Introduction of Product

Development of D85MS-15 Demining Dozer

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More than one hundred million landmines are reported buried all over the world. The buried landmines are injuring many civilians and deminers every year. In August 2002, the antipersonnel demining dozer was removed from the list of military vehicles. In 2003, KOMATSU started the development of antipersonnel demining dozer for humanitarian aid with support provided by the Japanese government. The base machine was designated D85EX-15 and the machine was named "Model D85MS-15." The most important functions for the demining dozer are working speed, demining accuracy and durability. D85MS-15 has achieved all these functional requirements as reported in the following.

Key Words: *Demining dozer, D85MS-15, Afghanistan, Cambodia, humanitarian aid*

1. Introduction

Aimed at supporting humanitarian aid, this development was conducted and subsidized by the Ministry of Economy, Trade and Industry and the New Energy and Industrial Technology Development Organization (NEDO). Afghanistan was selected as a target country for the initial stage of development. The country had decided the areas in which mines should be removed preferentially. Farmlands, pastures and roads account for 95% of the total area. The equipment was developed designed to remove mines in these land segments.

As the base machine, the D85EX-15 with a machine body weight of 27 tons was selected and the machine used the technology of the CS210 stabilizer as a high-efficiency mine processing device.

The machine is installed with a dedicated transmission, excavation control, shellproof device, radio control device for remote operation and a basket device for the recovery of mine fragments. It is no exaggeration to say that the demining dozer brings together the technologies of all the development centers of Komatsu. The details of the development are reported in the following (**Photo 1**).

Photo 1 General view of D85MS-15

2. Aim of Development

(1) Analysis of current situation

Afghanistan is a landlocked country surrounded by six countries. The southern part of the country is deserts, while the eastern, central and northern parts are mountainous areas. About 75% of the land area of the country totaling 652,000 km^2 (about 1.7 times the land area of Japan) is mountainous areas.

The land described above was classified by area and targets were narrowed down (**Fig. 1**).

- Classification of work sites in priority areas for demining and equipment types

	Farmlands	Pastures	Roads	Dwelling houses	Irrigation
Area (km^2)	163	143	35	16	3
Percentage	45%	40%	10%	4%	1%

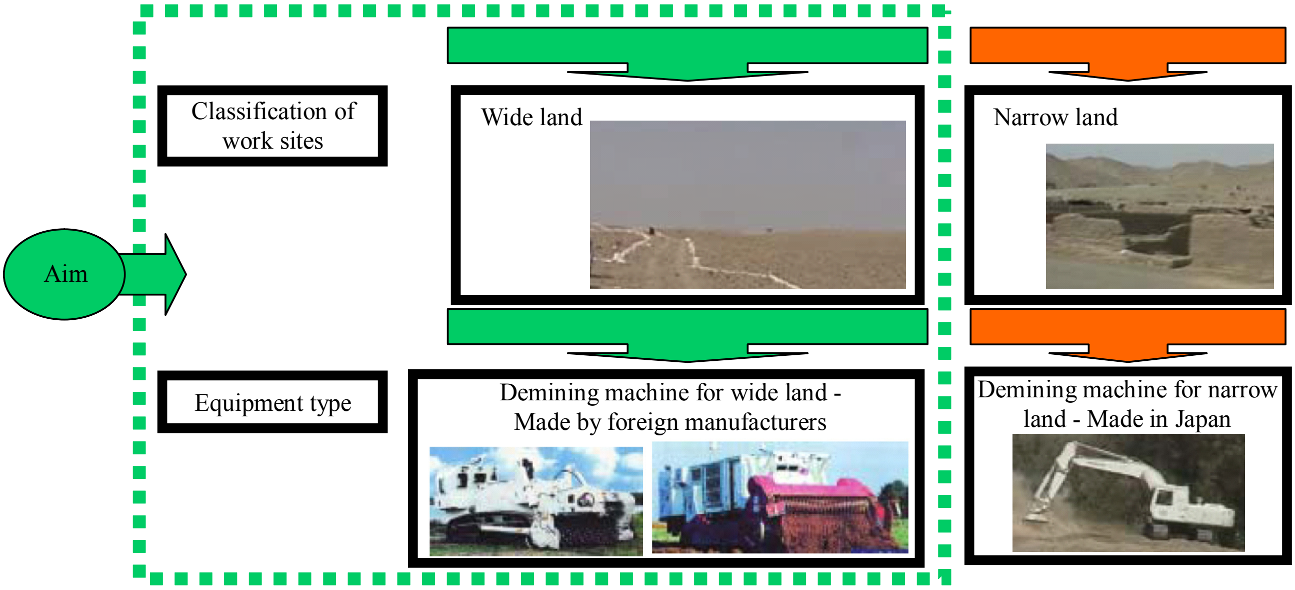


Fig. 1 Narrowing down of targets

(2) Goal setting and accomplishment means

A swift work capacity and high safety were demanded for the deminer and goals were set as shown in **Table 1**.

