Technical Paper

Hydraulic cylinder for Tier4

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As the model change for being adapted for 4th emission gas emission regulation, experience of the market in China, quality improvement and cost reduction was reflected on a hydraulic cylinder. The features of the new cylinder are described.

Key Words: Tier4, Hydraulic cylinder, Dust seal, Piston rod, Rod packing, Buckup ring

1. Introduction

Construction machinery was invented about two centuries ago and originally driven by steam engines. The current version of the hydraulic excavator was developed in the 1950s. This paper describes the hydraulic cylinder used in hydraulic excavators.

In the history of Komatsu's main model 20-ton hydraulic excavators, Type 1 was introduced in the 1980s, while the Type 10 series was launched in 2012 as the 8th generation. During this time, the pressure of the hydraulic excavator was boosted to miniaturize the hydraulic system. **Fig. 1** summarizes the changes in rated pressure, from models PC200-1 to PC200-10.

Type	Model	Year	Rated Pressure (MPa)	Bore Diameter (mm)	Rod Diameter (mm)
Type PC200	-1	1980	24.5	150	100
	-2	1982	27.5	140	90
	-3	1984	31.4	130	95
	-5	1988	33.3	135	95
	-6	1992	34.8	135	95
	-6 m/c	1996	34.8	135	95
	-7	2001	37.3	135	95
	-8	2005	37.3	135	95
	-10	2010	37.3	135	95

Fig. 1 Changes in the rated pressure of PC200 (Arm cylinder)

As an indicator of hydraulic excavator miniaturization, the amount of work per unit weight increased 1.58 times when translated into a functional value (**Fig. 2**). Assuming constant thrust, the cylinder diameter can be reduced by boosting the pressure. However, this presents problems such as an inability to reduce the cylinder rod diameter due to the strength of the piston rod that transmits the power to the work equipment and the increased cylinder tube wall thickness required. Pressure is not boosted significantly in the several recent model changes.

* Functional value: Thrust x Stroke/Cylinder weight

Photo 1 HB205-1 (From the Komatsu catalog)

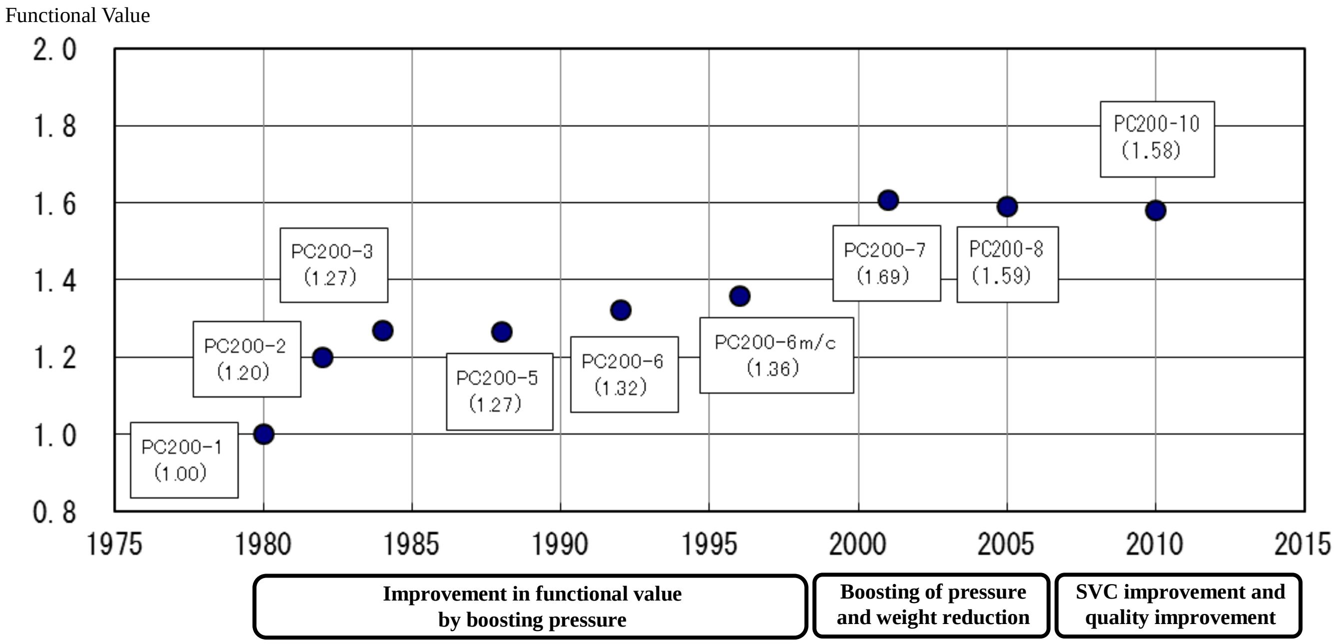


Fig. 2 Functional value of the hydraulic cylinder

2. Development Objective

The cylinder under development incorporates quality enhancement and cost reduction achieved by utilizing experience gained in the Chinese market and changes in materials and processes into the material manufacturing process in response to the high material prices compared with conventional cylinders. These plus factors were implemented based on model changes made to meet Tier 4 emission regulation (**Fig. 3**).

