Introduction of Products

Hydraulic Excavator PC78US-11

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We have developed a small hydraulic excavator PC78US-11 and introduced it to the market. The machine achieves high quality in both the ecology performance such as fuel consumption and noise, and the workability performance such as production and digging speed by equipping newly-developed 3-cylinder engine. This paper explains the technologies and introduces the machine.

Key Words: *Fuel consumption, Noise, Workload, Scooping, Maintainability, Environmental performance, Operating performance*

1. Introduction

PC78US is the flagship model of our small hydraulic excavators. It is in operation at various sites from narrow sites for piping work to general civil engineering. Therefore, there are a wide variety of required functions, and there were many requests for both environmental considerations such as fuel consumption and noise, as well as for standard work performance such as workload and scooping speed. In addition, in the context of needing to comply with the European Stage V exhaust gas regulations, we developed a new 3-cylinder high-power engine in-house, and developed a significantly more appealing product while complying with the exhaust gas regulations. We have now introduced the product into the Japanese, North American, and European markets, so here is an overview (**Fig. 1**).

Fig. 1 Appearance of PC78US-11

2. Aims of development

The high-level development concept is to achieve both environmental performance in terms of fuel consumption and noise, as the market demands, as well as Komatsu's characteristic standard operating performance, building on Komatsu quality and reliability. The in-house development of a new 3-cylinder high-power engine has also achieved compliance with European Stage V exhaust gas regulations. In addition, the machine cover has been redesigned with the development aim of improving maintenance, a major service request from clients.

(1) Environmental performance

- Development of a new 3-cylinder high-power engine
- Japan/US/Europe exhaust gas regulations compliant (H26 regulations / Tier 4F / Stage V)
- JCMAS fuel consumption 2020 standard 100% achieved (3 stars)
- Market-equivalent fuel consumption 20% reduction compared to existing models
  (Average working pattern comparison by Komtrax analysis)
- Compliant with JMLIT Super Low Acoustic Noise Regulation Standards
  (Exterior noise decreased by 5.2 dB(A) compared to existing models)

(2) Operating performance
- Work volume P mode up 8% compared to existing models
- Scooping speed up 18% compared to existing models
- Lift from swinging with hoisting up 12% compared to existing models
- Improved attachment performance
- Improved blade operating performance
- Improved arm crane performance
- LED light standard equipment

(3) Maintainability
- Enlarged machine cover opening
- Centralized engine auxiliaries
- Simplified cooling and cleaning
- Adopted a sealed engine cooling system

3. Selling points

This section describes the selling points of PC78US-11, and the means.

3.1 Improved environmental performance

By incorporating the technologies described below, we have achieved significant reductions in fuel consumption and noise, as well as compliance with exhaust gas regulations.

3.1.1 Development of a new 3-cylinder high-power engine

Displacement is downsized to 3/4 compared to existing 4-cylinder engines by switching to 3 cylinders to reduce fuel consumption. By increasing the boost pressure, we have developed a new engine that maintains the same high output as existing models and achieves both low fuel consumption and high output. In addition, fuel consumption reduction technologies such as combustion improvement and friction loss reduction have been incorporated to further improve fuel consumption.

Table 1 Comparison of engine specifications

		Developed model	Existing model
Engine model		SAA3D95E-1	SAA4D95LE-6
Piston displacement	L	2.45	3.26
Number of cylinders		3	4
Maximum output	kW/min^{-1}	50.7/1900	50.7/1950

