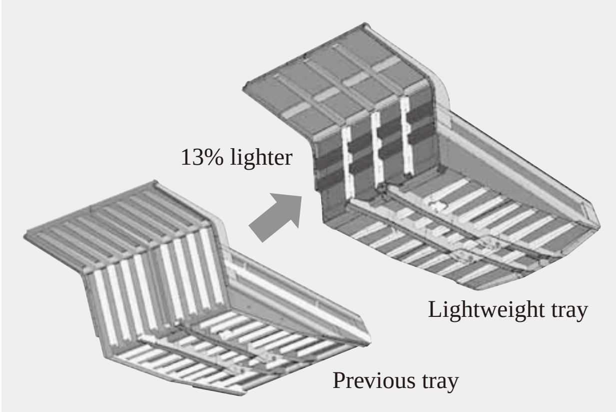

Fig. 2—Reducing Weight of Dump Truck Tray.
A redesign of the structure using a strength evaluation technique succeeded in reducing the tray weight by 13% compared to the previous design.

RAILWAY SYSTEMS

Railway systems are a means of transport with low CO_2 emissions per unit of load carried and recent years have seen plans to build new railway systems in various parts of the world. This wider adoption of railway systems requires technology to reduce effects that passing trains have on the surrounding environment such as noise and pressure fluctuations. As improvements in operational efficiency and the prevention of stoppages due to faults or other problems in the railway system also lead to a reduction in the burden on the environment, maintenance technologies that provide such reliable operation are also important. This section describes these maintenance technologies along with a technique for reducing pressure fluctuations.

Technique for Reducing Pressure Fluctuations Caused by Moving Trains

One of the effects that high-speed trains have on the railway infrastructure and surrounding environment is the pressure fluctuation associated with a passing train. In particular, tunnel walls can be damaged by the force imparted by pressure fluctuations generated as a train passes through a tunnel. Also, the transmission of the pressure fluctuations into the train interior causes the cabin pressure to fluctuate resulting in passenger ear discomfort. In Europe, regulations stipulate maximum limits for these pressure fluctuations to minimize the effect on tunnel walls and in consideration of passenger comfort(3).

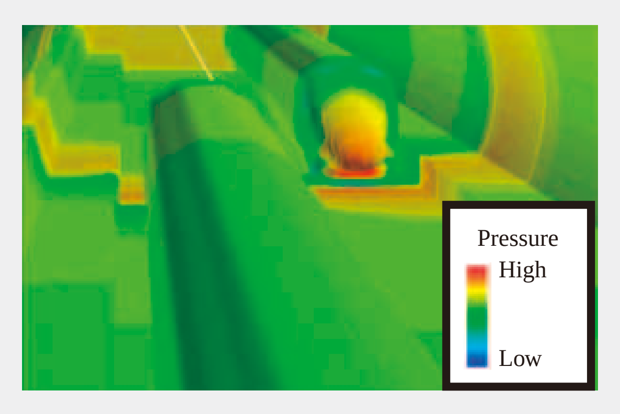

Fig. 3—Distribution of Pressure on Tunnel and Train Walls as Trains Pass through Tunnel.
A massively parallel supercomputer was used to analyze the pressure fluctuations that occur when two Class 395 trains in the UK pass each other in a tunnel.

It is known that the pressure fluctuations in a tunnel are the most severe when two trains pass in opposite directions. Fig. 3 shows the results of analysis using a three-dimensional model of trains passing in a tunnel in this way. This analysis can be used to estimate the pressure fluctuations that occur in the tunnel which vary depending on factors such as train speed and the shapes of the tunnel and trains. A parameter survey covering the train shape and other factors is conducted and the train shape designed to be within the permitted level of pressure fluctuation even under worst-case conditions.

Rolling Stock Maintenance

Hitachi designs rolling stock to prevent stoppages and improve operational efficiency, taking account of rolling stock maintenance from the design stage on the assumption that the manufacturer will be responsible for the life of the train. Because a contract to supply new rolling stock in the UK included a requirement to maintain the trains, Hitachi established a local subsidiary to handle maintenance in December 2005 and in October 2007 constructed a new maintenance depot near Ashford International Railway Station for the High Speed 1 (HS1) trains (see Fig. 4). The main equipment at the depot includes a drop pit in the workshop that can be used to fit or remove all under-floor components and systems able to measure things like wheel tread shape, wheel diameter, and remaining brake pad thickness automatically while the train is moving at low speed (10 km/h). The facility has attracted attention in the UK as an example of a modern railway depot.

The large staff at the depot work 24 hours a day on a three-shift system using their own distinctive maintenance practices which are based on maintenance of the Shinkansen bullet trains but also draw on methods used for maintenance of high-speed trains in other countries such as France's TGV (Train à Grande Vitesse) and Germany's ICE (Intercity-Express). Hitachi has also built a system for the central computerized management of information such as depot inspection records, materials information, fault information, design documents, and rolling stock logs to help improve maintenance and conduct the work more efficiently and with the aim of further improving operational reliability by using the system to perform maintenance based on the condition of the rolling stock.

AUTOMOTIVE SYSTEMS

In developing automotive systems, Hitachi is working to develop technologies that reduce the burden on the environment on two fronts: efficiency improvements for internal combustion engines, the current mainstream vehicle power source, and energy saving technologies for electrically operated vehicles such as EVs (electric vehicles) and HEVs (hybrid EVs) which are starting to become more widespread.

Fig. 4—Ashford Maintenance Depot for Class 395.
The photographs show parts of the maintenance depot for the 29 Class 395 trains which operate on conventional track in Kent in the southeastern UK and also the High Speed 1 (HS1). The workshop has five service tracks and the ability to install and remove under-floor components. Outside, the depot has automatic measurement systems that can automatically perform train wheel, brake pad, and other measurements.