The foregoing functional value is high compared with other manufacturers, whereas the main cylinder specification remains unchanged.

When broken down, the material cost accounts for about 70% of the cost of the hydraulic cylinder and countermeasures to cope with the recent high price of steel materials remain a major issue.

(1) Quality improvement items
- The use of a seal with enhanced dustproof performance against dust entering from outside.
- The use of a rod seal with enhanced heat resistance and a contact-surface seal.

(2) Cost reduction items
- A review of piston rod material and change in alloy components to secure strength equivalent to conventional rod.
- Changed and added heat treatment processes for piston rods, securing strength equivalent to conventional rod, using a material one class below.
- Restrained the residual tensile stress of the cylinder steel tube, securing strength equivalent to conventional tube, using a material one class below.

Factors Incorporated in Cylinder Development		Description
Quality enhancement	· Dustproof performance	Change in the dust seal shape
	· Heat resistance	Change in the rod packing material
		Change in the O-ring material
Cost reduction	· Review of the piston rod material	Change in the alloy component
	· Change in the piston rod material + Change in heat treatment	Change in hardness penetration
		Heat treatment applied to threaded parts
	· Change in the cylinder steel tube	Material change by control of residual stress
	· Deposit metal for cushion collar	Review of the amount of deposited metal

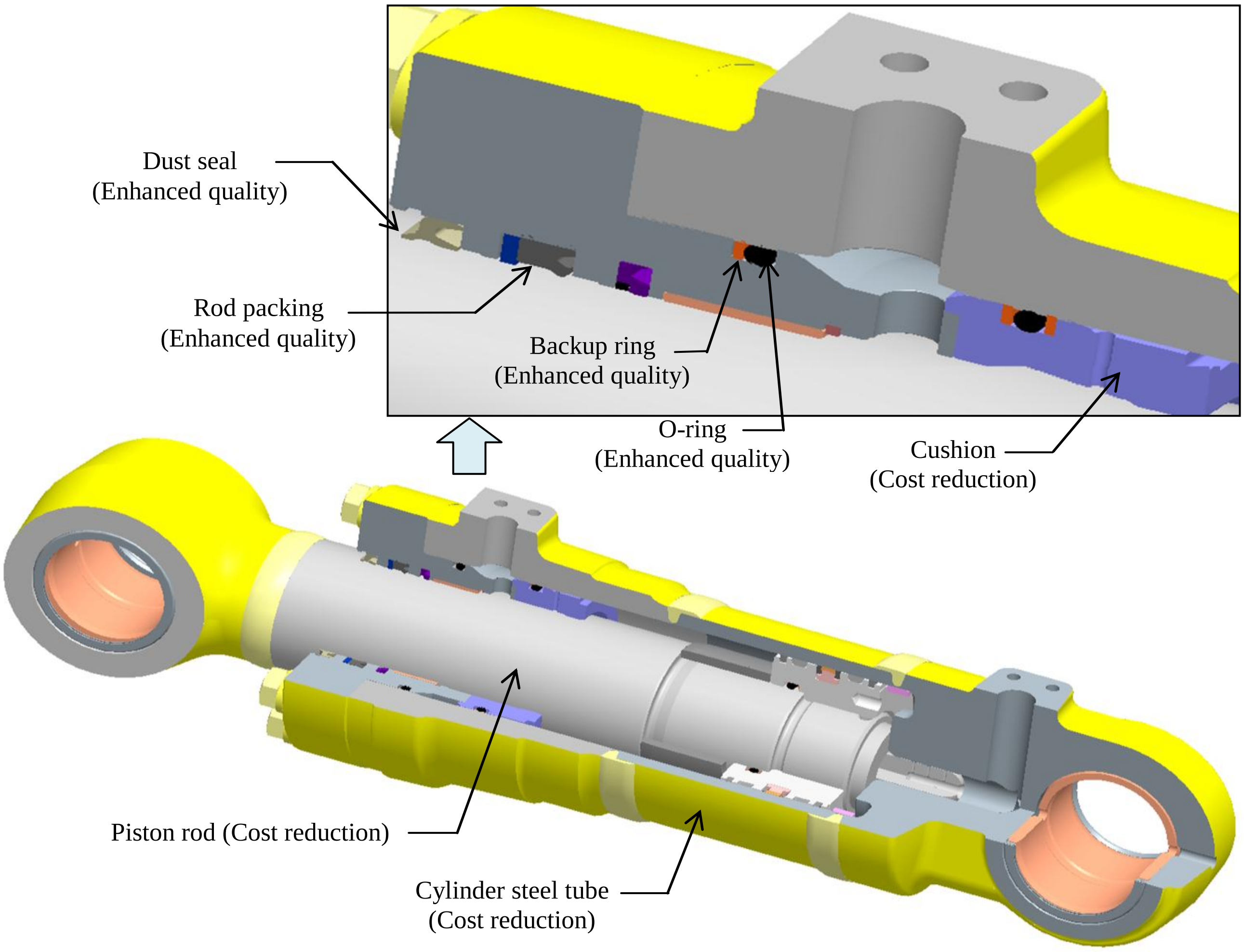


