Introduction of Product

Introduction of New Motor Grader Models GD555/655/675-5

Yukihisa Sakai

Kazuhiro Takemoto

The global model GD555/655/675-5 in the medium-size class, which will be the core market for graders, has undergone a model change over the existing GD555/655/675-3 models, featuring a higher fuel efficiency and effective cost reduction. The technologies incorporated in the new global models are described.

Key Words: *Motor grader, Hexagonal cab, Visibility, Dual mode transmission, Fuel efficiency, KOMTRAX*

1. Introduction

The GD555/655 and GD675 are motor graders with a blade width of 12ft (3.7m) and 14ft (4.3m), respectively and belong to the medium class, which is the core segment in the market of graders that are mainly segmented by their blade width.

Aimed at sales promotion in the North American market, which demands high performance in this medium class, Dash 3 was launched in the market in 2001. The graders manufactured by Komatsu before this model were based on the design of installing the operator compartment on the rear frame. Beginning with Dash 3, however, a change has been made to install the operator compartment on the front frame as in competitors' products. At the same time, an increase in the power and significant expansion work equipment mobility. These Komatsu grader have become machines that can compete with competitors produced by overseas manufacturers on an equal footing in the commercial market. A model change from Dash 3 to Dash 5 has now been made inheriting good visibility and ease of operation through Dual mode transmission and enhancing the environmental performance to a state-of-the-art level such as fuel consumption and noise.

Fig. 1 Appearance of GD655

2. Aims of Development

Since its debut with Tier 1 graders, Dash 3 has been manufactured and sold up to Tier 3 graders with GD655 and 675. However, Dash 3 lagged behind today's technology level such as an inability to transmit error codes to KOMTRAX. The GD555 is compliant with Tier 2 and measures to be taken against the latest emission regulation have been an urgent task to be addressed. For this reason, a decision was made to develop Dash 5 aimed at providing price competitiveness compared with existing models through a cost reduction and equipped with functions that have become a Komatsu standard at present while incorporating the features of the existing models such as basic structures of work equipment. Needless to say, Dash 5 was designed to satisfy the regulations implemented in the European market. The principal improvement items incorporated in the new model are described below.

2.1 Long Wheel Base and Forward Mount Power Train

A dimensional characteristic of Dash 5 is an increase of 400mm in the long wheel base compared with existing models, becoming the longest wheel base for this class (GD655).

The basic blade length for this class is a 12ft blade. However, more graders have been installed recently with a 14ft blade for a higher grading efficiency. A machine style with a wide space for the operator was designed by a significant moving back of the rear wheel positions for easy operation when put a longer blade onto the between front and rear wheels and when moving to a bank cut. While grading by a machine, the grader receives a side thrust from the blade and a long wheel base is also advantageous in terms of enhancing grader stability during forward traveling. The minimum turning radius, which runs counter to a longer wheel base, is managed to be smaller than those of competing machines by increasing the articulate angle. This wheel base and overall length are the limits for transporting on a low deck trailer with a ripper mounted in domestic transport.

The longer wheel base allows forward mount of the transmission so that fuel can be supplied from the ground by moving the fuel tank to the rear overhang which used to house the over transmission before.

In the past, an electric motor operated pump system had to be installed on the hood to supply gas to the fuel tank from the ground depending on the grader shipping destination. This is the long-awaited grader layout.

The basic configuration of the transmission of eight forward travel gear shifts and four backward travel gear shifting with a torque converter remains the same as before. By changing the power forward mount, the clutch control valve was moved from the rear end to the upper side to improve the maintainability.