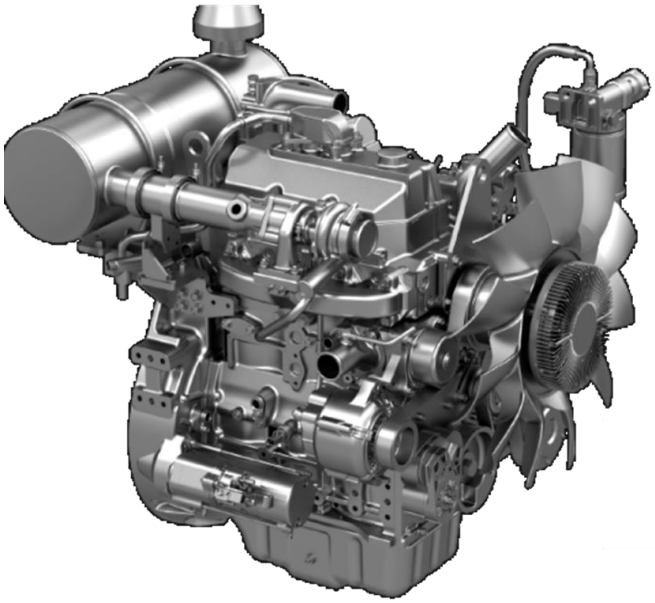


Fig. 2 Appearance of the newly developed 3-cylinder engine

3.1.2 Compliance with exhaust gas regulations

Exhaust gas regulations for the diesel engines of construction machinery are entering a new stage, with regulations called Stage V introduced in Europe from 2019. **Figure 3** shows the trends in exhaust gas regulations in Japan, North America, and Europe. **Figure 4** shows the transition centered on the exhaust gas control values of nitrogen oxides (NOx) and particulate matter (PM) at 37 to 56 kW, with EU regulations as a typical example. In addition to emission limits for PM, emission limits for particle number (PN) were included from Stage V.

The exhaust gas purifying system designed for Japan and North America uses a KDOC *1 muffler capable of providing necessary and sufficient exhaust gas purifying performance just as existing ones. As illustrated in **Fig. 5**, the KDOC muffler is filter-less and therefore advantageous in cutting back on costs required during the life cycle of the entire vehicle. Meanwhile, for the European specifications, a dedicated KDPF *2 for this engine was specially developed in order to conform to regulations on PN emissions included in Stage V. **Figure 6** shows the structure of the KDPF.

*1: Komatsu Diesel Oxidation Catalyst
*2: Komatsu Diesel Particulate Filter

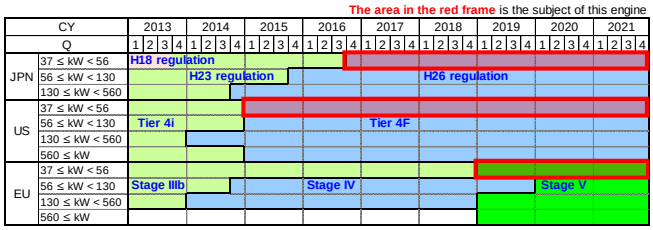


Fig. 3 Trends in the change of emission regulations in Japan, the U.S. and Europe

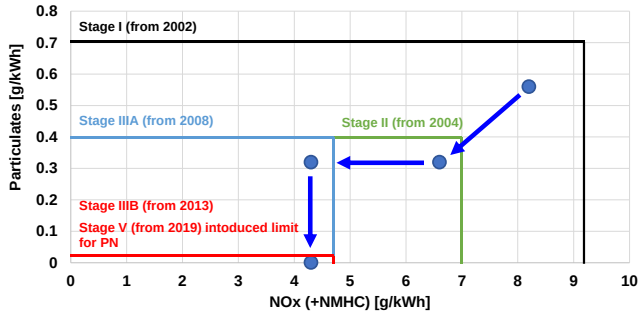


Fig. 4 Changes in the EU emission regulations (for 37 - 56 kW engines)

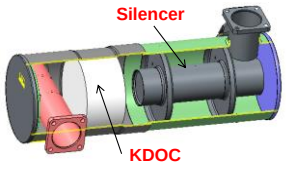


Fig. 5 Structure of the KDOC muffler

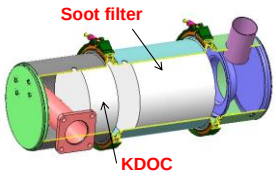


Fig. 6 Structure of the KDPF

Table 2 Corresponding exhaust gas regulations and aftertreatment devices

		Developed model	Existing model
Corresponding exhaust gas regulations	Japan	H26 regulation	
	North America	Tier4 Final	
	Europe	Stage V	Stage IIIB
Exhaust gas purifying system		Japan, US: KDOC Europe: KDPF	KDOC

3.1.3 Reduced fuel consumption

Incorporating the technology described below, we achieved 100% (3 stars) based on the JCMAS fuel consumption 2020 standard. In addition, a 20% reduction in fuel consumption compared to existing models was achieved by comparing the average work patterns with Komtrax analysis.

(1) Reduced hydraulic pressure loss

The hydraulic pressure loss was reduced by rethinking and optimizing the amount of oil required according to the lever control. In addition, by rethinking the entire hydraulic circuit to identify items that cause hydraulic pressure loss, and incorporating many improvements with effects small and large, a large reduction in hydraulic pressure loss was achieved for the overall machine body.