Table 1 Goals and accomplishment means

	Requirements and goals	Accomplishment means
Working capacity	• Processing speed about 20 times the human capability designed for use in wide land	◊Wide-width crushing structure ◊Low-speed transmission
	• Farmlands are generally plowed 20 cm. Processing depth is 20 cm or more.	◊Rotor shape
	• Demining in uneven ground is feasible	• Utilize conventional construction machinery (bulldozers)
	• Demining in mountainous areas (steep grade) is feasible	• Utilize conventional construction machinery (bulldozers)
Safety	• Structure to protect operator and equipment	◊Shellproof device
	• Ability for remote operation for safe operation	◊Radio control device
	• Fragments can be recovered.	◊Basket device
Others	• Can be used in infrastructure development after demining	◊Low-speed transmission
	• Vehicle structure suiting natural environment	◊Tractor for sandy terrains
	• Structure that keeps price to a minimum for use at more sites	

3. Accomplishment Means

3.1 Working Capacity

(1) Selection of base machine

Taking into consideration the work on uneven ground and at a steep grade among the requirements mentioned on the previous page and in accordance with Komatsu's policy "What is important for Japan is to build a demining system rather than competing among enterprises," a unique bulldozer of Komatsu that was not manufactured by other companies was selected as the base machine.

In the selection of a machine type, a processing capacity about 20 times that of human capability was set as a goal. The processing capacity by human labor would be about 20 m^2 per hour or 400 m^2 by simple calculation.

Because a device developed in advance for the stabilizer (road repair machine) will be used in the mine processing device (rotor), the rotor will require a machine type that can run inside the processing width and power to rotate and process the rotor will be required. As the model that satisfies both of these requirements, the D85EX-15 was selected (**Photo 2**).

Photo 2 D85EX-15

(2) Low-speed transmission

During normal work on an ordinary bulldozer, the gear is changed by:

- The gear shift is fixed and an optimum speed is maintained by controlling the blade, or
- The gear is shifted down automatically when the load is high using the auto shift down function and the maximum speed is maintained by controlling the blade when the load is high.

In both cases, the load is controlled ultimately by lifting or lowering the blade (**Fig. 2**).

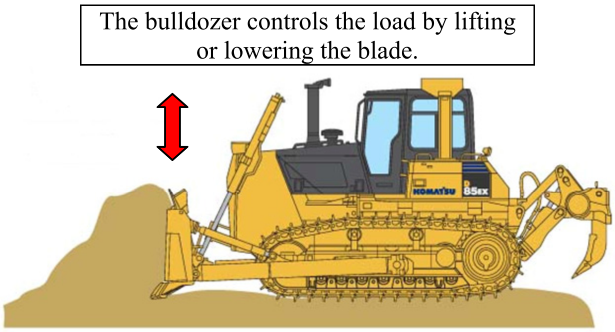


Fig. 2 Control of normal bulldozer

The demining dozer can only retract to demined land and cannot change its cutting depth. For these reasons, an ultra-low-speed transmission had to be developed.

The F1 travel speed (demining gear shift) was set at **0.4 km/h** based on an empirical value of 0.1 to 0.5 km/h for the rotor width of 2550 mm (stabilizer) and the goal of 400 m^2/h, which was more than 20 times the human capability.

Bases for calculation

- The working capacity was set at 500 m^2/h providing an allowance to the goal of 400 m^2/h or more.
- The efficiency was set at 50% as the demining dozer had to always retract after demining.

Demining area: 500 m^2/h ÷ 50% = 1000 m^2/h

$$\textbf{Vehicle speed (km/h)}\ \textbf{0.4km/h} = \frac{\text{Demining area per hour } 1000\ m^2/h}{\text{Rotor width } 2.55\ m}$$

Table 2 Comparison of speed reduction ratio and vehicle speed

	Demining dozer		Standard bulldozer	
	Speed reduction ratio	Vehicle speed (km/h)	Speed reduction ratio	Vehicle speed (km/h)
Forward 1st gear	10.607	0.4	1.727	3.3
Forward 2nd gear	0.832	5.1	0.991	6.1
Forward 3rdgear			0.575	10.1
Reverse 1st gear	7.875	0.52	1.282	4.4
Reverse 2nd gear	0.618	6.8	0.736	8.0
Reverse 3rd gear			0.426	13.0
Bevel	2.105	——	1.522	——

(3) Excavation control

Depending on soil type, soil cannot be dug by the demining rotor even by a low-speed transmission. A reliable demining method for a demining depth of 30 cm was accomplished by automatically controlling the transmission and rotor.

1) System configuration

The control system configuration is illustrated in **Fig. 3**. Each ECU is connected by CAN through which information and commands are transmitted.