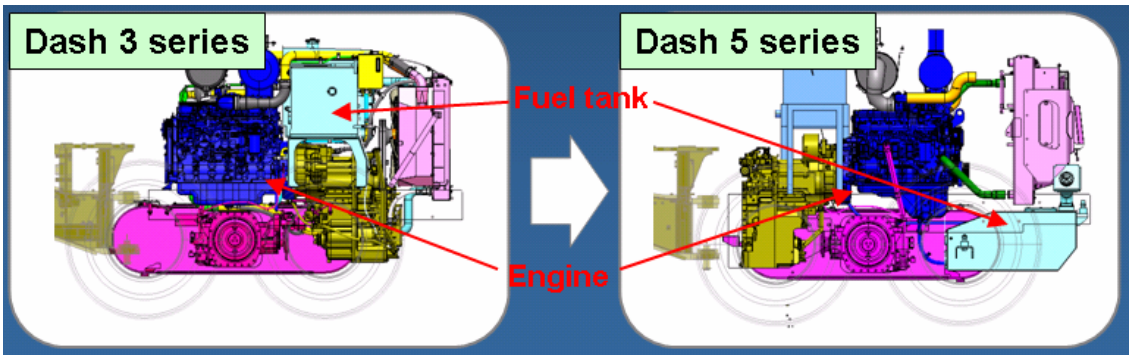


Fig. 2 Layout of power train

Fig. 3 Improvement in fuel supplying method

2.2 SAA6D107 Tier 3 Engine

(1) Standardization of power train

In the past, the GD655 and GD675 had a common chassis and the SAA6D114E engine that was mounted on them already certified the Tier 3 regulation. Nevertheless, a reduce displacement was achieved while increasing the maximum output by mounting the SAA6D107E engine. (**Fig. 4**) Conversely, the GD555 is now installed with the SAA6D107E engine, instead of the former Tier 2 SAA6D102E engine to meet Tier 3 and to compete with a drastic output increase provided by competing machines. As a result, three machine models in Dash 5 have the same power train. The differences in the rear frame among different machine models could be reduced only to a difference in tuning by the engine controller. The machine models could achieve a high level of commonization.

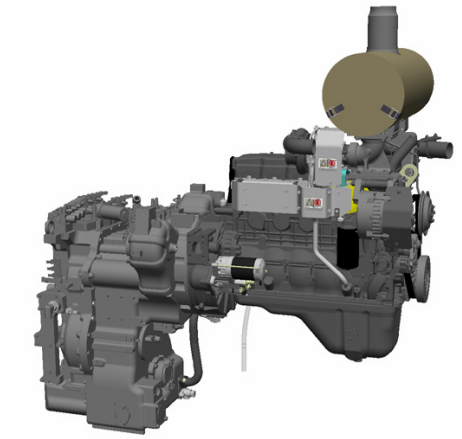


Fig. 4 Power unit

(2) 3-stage shift VHPC

Two stage shifts in VHPC (variable horsepower) in the past have been increased to three stage and two modes have additionally been set, namely, Mode P with a focus on horsepower and Mode E with a focus on fuel consumption. VHPC features 3-stage in two modes. (**Table 1**)

A low speed in Mode E curbs extra horsepower and improves the controllability and fuel consumption during grading. To achieve them, maximum output is set low compared with the existing models. Conversely, the power at a high speed in Mode P is increased compared with the existing models to improve the speed on-road travel speed during travel without load.

(3) Engine speed restriction function

In Mode E with a focus on fuel consumption, a function has been added to restrict the maximum engine revolution speed to 75 and 85% in accordance with the operating gear shift to encourage shift change to a higher gear shift.

During grading with a low load, a gear shift such as F1 and F2 and at a high engine speed that is unique to grader operation, a fuel consumption reduction effect cannot be achieved simply by a horsepower setting difference by VHPC. For this reason, settings were made to lower the operating revolution. This was devised as a fuel consumption reduction project to maintain the same fuel consumption as before with the same work rate with GD555 that has larger displacement and output compared with the existing models. At 1st gear, for example, engine speed is the same up to 75% in accelerator opening as before and keep 75% speed is maintained also at a higher accelerator opening. In this study of a restriction rate, a restriction rate that would achieve a high fuel consumption effect without a sense of uneasiness could be confirmed in a test in an actual work condition.

