



The "GRENDA" 1 to 3.5 ton Class Forklift Trucks of New Generation

MASATAKA SHINYA*1
SATOSHI MATSUDA*1
TOMOYUKI ENOMOTO*1
MASATAKA KAWAGUCHI*2
NAOKI SHIBATA*3

1. Introduction

Forklift trucks are one of the mainstay products supporting the business activities of Mitsubishi Heavy Industries, Ltd. (MHI). In 1991, MHI introduced former model of 1 - 3.5 ton class forklift truck to the market. MHI has accommodated the model to the needs of the market by making two times of minor changes since then. The major design change has been made that aims to satisfy the changing needs of users and even more, to place the product ahead of market needs. This full model change has been undertaken in joint cooperation with the Nissan Motor Co., Ltd.

2. Business Environment around Products

A long time has passed since forklift trucks have come to be considered as mature products, with competition among manufacturers of these products heating up within a limited market. The recent business environment can be summarized as follows.

- (1) Users have come to aware of the importance of protecting the environment in recent years, with the result of this numerous governments have come to implement environmental regulations.
- (2) The market has been changing to demand more comfort for operators equivalent to that of automobiles

and also to demand the introduction of measures to reduce the causes of personal injury.

- (3) Users have been placing more attention on the operating costs of forklift trucks to improve their efficiency of operation.

3. Product Concept

In order to accommodate the evolving needs of the business environment as described in Section 2, MHI has built up the product concept for new forklift trucks as follows.

- (1) The basic product competitiveness of new forklift trucks is to be raised up to the top level among competitors.
- (2) Maintenance costs are to be reduced reflecting the growth in the demand for lease and rental use.
- (3) To meet the demand toward the higher efficiency of truck operation from users, the system to monitor the status of forklift trucks will be developed and truck system shall enable itself to equip these new systems.

The name "GRENDA" is a coined word formed by combining "GREEN" expressing the global environment with the Mitsubishi trademark of "THREE DIAMONDS". It is also the nickname of the product, which plainly expresses its nature. The major specifications of the GRENDA are shown in **Table 1**.

Table 1 Major Specifications of GRENDA

Model name		FD 15	FG 15	FD 25	FG 25	FD 35 A	FG 35 A
Rated capacity	(kg)	1 500	1 500	2 500	2 500	3 500	3 500
Dimensions	Overall length (mm)	3 180	3 180	3 625	3 625	3 860	3 860
	Overall width (mm)	1 065	1 065	1 150	1 150	1 290	1 290
	Overall height (mm)	2 065	2 065	2 070	2 070	2 105	2 105
Performance	Max. speed (km/h)	19.0	19.0	19.0	19.0	19.0	19.0
	Lift speed (load) (mm/s)	600	560	640	590	430	430
Engine		Diesel engine	Electronic controlled gasoline engine	Diesel engine	Electronic controlled gasoline engine	Diesel engine	Electronic controlled gasoline engine
	Displacement (cc)	2 505	1 486	3 331	2 065	3 331	2 488
	Rated output (kW)	36	31	44	42	44	47

*1 General Machinery & Special Vehicle Headquarters

*2 Takasago Research & Development Center, Technical Headquarters

*3 Nagoya Research & Development Center, Technical Headquarters

4. New Technologies of the GRENDiA

4.1 Electronic Controlled Gasoline Engine

To meet the requirements for the regulation of exhaust emissions in the market, MHI introduced the industry's first three way catalytic converter + electronic controlled fuel injection system to a gasoline engine truck as a standard model. This reduces the harmful components of exhaust emissions, CO, HC, and NOx, by more than 90% (compared with previous MHI engine models).

4.2 Diesel Engine for Forklift Truck

MHI introduced a long-stroke, low-speed diesel engine manufactured by MHI itself on forklift trucks which is exclusively designed for industrial truck use from previous generation. Moreover, by improving the fuel injection pump and optimizing performance to actual forklift truck use, as shown in **Fig. 1**, GRENDiA has achieved extremely low levels of smoke emissions, which are the best among competitors.

4.3 Vehicle Control System

In order to reduce the causes of personal injury and to monitor the state of operation, GRENDiA is equipped

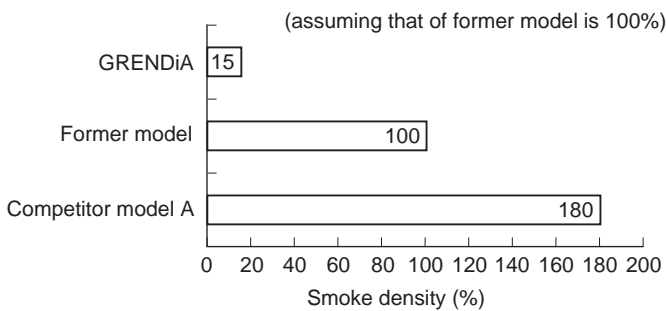


Fig. 1 Reduction of emissions of smoke from diesel engine
Black smoke has been reduced by 85% compared with that of former MHI models, which places this engine at the top level in the industry.

with new vehicle control system consisting mainly of a VCM (Vehicle Control Module) that has vehicle operation control function and data communication function. This system prevents the traveling gears and load-handling equipment from being operated when the operator is not seated, thereby helping to reduce some major causes of personal injury. On the truck that has electronic-controlled gasoline engine, the ECM (Engine Control Module) is connected to the VCM through CAN-Bus developed as on-vehicle LAN so that the operating condition of the engine can also be monitored from the VCM together with other information.