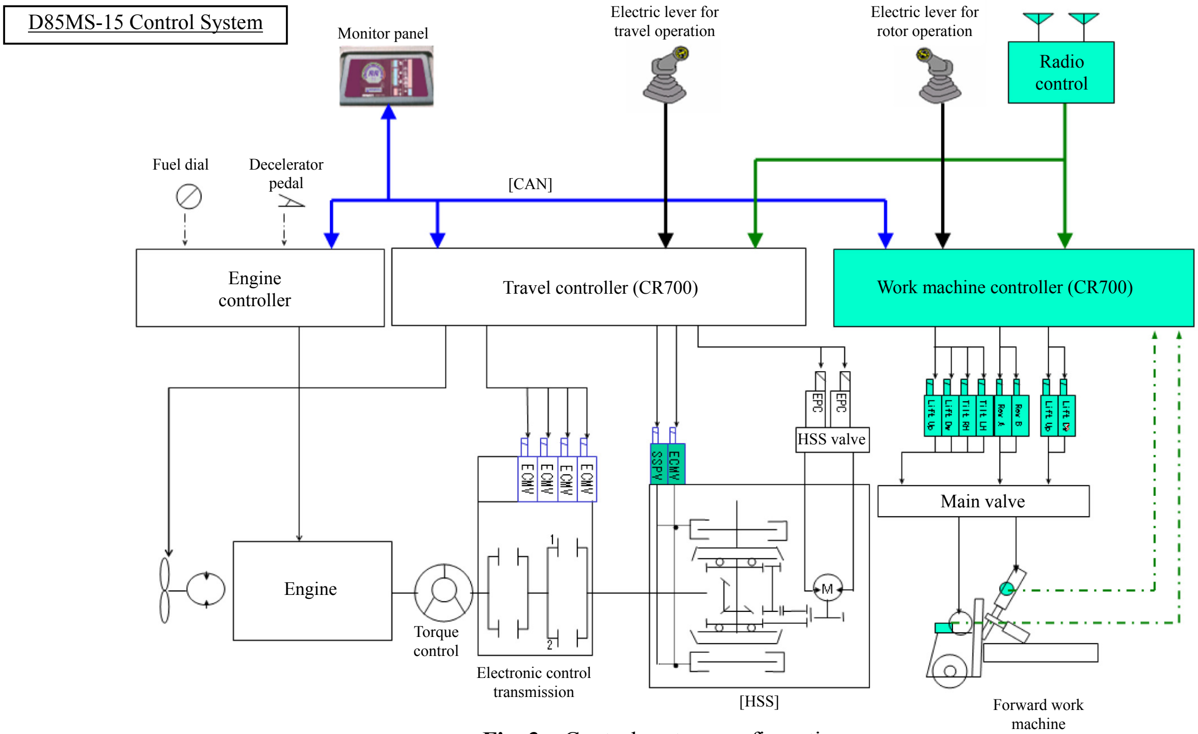


Fig. 3 Control system configuration

2) Gear shift control

The excavating depth of the demining dozer is pre-determined and the vehicle has to be stopped if excavating is not possible (**Fig. 4**).

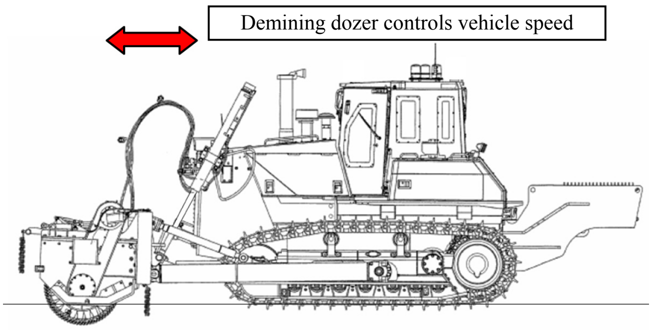


Fig. 4 Control of demining dozer

Neutral control condition

Mines are removed reliably through the control specified in **Table 3**.

Table 3 Neutral control

Rotor rotation speed	Operation
200 rpm or less	Transmission neutral, brake ON
250 rpm or more	Forward 1st gear (F1) restart

3) Load control

If rotations do not recover by the foregoing control, the operator has to lift and lower the rotor to remove the load. Rotor load control is adopted to further enhance demining work and to ease operator operability. Switching on the switch installed on the rotor lever starts load control (**Photo 3**).

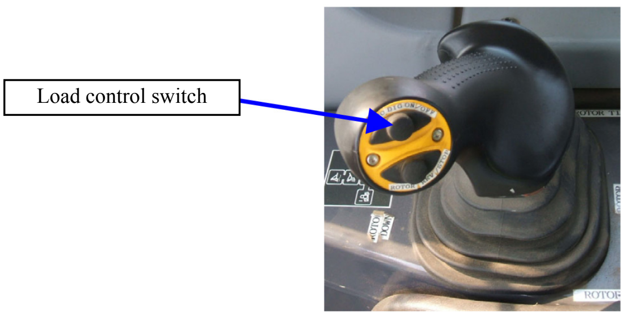


Photo 3 Load control switch

Load control condition

Angle sensors installed on the rotor lift cylinders (**Fig. 5**) determine the rotor position and a mine is removed reliably through the control specified in **Table 4**.