A significant fuel consumption reduction could be achieved during grading without experiencing a sense of uneasiness during grading and without lowering the maximum speed by changing the restriction ratio for each gear shift. The GD555 with a drastic increase in horsepower combined other technology allows grading with lower fuel consumption compared with before. The GD655 has achieved a 20% improvement in fuel consumption during grading. (**Table 2**)

Table 1 Outputs by former and new models

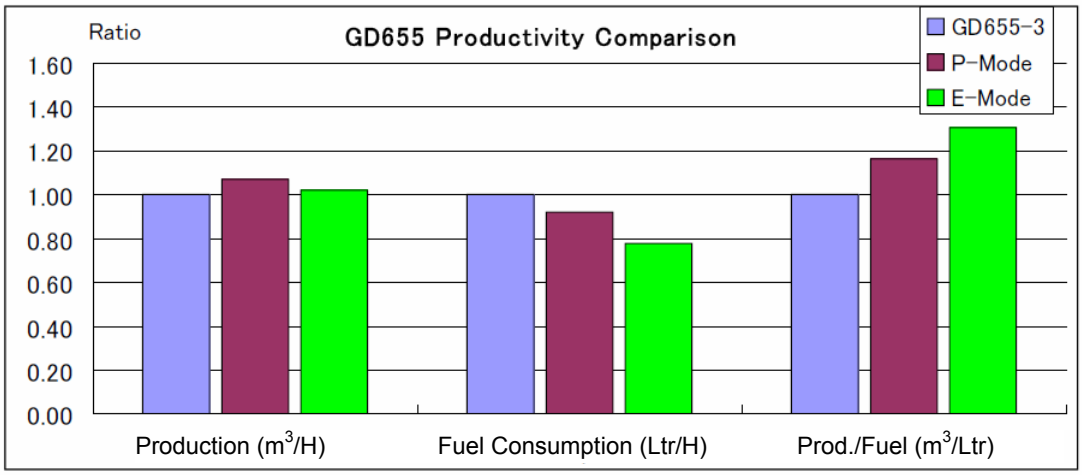
GD655-5 kW (HP)

	P		E	
	AUTO	MANU.	AUTO	MANU.
F1	134 (180)	134 (180)	108 (145)	108 (145)
F2				
F3	149 (200)	149 (200)	134 (180)	134 (180)
F4				
F5				
F6				
F7	163 (218)	163 (218)	149 (200)	149 (200)
F8				
R1	134 (180)	134 (180)	108 (145)	108 (145)
R2				
R3	149 (200)	149 (200)	134 (180)	134 (180)
R4				

GD655-3E0 kw(HP)

	AUTO	MANU.
F1	134 (180)	134 (180)
F2		
F3	149 (200)	149 (200)
F4		
F5		
F6		
F7		
F8		
R1	134 (180)	134 (180)
R2		
R3	149 (200)	149 (200)
R4		

Table 2 Comparison of fuel consumption and work rate



3. Hydraulically Driven Cooling Fan

A hydraulically driven variable fan was adopted to enhance the cooling efficiency and compliance with the EU noise regulation.

A fixed pump + flow control system which is proven viable in the small-size WA type was adopted because of cost consideration and the whole system was increased in size. The fan motor contains a rotation sensor to check and adjust the revolution speed on the monitor.

Tests were conducted during the development stage preconditioned on automatic reserve revolutions. However, because of use on sand terrains, manual reverse revolutions only by a switch were finally implemented. Additionally, the specification calls for accepting reverse revolution change operation only when the shift is in p position. In addition to the fan reverse revolution function, the service hole for cleaning is moved from the top panel of the hood to one side of it. The serviceability could be improved through this and other changes.

A large-capacity specification for Australia was prepared in the cooling system for Dash 3. In Dash 5, the same standard as that for the large-capacity specification was made the standard.

In a stress test of the grader cooling unit, the grader would travel at a high speed with tire chains on wheels assuming plowing of snow. As for countermeasures for high stress zones, the conventional analytical method could not forecast an improvement level with high precision. However, a technique was developed to analyze by combining vibration analysis based on an glavity on the frame. This technique contributed to a reduction of test cycles.