Environmentally Conscious Engine Systems

Hitachi is developing a fuel supply system for direct injection engines that improves engine efficiency by injecting gasoline directly into the cylinder.

Because less time is available for the fuel to vaporize compared to conventional systems that inject fuel via the air intake port, vaporization of the fuel needs to be promoted by increasing the fuel pressure. Achieving this requires a large driving force for the high-pressure pump used to boost fuel pressure, the injectors (fuel injection valves), and other mechanisms but with this comes the problem of increased noise. In response, Hitachi developed a very quiet direct injection system by reducing the forces that induce vibration in the noise sources and by devising a proprietary low-noise design that inhibits the transmission of vibrations from the noise sources to the rest of the vehicle (see Fig. 5).

Improvements in corrosion resistance also allow the system to be used with alcohol fuel which can reduce effective CO_2 emissions. Hitachi intends to deploy the technology more widely in future in the down-sized engines being adopted to achieve even better fuel efficiency.

Components for EVs and HEVs

When environmentally conscious electric vehicles such as EVs and HEVs decelerate, the heat energy that would previously have been wasted in friction braking is instead converted to electricity by a generator and stored in the batteries. Reusing this stored energy to power the vehicle can significantly improve fuel efficiency. This requires a coordinated regenerative brake system that can achieve an appropriate balance between the braking force produced by the generator and that produced by the friction brake based on how hard the driver is applying the brake pedal.

By combining the highly reliable brake technologies and motor control technologies which have been built up over time together with its own hydraulic pressurization mechanism, Hitachi has developed and commercialized a coordinated regenerative brake system that can handle significantly improved levels of regenerative energy (see Fig. 6). To facilitate its use as a replacement for conventional brake systems, the brake system has a compact actuator that uses a motor and ball screw to pressurize the hydraulic master cylinder. It also includes a mechanism to inhibit variation in the resistance of the brake pedal during coordinated regenerative braking which provides a natural feel for the driver.

Fig. 5—Fuel Supply System for Direct Injection Engines.
These components are used in the fuel supply sub-system for direct injection engines.

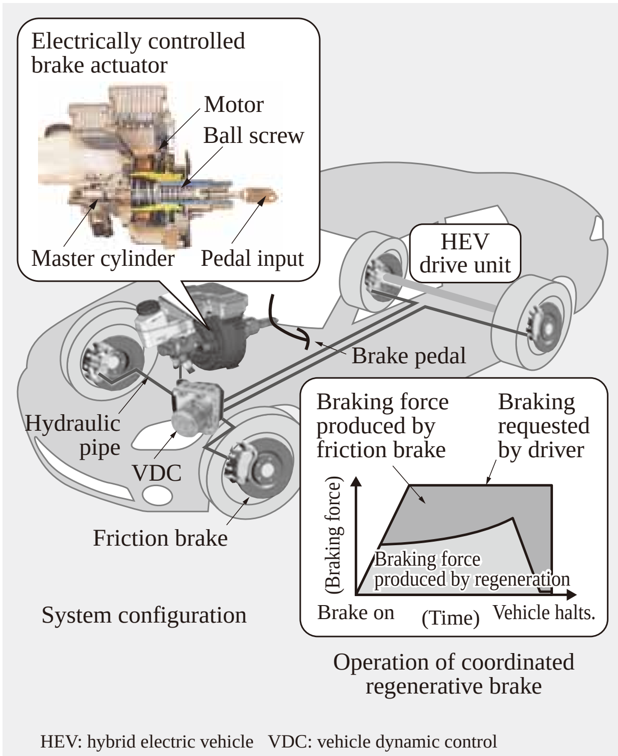

Fig. 6—Electrically Controlled Brake System Supplied to Nissan Motor Co., Ltd.
The diagram shows the location and design of the brake actuator together with an example of how the friction and regenerative braking forces are balanced based on how hard the driver is applying the brake pedal.

The system has been adopted for the electrically controlled brakes on the Fuga Hybrid (HEV) and Nissan LEAF (EV) models of Nissan Motor Co., Ltd.

CONCLUSIONS

This article has described the environmental technologies used in construction machinery, railway systems, automotive systems, and other types of green mobility being developed and supplied by Hitachi.

Influenced by the earthquake in eastern Japan, concern about issues such as energy conservation and the environment continues to grow. Hitachi intends to continue working toward better energy efficiency throughout society by improving the energy efficiency of green mobility products.

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ABOUT THE AUTHORS

Tomohiko Yasuda

Joined Hitachi Construction Machinery Co., Ltd. in 1981, and now works at the Development Center, Mining & Heavy Equipment Division. He is currently engaged in the development of large-sized excavators and dump trucks.

Takashi Kamei

Joined Hitachi, Ltd. in 1993, and now works at the Global Rail Business Development Division, Rail Systems Company. He is currently engaged in the coordination of overseas railway rolling stock projects.

Masakatsu Fujishita

Joined Hitachi, Ltd. in 1980, and now works at the Control System Design Section, Power Train Design Department, Power Train and Electronics Division, Hitachi Automotive Systems, Ltd. He is currently engaged in the development of direct injection engine systems and hybrid systems. Mr. Fujishita is a member of the Society of Automotive Engineers of Japan.

Kazuhiro Umekita

Joined Hitachi, Ltd. in 1987, and now works at the Transportation Systems Research Department, Mechanical Engineering Research Center, Hitachi Research Laboratory. He is currently engaged in the research and development of transportation systems. Mr. Umekita is a member of The Japan Society of Mechanical Engineers and The Robotics Society of Japan.