Operation after neutral control

Table 4 Load control

Rotor rotation speed	Operation
50 rpm or less	Rotor lifted
50 rpm or more	Rotor lifting stopped
50 to less than 250 rpm	Rotor position maintained
250 rpm or more	Rotor lowered
Rotor lowering completed	In 1 second, forward 1st gear (F1) restart

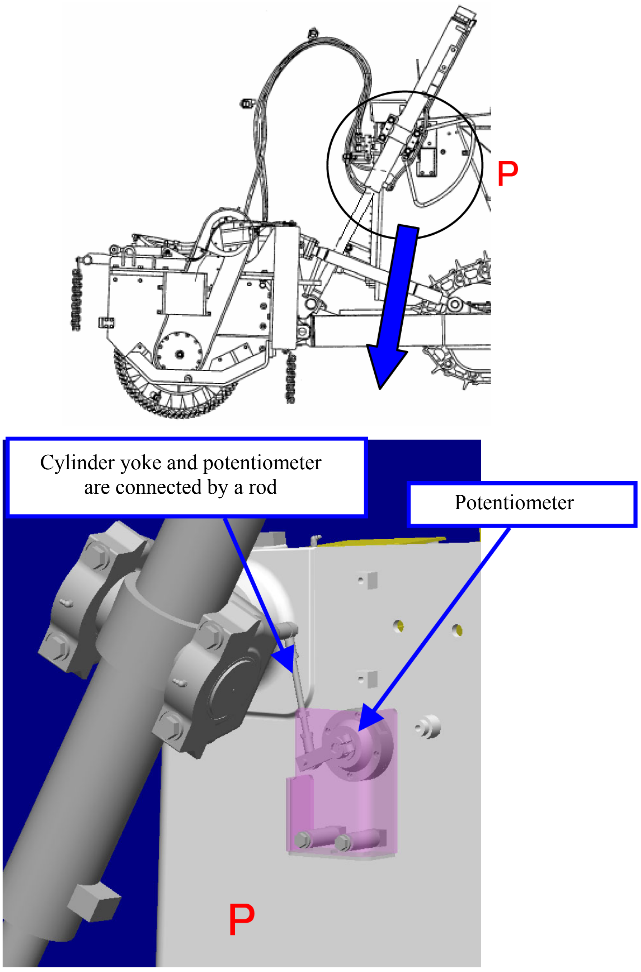


Fig. 5 Rotor position sensors (Mounted on left and right of vehicle)

(4) Wide-width crushing device

The rotor was modified to enhance the working capacity and the excavating efficiency could be improved by about 50%.

Rotor modification

1) Fewer rotor bits (**Fig. 6**)

The excavating resistance varies in proportion to the number of bits. The number of bits was reduced from 206 to 142, thereby improving the excavating resistance by 31%. The reduction in the number of bits penetrating into the ground per second is compensated by increasing the rotor rotation speed through a reduction in the excavating resistance.

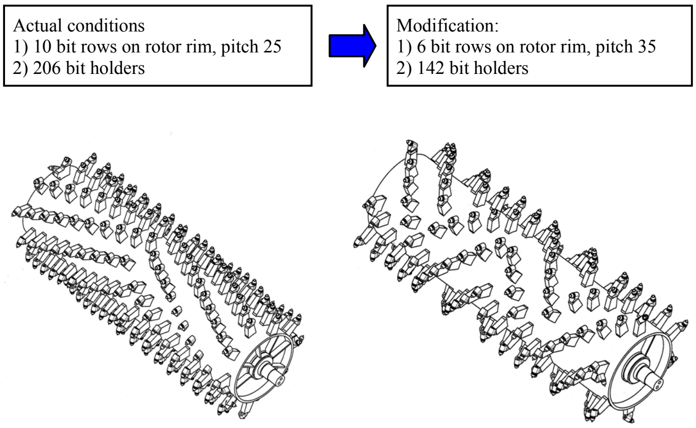


Fig. 6 Fewer bits

Reduction ratio of excavating resistance (Comparison in number of bits)

100 - (142/206) x 100 = 31% reduction

2) Rotor bit arrangement changed from Type A to Type M (**Fig. 7**)

In demining work, it is dangerous to unload soil to the outside of the rotor width after demining and the bit arrangement of Type A has been adopted in the past. Soil that is ejected after demining is heaped in the center of the rotor, acting as a resistance to excavating. After demining, Type M bit arrangement was adopted and evenly ejected soil inside the rotor width, thereby reducing the excavating resistance.