4. Work Equipment

Reliability could be improved by adding a cover to keep earth and sand away from the blade shift cylinders which are exposed to earth and sand most while retaining the structures of work equipment that have received a high evaluation. Together with the addition of a cover, dust seals have also been improved, to enhance reliability.

Six different blade types are available by varying the width, plate thickness, material and radius of a circular arc in accordance with the shipping destinations of graders.

Blades for shipment to North America had been manufactured in the past by pressing high carbon steel including side edge mounting portions. The press process exactly to the specification was not available in Japan and blades for shipment to North America only have been locally procured in North America and graders without a blade have been shipped from the Awazu Plant. The side edge mounting portion of Dash 5 was changed to an independent welding structure to allow local manufacture of blades in Japan, to improve quality and to reduce cost. This allows shipment of graders in a completed condition and pre-shipment inspection of clutch type circle rotating unit that have become standard provision equipment can also be made, thereby contributing to a more stable quality level.

The commonization of the power trains mentioned above has left the front frame side as the only difference between GD555 and GD655/675 in Dash 5 with which to create different parts. Compared with the GD655/675 whose wheel base is the longest in the class placing an emphasis on user friendliness that can be achieved with a 14ft blade, the GD555 that focuses on a 12ft blade has a short draw bar and front frame.

5. Hexagonal ROPS Cab for Visibility Improvement

The visibility of the hexagonal ROPS cab has won high evaluation among the users. However, a challenge was made to further improve the visibility. The square cab has its limits in improving the visibility around the blade in front of the operator's seat due to the A pillar and corners of the front part of the floor. A visibility improvement was made therefore by changing the cab structure.

The Komatsu graders for the market in Japan up to two generations before had a hexagonal cab. However, due to cost and difficulties in providing a space for valves, the cab shape was integrated to square cabs that were the standard in the market when graders were changed to Dash 3. Nevertheless, the competitors started to sell graders with a hexagonal cab and further improvement in visibility has become important. Komatsu therefore decided to mount the hexagonal cab again and to make a new design of it.

There was no difference in the floor structure between the former hexagonal cabs and square cabs. Control valves were placed underneath the left and right floors holding the steering post. For this reason, the width of the front part of the floor was restricted by the space for valves. To improve the visibility as much as possible, Dash 5 has control valves in front of the cab and the shape of the floor gives its highest priority to the work equipment visibility. The steering post was made as narrow as possible to secure a pedal space in accordance with the ISO standard using this floor shape. As a result, the pedals can now be operated without opening the feet as wide as before and the can now be operated in a natural position.

The space behind B pillar is now wider by 100mm each on the left and right compared with before, thereby improving the comfortability.

The pillar position, which greatly affects the workability, was studied while checking the visibility during grading using a head mount display (HMD). Through this study, a characteristic A pillar in "Y" shape and intermediate B pillar that is greatly moved back were adopted. These pillars significantly improved the blade visibility during grading. At the same time, an extremely stylish silhouette could be implemented having a forward tilt front window in a grader which normally has a backward tilt front window. The Cab Development Center was asked to undergo great pains in solving problems with the doors that were made larger as a result of the focus on visibility. Nevertheless, through the cooperation of the center, high volume production of the new machine models could be commenced. (**Figs. 5 and 6**)

Fig. 5 Comparison of visibilities of work equipment between former and new models

Fig. 6 Appearance of cabs

The cab incorporates levers of the conventional type. Only ten levers can be installed if this shape of the cab was to be used. The normal specification specifies a maximum of ten levers. However, the market requires 14 levers for special attachments (14 hydraulic systems). Solenoid operated valves are therefore separately installed for the four systems in shortage. This decision was one of the reasons that made the cab shape change possible.

The work equipment levers of graders are entering an era of evolution and their operations are expected to change to a new operation mode in the near future. However, at present, the manufacturers are still getting to grips with it and the conventional operation system is still several steps ahead.