(2) New engine and pump matching control

The new engine and pump matching control is a technology that reduces the engine speed according to the input of the work equipment control lever and the pump pressure after ensuring the necessary and adequate pump discharge amount.

Utilizing the engine fuel consumption map which illustrates that the lower the engine speed is, the better the fuel consumption is for a given horsepower, the fuel consumption has been reduced by matching the engine speed at low speeds (**Fig. 7**).

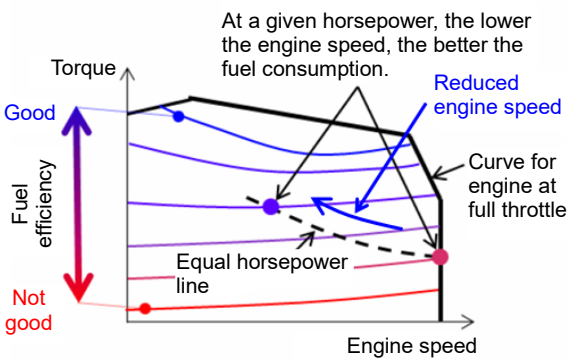


Fig. 7 Engine fuel consumption map and conceptual diagram of reducing engine speed

(3) Fan clutch control

By adopting a fan clutch that can control fan rotation with a built-in fluid clutch, it is possible to reduce fan rotation without worsening the heat balance. In addition, fuel consumption was reduced by reducing unnecessary fan horsepower consumption while ensuring the required horsepower (work load).

3.1.4 Compliant with JMLIT super low acoustic noise regulation standards

By reducing the engine speed with the engine and pump matching control mentioned above, reducing the fan speed with a fan clutch, and devising the machine cover described below, the super low acoustic noise standard of the Japanese Ministry of Land, Infrastructure and Transport, impossible with existing models, was cleared. The newly devised machine cover structure reduces the exterior noise by optimizing the relationship between the wind flow until engine sounds comes out and the arrangement of sound absorbing material.

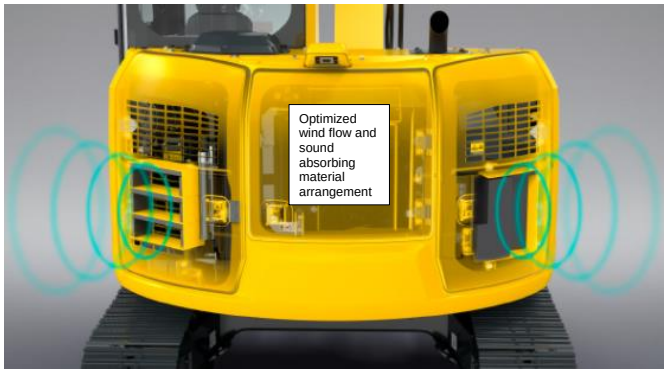


Fig. 8 Noise reduction by changing the machine cover structure

3.2 Improved operating performance

By incorporating the technologies described below, we have achieved significant improvements in essential performance, improved attachment performance, improved blade operating performance, and other operating performance improvements.

3.2.1 Improved essential performance

By taking advantage of the strength of in-house component development, optimizing the flow rate distribution to each actuator during combined operation, and optimally controlling the pump discharge according to lever control, the following essential performance improvements have been achieved.

- Work volume P mode up 8% compared to existing models
- Scooping speed up 18% compared to existing models
- Lift from swinging with hoisting up 12% compared to existing models

3.2.2 Improved attachment performance

(1) Increased attachment oil flow rate

Conducting market research led to a request from mainly users in forestry to increase the attachment oil flow rate. Therefore, by optimally controlling pump discharge, we increased the maximum flow rate at low pressures, and increased the attachment oil flow rate so that the flow rate would not drop even at high pressures.