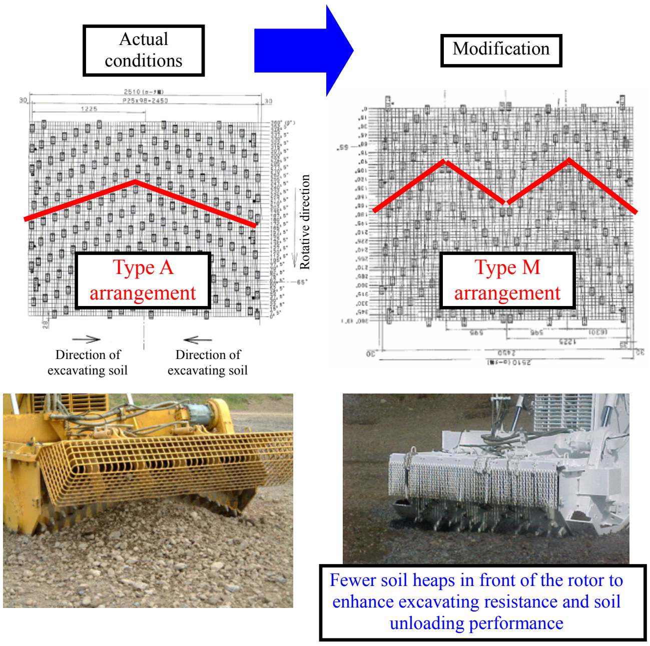


Fig. 7 Bit arrangement change

3) Test results

• Test of work amount at excavating depth of 30 cm (**Table 5**)

Table 5 Results of work amount test

Soil	Unit		Work rate	Ratio
Sandy soil mixed with gravels	m^2/h	Actual condition	467	1.0
		Modification	770	**1.65**
Sandy soil	m^2/h	Actual condition	1043	1.0
		Modification	1043	1.0

Result: 65% improvement recorded

• Destruction test

Destruction of dummy mines classified by excavating depth was checked (**Photo 4**).

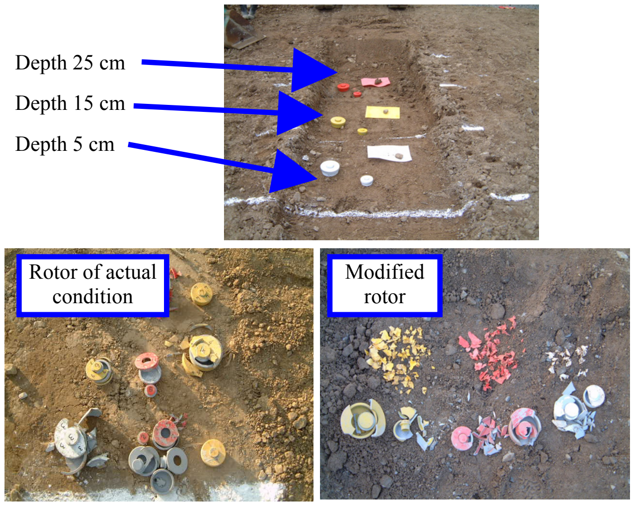


Photo 4 Crushed mine

Result: The modified rotor crushed mines more finely

3.2 Safety

(1) Shellproof device

The D85MS-15 can be operated both by an operator on the vehicle and by radio control. A shellproof-specification cab was developed to protect the operator on the vehicle and shellproof covers were installed to protect the vehicle in case of mine explosion near the vehicle.

1) Cab (**Photo 8**)

• All exteriors are lined with high tensile strength steel

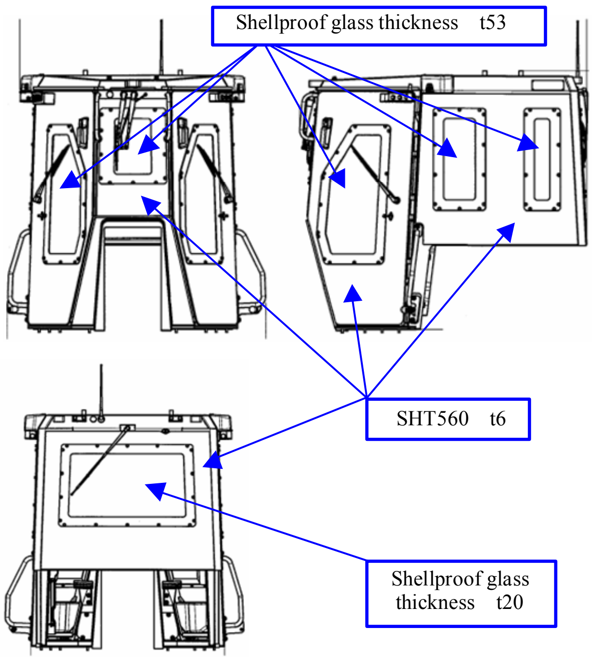


Fig. 8 Shellproof cab

- All window glass panes adopt shellproof glass (Wreck Guard RS-1250).
  Front windows, door windows, side windows:
  t33 + t20 = t53
  Rear windows: t20

(2) Protection of vehicle body

- The engine side covers are closed side covers made of high tensile strength steel (**Fig. 9**).
- Covers made of high tensile strength steel have been added to fuel and hydraulic oil tanks (**Fig. 10**).