6. Independent Hydraulic Circuit and Multi-function Valve

A fixed pump has been added to add a hydraulic cooling fan. In the past, one pump has been responsible for the operation of steering, brakes and work equipment. In Dash 5, the hydraulic system has two independent systems because a pump has been added, namely, the work equipment + steering system and fan + brake system, to enhance reliability.

Through the cooperation of the Development Center, a multi-function valve that integrates the float function, PCV, safety valve and other functions was newly manufactured as the main valve.

In the past, an external PCV and float valve were combined in two main valves that were provided one each on the left and right. By integrating them, the float can be operated by lever operation of the work equipment, thus improving the controllability. The valves have been integrated into one valve, but the new valve has Ports P and T on the left and right to secure the necessary flow rate.

7. Transmission Control

The transmission control has been changed from the LX controller to CR710 and more service information items can be displayed on the monitor. Additionally, the KOMTRAX Step 2.5 services are now accessible.

In conjunction with the change of the controller, elimination of complaint items in the past and addition of new functions have been made.

①Shuttle shift control

When the operator shifted the gear in a direction opposite to the traveling direction before stopping the grader, the machine had to make inertial traveling in neutral gear to protect the transmission. This type of operation is prohibited, but the market has pointed out uneasiness about this. For this reason, a countermeasure was devised. Beginning Dash 5, integrated control of shift operation and accelerator opening has become feasible. By adding a deceleration logic to a region that has used "wait" operation in the past, the gear shift can now be changed continuously in a desire travel direction.

②Engine stall prevention control

Perfect compatibility between automatic operation by a torque converter with lockup drive and power shift direct manual travel is a feature of the dual mode transmission. This is why engine stalls in the direct manual mode and problems caused by traveling with a balanced load at an engine speed below low idling are prevented by adopting "engine stall prevention control" to temporarily change to the torque converter mode when the engine speed lowers below a preset speed during the direct manual mode. (**Fig. 7**)

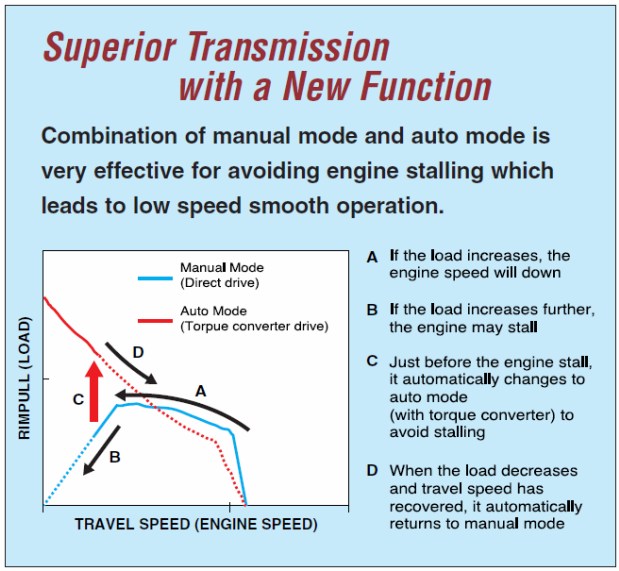


Fig. 7 Conceptual diagram of engine stall prevention control

The torque converter drive mode set by this control is return to the direct manual mode under the following conditions.

- Apply the accelerator and engine speed exceeds 1000rpm.
- When inching (corresponding to the clutch pedal) is fully applied, this function machine assist inching operation and work with no shocks is feasible regardless of operator skills.

8. Regional Specification

Dash 5 is regarded as a global machine and incorporates features to satisfy safety standards such as a work equipment lever lock (generally, a lever lock is not provided with graders) in the early phase of the development already anticipating sales in the EU region.

The grader specification for Australia called for large-capacity cooling and grader appearance also was different. Dash 5 commonized machine bodies and features a cab fixed window as an option for shipment to Australia to enhance sealing performance, rotating lamp with a guard net, air inflation kit (hydraulically driven air compressor to replenish tire air) and other features.

In deciding these specifications, a global evaluation council meeting was convened in the early stage of the development to incorporate evaluations by operators in Europe and North America and the wishes of local corporations of Komatsu.