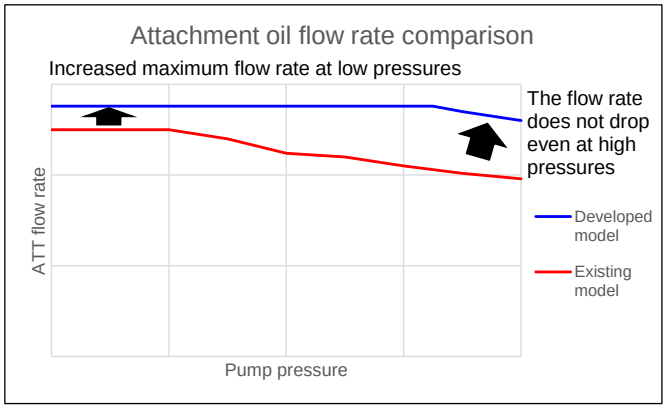


Fig. 9 Conceptual diagram of increased attachment oil flow rate

(2) Automation of the attachment switching valve

When switching between attachment mode and breaker mode in existing models, it was necessary to get down from the operator's seat and manually operate the switching valve to switch the circuit pressure. In the newly developed model, the circuit pressure is automatically switched in conjunction with monitor operation.

3.2.3 Improved blade operating performance

(1) Improved soil dynamics by changing the blade shape

The shape of the blade was optimized for favorable soil dynamics during dozing. There was less spillage of soil on the back surface of the blade when carrying and dozing soil, and more soil was dozed.

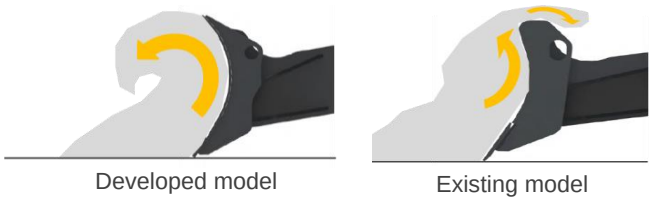


Fig. 10 Conceptual diagram of changed blade shape

(2) Addition of a travel changeover switch to the blade control lever

Switching between Hi and Lo in existing models is only possible with monitor operation. The newly developed model allows switching with both monitor operation and with a switch added to the blade control lever. This makes it possible to switch between Hi and Lo while operating the blade, improving the efficiency of blade leveling tasks.

Fig. 11 Travel changeover switch added to the blade control lever

3.2.4 Improved arm crane performance

(1) Increased rated load

The rated load has been increased by rethinking the machine body balance and improving the hook durability.

1.7 t (existing models) → 2.3 t (newly developed model)

(2) Addition of arm crane mode one-touch changeover switch

A switch has been added to the right console that allows you to switch to arm crane mode with a single touch without having to operate the monitor button many times.

Fig. 12 Arm crane one-touch changeover switch

3.2.5 LED light standard equipment

LED lights are now standard equipment on the boom and cab. Visibility has improved in low-light environments, making it possible to work safely at night or indoors.

Fig. 13 LED light standard equipment

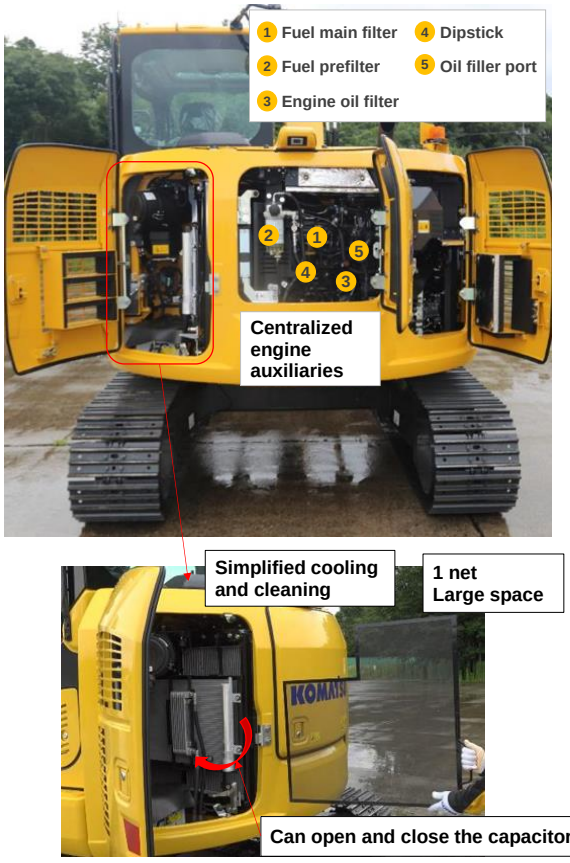


Fig. 14 Machine cover structure of the newly developed model

3.3 Improved maintainability

3.3.1 Improved maintainability with a redesigned machine cover structure

The machine cover structure has been redesigned to significantly improve maintainability.