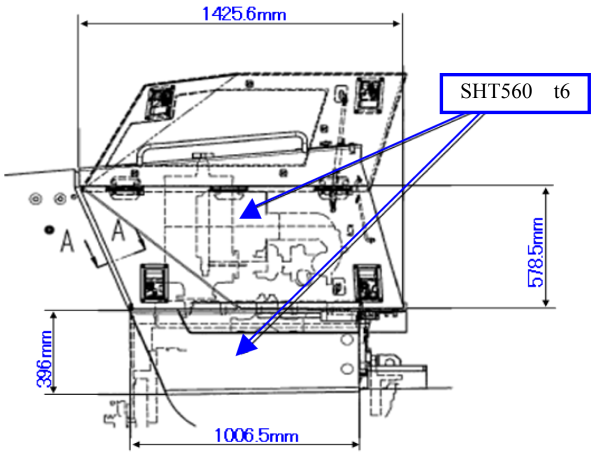


Fig. 9 Engine protection side cover

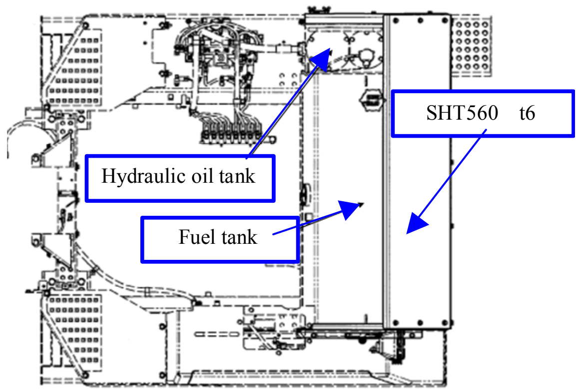


Fig. 10 Protection covers for fuel tank and hydraulic oil tank (Top view)

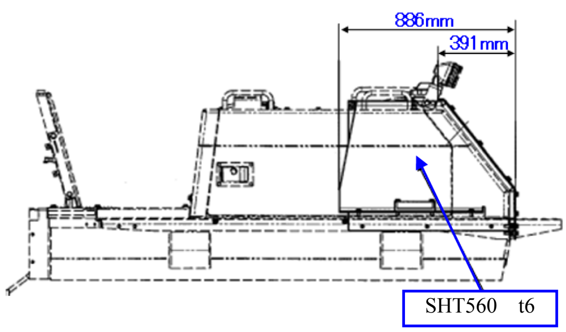


Fig. 10 Protection covers for fuel tank (Left side view)

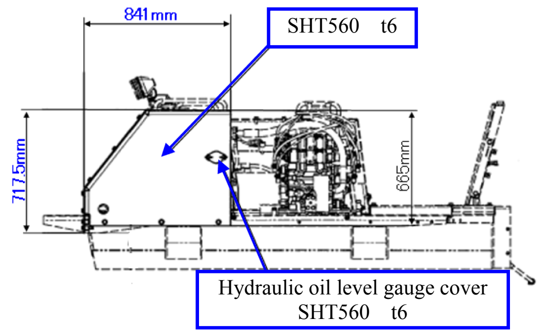


Fig. 10 Protection covers for hydraulic oil tank (Right side view)

(2) Radio control device

Remote operation by radio control has been made possible to ensure safe mine removal work. This has been accomplished by turning all equipment to electronic equipment and by transmitting commands from the radio control system to the controller to drive each equipment as shown in the system configuration diagram.

- Electronic work equipment control (**Fig. 11**)

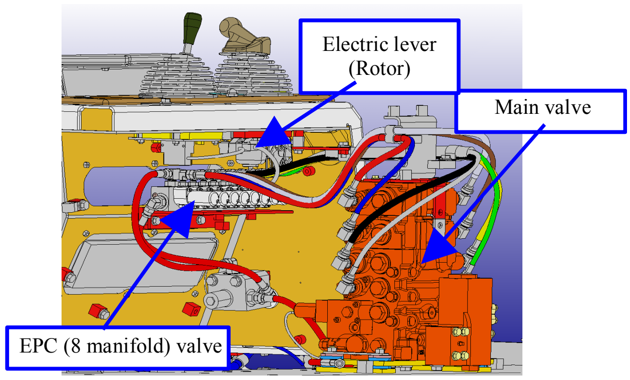


Fig. 11 Electronic work equipment control

- Electronic brake control (**Fig. 12**)

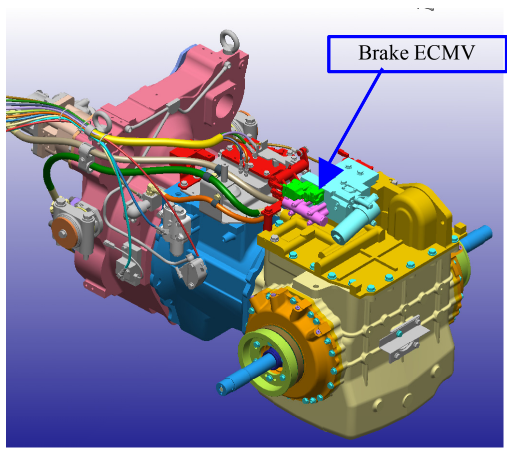


Fig. 12 Electronic brake control

(3) Front guard device

Stones, rocks, mine fragments and other debris dug during demining may eject in front of the rotor.