More specifically, the differential lock switch is moved in Dash 5 to a position that enables operation of it without removing one's hand from the control lever. This change was made in response to wishes made by overseas users.

9. Conclusion

The GD555/655/GD675-5 excel in economical efficiency and are the graders that incorporate the IT technologies of today. As a result of pursuing a better visibility, the graders have product appearances that change the grader image. It is hoped that the graders will be received favorably in the market in addition to exploration of the EU market and that they will gain a good reputation in the regions in which price has been a bottleneck in the past.

Table 3 Principal specifications

	Model	GD555-5	GD655-5	GD675-5
HORSEPOWER:				
SAE J1995: Gross	kW (HP)/rpm	146 (196)/2000	165 (221)/2100	165 (221)/2100
ISO9249/SAE J134 Net	kW (HP)/rpm	144 (193)/2000	163 (218)/2100	163 (218)/2100
OPERATING WEIGHT:	kg (lb)	15135 (33,370)	15495 (34,160)	15955 (35,170)
Front		4140 (9,130)	4205 (9,270)	4375 (9,650)
Rear		10995 (24,240)	11290 (24,890)	11580 (25,530)
PERFORMANCE:				
Max. reverse speed		40.3 (25.0)	40.3 (25.0)	40.3 (25.0)
Min. turning radius	mm (ft.in)	7300 (23' 11")	7400 (24' 3")	7400 (24' 3")
MOLD BOARD:				
Length	mm (ft.in)	3710 (12' 2")	3710 (12' 2")	4320 (14' 2")
Height	mm (in)	645 (25.4)	645 (25.4)	645 (25.4)
Thickness	mm (in)	19 (0.75)	19 (0.75)	19 (0.75)
DIMENSIONS:				
Overall length	mm (ft.in)	8995 (29' 6")	9205 (30' 2")	9205 (30' 2")
Overall width (excl. blade)		2485 (8' 2")	2485 (8' 2")	2630 (8' 8")
Overall height		3200 (10' 6")	3200 (10' 6")	3200 (10' 6")
Wheelbase	mm (ft.in)	6270 (20' 7")	6480 (21' 3")	6480 (21' 3")
Blade base		2380 (7' 10")	2580 (8' 6")	2580 (8' 6")
Tread: Front		2060 (6' 9")	2060 (6' 9")	2060 (6' 9")
Rear		2060 (6' 9")	2060 (6' 9")	2060 (6' 9")
ENGINE:				
Model		Komatsu SAA6D107E-1	Komatsu SAA6D107E-1	Komatsu SAA6D107E-1
Type		Direct injection Turbocharged Aftercooled	Direct injection Turbocharged Aftercooled	Direct injection Turbocharged Aftercooled
No. of cylinders -	mm (in)	6 - 107 x 124	6 - 107 x 124	6 - 107 x 124
POWER TRAIN:		F8/R4	F8/R4	F8/R4
Torque converter or Main clutch		Single stage T/C with lockup clutch	Single stage T/C with lockup clutch	Single stage T/C with lockup clutch
Transmission		Powershift Countershaft	Powershift Countershaft	Powershift Countershaft

Introduction of the writers

Yukihisa Sakai

Entered Komatsu Ltd. in 1995.
Currently Chief Engineer of the Motor Grader Development Group, Construction Equipment Technical Center 2, Development Division.

Kazuhiro Takemoto

Entered Komatsu Ltd. in 1981.
Currently Manager of the Motor Grader Development Group, Construction Equipment Technical Center 2, Development Division.

[A few words from writers]

The development of Dash 5 was originally planned with a focus on the American market and the Lehman Crisis was a serious shock also to the development team. Fortunately, a cost reduction was the most important target and sales of the model could be launched by steering to GA. The writers thank those at the Component Development Center and at the Production Department of the Awazu Plant for their cooperation.

It is hoped that Dash 5 will get to the market which remains as it was and in which machines two and three generations before are also sold, utilizing cost improvement and user friendliness in operation as strong points to upgrade the image of Komatsu graders.