In addition, MHI has developed a truck management system to indicate the timing of maintenance and truck disposition through the information terminal installed on each truck and transmitting information on the operating condition of each truck to a database dedicated to this purpose. The truck control system is shown in **Fig. 2**, and a sample output of the truck management system is shown in **Fig. 3**. Fig. 3 shows a large difference between two trucks. From this information, it can be seen that in order to improve operating efficiency, the arrangement of trucks must be re-considered.

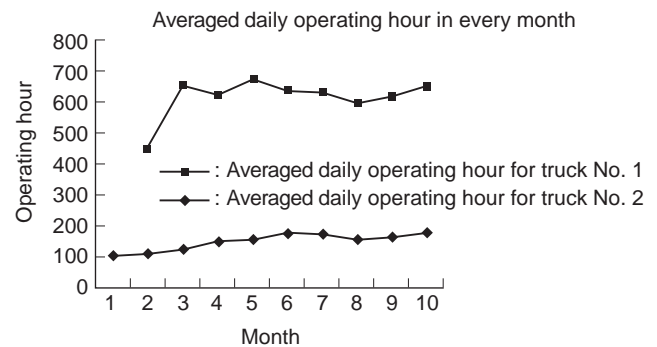


Fig. 3 Example of analysis of the operating state of an actual vehicle using the Truck Management System
The figure shows an example of a comparison of data on the averaged daily operating hour between two vehicles in every month.

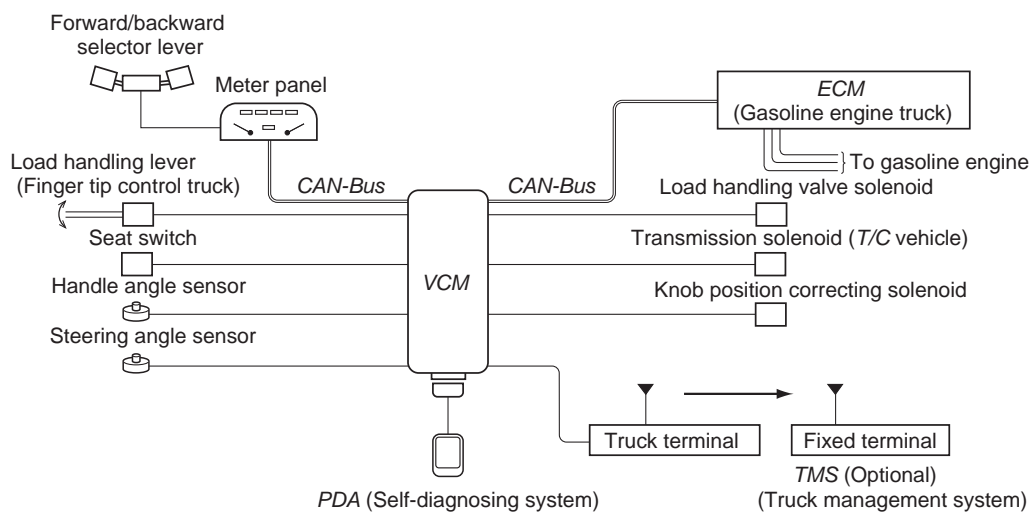


Fig. 2 Vehicle control system Control system mainly consists of VCM (Vehicle Control Module).

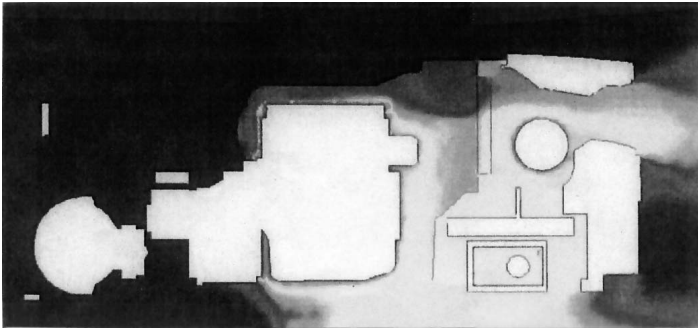


Fig. 4 Example of analysis of virtual mockup
 This figure shows that cooling air (the left hand) from the outside passes through the engine and radiator, and the heated air (the right hand) is exhausted.



Fig. 5 Truck design image
 In this "Egg Hold" image, an egg (operator) is supported by a hand (sturdy body) for protection.

4.4 Development Support Tool

In order to shorten development periods, ways need to be found to minimize repeated trial productions and tests with actual trucks. For this purpose, MHI has built a "virtual mockup," a computer simulated analysis system for forklift trucks and has used this system in the development of new model. In this system, analysis programs for motion, strength, heat flow, and that for other factors are integrated together, and the performance of the actual truck is predicted using the three-dimensional CAD data prepared during the design stage of development. A sample analysis results made using this system is shown in **Fig. 4**.

5. Truck Design

In mass-produced products, the design of the product is also an important factor in the commercial appeal and

competitiveness of the product. In the GRENDiA, MHI adopted the concept of placing emphasis on the operator comfort, and created a design image named as the "Egg Hold". As shown in **Fig. 5**, this clearly separates the interior section from the exterior section so that the operator can have a feeling of being protected inside an enclosed working space.

6. Conclusion

The GRENDiA produced by MHI has the highest levels of commercial appeal and competitiveness among competitors, and is a forklift truck that is the vanguard of future market trends (awarded the JIDPO Good Design Award). In the future, MHI will keep on making every effort to improve "GRENDiA" in order to strengthen its appeal and competitiveness even further.



Masataka Shinya



Satoshi Matsuda



Tomoyuki Enomoto



Masataka Kawaguchi



Naoki Shibata