Safety of the demining dozer has been enhanced by capturing and reprocessing unexploded mine/s that bounce out during demining, even though this is not expected to occur.

• Basket type suitable for wide, dry land (**Fig. 13**)

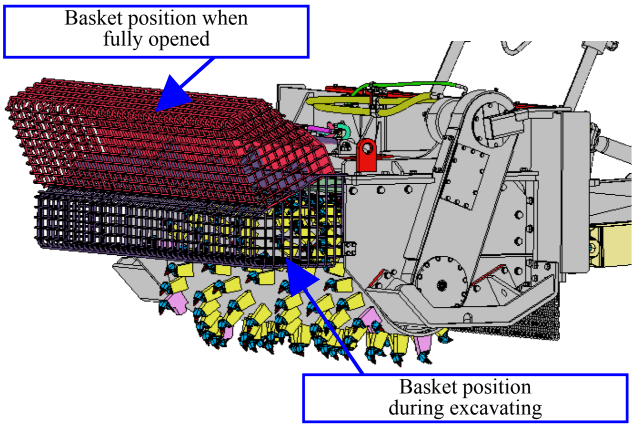


Fig. 13 Basket type

• Chain type suitable for narrow, wet land (**Fig. 14**)

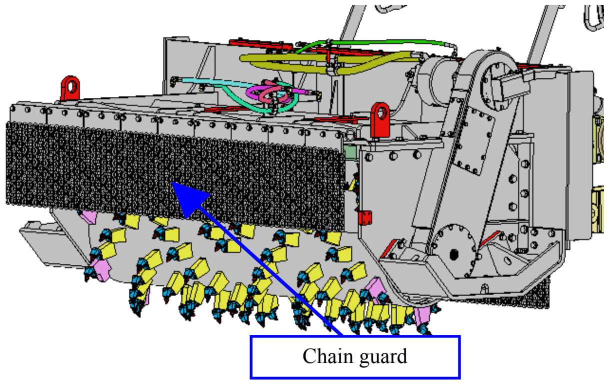


Fig. 14 Chain type

3.3 Other

(1) Rotor-free valve

The tip of each rotor claw is installed with a bit to destroy a mine (**Photo 5**). Bits are expendable parts and need to be replaced. A free valve (**Fig. 15**) connects Ports A and B of the motor to free rotor rotations. This makes bit replacement work easy.

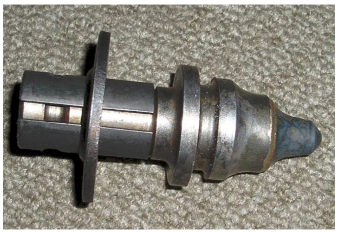
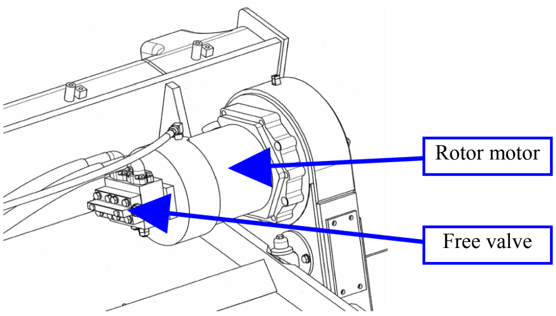


Photo 5 Bit



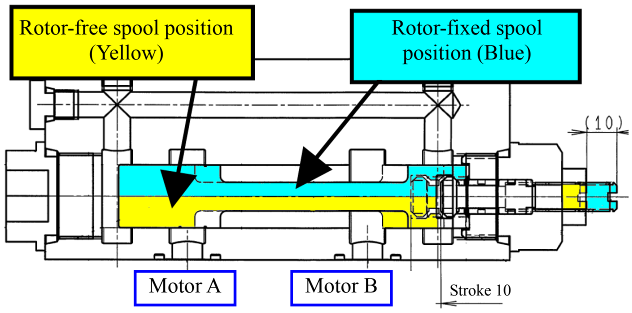


Fig. 15 Rotor-free valve

(2) Demining dozer for infrastructure works

After demining work, the demining dozer can be used in infrastructure development works as an ordinary bulldozer by changing its attachments (**Fig. 16**).

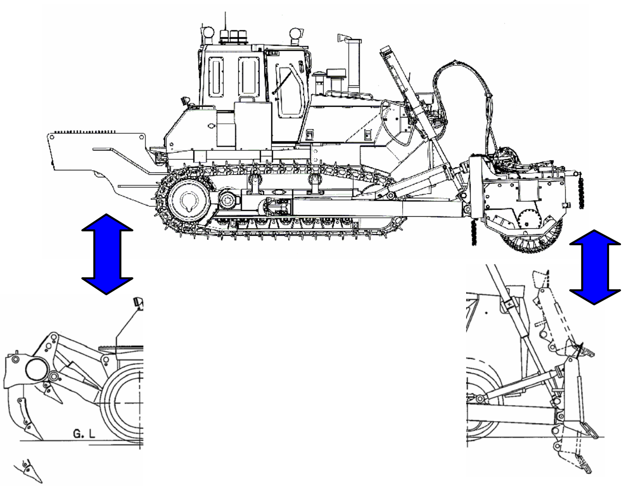


Fig. 16 Conversion to bulldozer

4. Anti-explosion Test

4.1 Result of Test in Japan

1) Test at Shimokita Test Site, Technical Research and Development Institute, Ministry of Defense
   - Stationary test (no running) simulating the following three conditions (**Fig. 17**).
   - Test under 750g of C4 gunpowder (equivalent to largest personnel mine)