- Improved accessibility by expanding the opening of the machine cover
- Improved maintainability with centralized fuel auxiliaries
- Improved ease of removal and installation from rethinking of the cooling net structure
- Improved cleaning performance from structure that allows the capacitor to be opened and closed

3.3.2 Adopted a sealed engine cooling system

Pressurizing the expansion tank makes it possible to prevent natural coolant decrease due to evaporation. Therefore, it is essentially unnecessary to replenish the coolant in daily inspections.

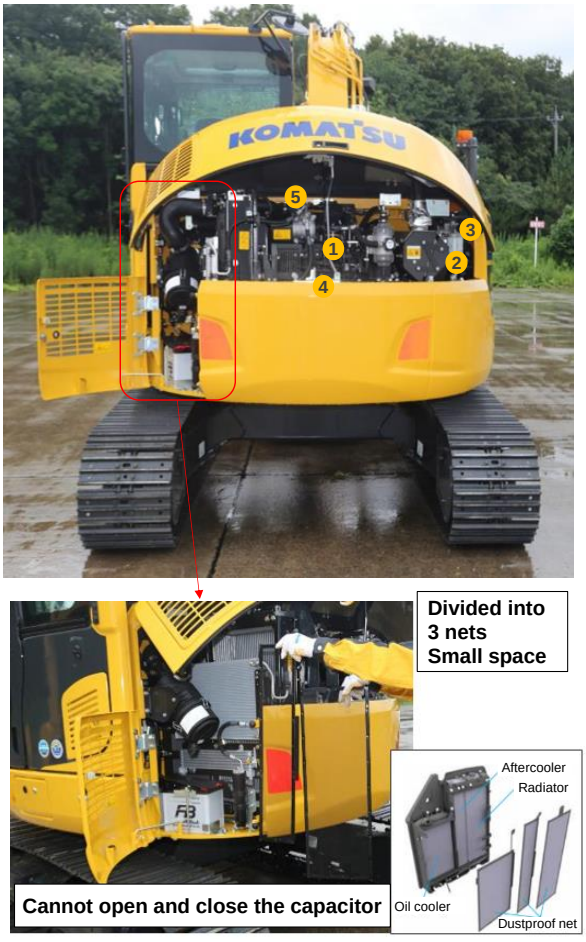


Fig. 15 Machine cover structure of existing models

3.4 Comfort

The equipment has been enhanced to improve the comfort around the operator's seat.

3.4.1 Suspension seat standardization

Standardizing the suspension seat that was optionally set even in existing models has enabled comfortable operation.

Fig. 16 Suspension seat standardization

3.4.2 Adopted multi-function audio

An AM/FM radio that can be connected via USB or Bluetooth® *3 is now standard equipment.

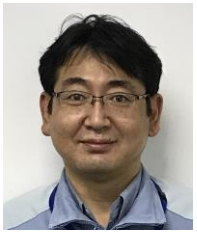
*3: The Bluetooth® wordmark and logo are registered trademarks and are the property of Bluetooth SIG. Inc. The Komatsu Group uses these marks and logos under license.

Fig. 17 Multi-function audio

4. Conclusion

PC78US is Komatsu's flagship small hydraulic excavator. In this development project, by developing a new 3-cylinder high-power engine, we were able to achieve both improved environmental performance (significant reduction in fuel consumption, meeting ultra-low noise regulations by the Japanese Ministry of Land, Infrastructure and Transport, compliance with European Stage V exhaust gas regulations) and improved operating performance (increased workload and scooping speed) at a high level. In addition, we were able to create a very attractive product by improving maintainability and incorporating countless market and service requests. We expect that the product will be very popular in the market.

Introduction of the authors



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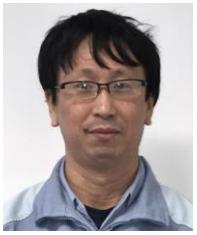

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[A comment from the authors]

With the cooperation of relevant departments, we were able to fully demonstrate Komatsu's strengths in in-house development of components and the development of machine bodies that connect them. We were able to optimally incorporate each component into the newly developed machine. In addition, we conducted market research with the cooperation of relevant departments and were able to incorporate various resulting requests into the newly developed machine. We are grateful for the good fortune to have been a part of this development, and we would like to express our sincere gratitude to all those involved in the development.