2) Test results
   - Shoe bolts sheared, one shoe plate fallen (**Photo 6**)
   - Tip of one bit chipped, 2 bits fallen (**Photo 7**)
   - Hydraulic pressure generated in hydraulic cylinder of work equipment: Max. 188 kg/cm2
   - Internal pressure generated inside operator's cab: Max. 175 mmAq

Photo 6 Fallen shoe, bent bolt

Photo 7 Chipped bit, fallen bit

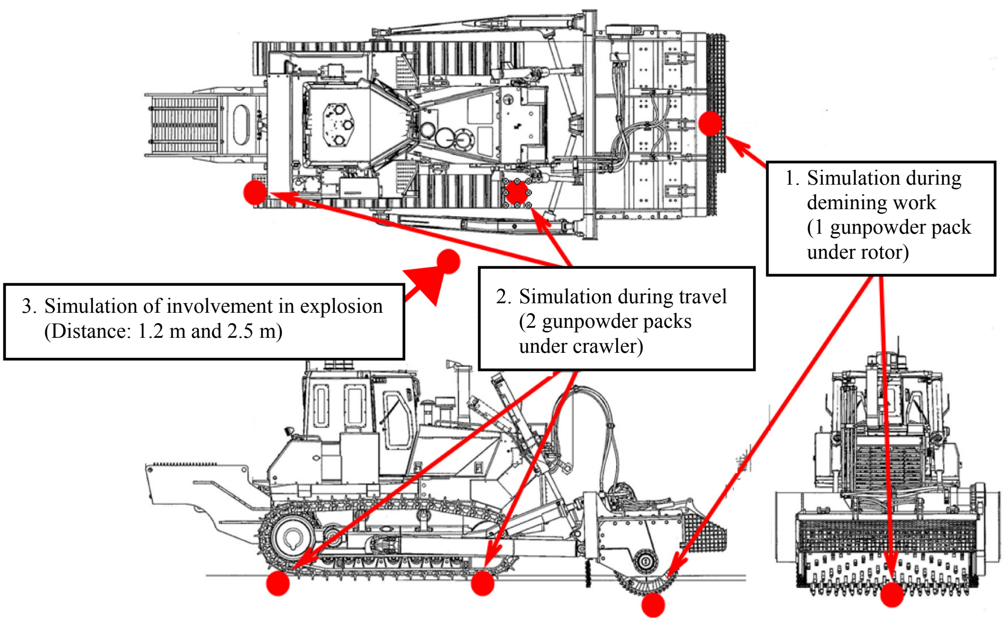


Fig. 17 Locations of gunpowder

3) Evaluation results (**Table 6**)

Aside from the following comments, the other parts and components suffered no damage and functioned satisfactorily.

Table 6 Evaluation results

No.	Evaluated part and component	Evaluation	Judg-ment
1	Bent shoe bolt	Could escape from a minefield. No problem found with present design.	**Accep-table**
2	Fallen shoe plate		
3	Chipped bit	Could be used continuously.	
4	Fallen bit	The bit holder stayed. Fallen bit was replaced with a new bit.	
5	Hydraulic pressure generated inside cylinder	Allowable pressure resistance: 315 kg/cm^2 or less	
6	Pressure inside the cab	20cm submerged level. No harm to human body.	

4.2 Results of Tests in Afghanistan and Cambodia

Field verification tests were conducted in Afghanistan in 2004 and in Cambodia in 2006. In the tests, the actual work rate in the two countries exceeded 500 m^2/h. The demining dozer proved viable also on a steep inclined surface of about 30° in Afghanistan which abounds with mountains and hills (**Photo 8**) and in a shrub area in Cambodia (**Photo 9**).

Photo 8 Demining on a steep inclined surface in Afghanistan

Photo 9 Demining in a shrub area in Cambodia

5. Conclusion

Several hundred million mines are mined throughout the world. Removal of these mines is an indispensable element to the development of the countries in which mines are placed.

The performance of the demining dozer will definitely be able to make a contribution to demining activities, as well as to social infrastructure development and maintenance.

Introduction of the writers

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[A few words from the writers]

Motivated by an official invitation to participate in a Government project in 2003, only a short time was allowed for the development work. The series of work during this short period of time included anti-explosion tests at a Self-Defense Forces test site, discussions with Government officials and interviews by newspapers and TV stations. These experiences can be used in future work also.

Being a humanitarian aid project, warm cooperation was extended by personnel in the various related fields and a No. 2 machine could be built. The writers would like to thank those who provided their cooperation in this project.