Fig. 3 Overview of the developed cylinder

3. Principal Features

The following items were incorporated into the new hydraulic cylinder:

3.1 Dust Seal with Enhanced Dustproof Performance

The conventional dust seal aims at reducing oil rings that are formed when minute amounts of oil film deposited on the piston rod are scraped by the dust seal. The newly developed and improved dust seal incorporates changes made in the seal lip shape, planar pressure and strained force and enhances the dustproof performance while restraining scraping of oil films (**Fig. 4**).

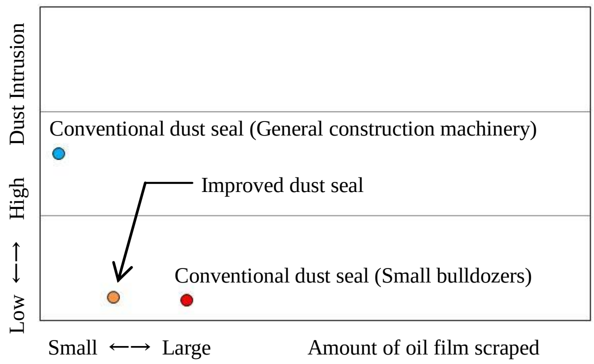


Fig. 4 Evaluation of dust intrusion and oil-film scraping performance

The dimensions of the dust seal itself are interchangeable with conventional dust seals and the new dust seal can also be fitted into conventional cylinders (**Fig. 5**).

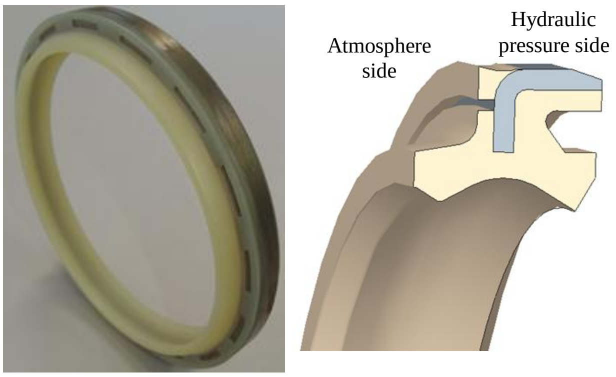


Fig. 5 Appearance of the improved dust seal

3.2 Use of Rod Packing with Enhanced Heat Resistance

The reason for the enhanced heat resistance of the packing material is to mitigate fatigue and deterioration of the packing material if the packing is used at the same hydraulic oil temperature, instead of raising the permissible temperature of the hydraulic oil. The principal aim is to extend the seal life (**Fig. 6**).

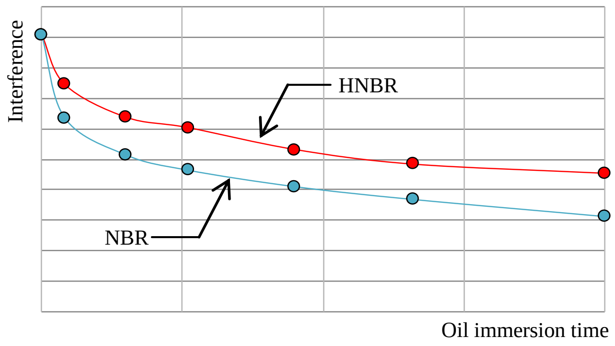


Fig. 6 Result of the oil immersion test of NBR and HNBR

The material of the backup ring, which is used in combination with the rod packing to ensure pressure resistance performance, was changed from Teflon to Nylon to enhance pressure resistance and simultaneously reduce cost (**Fig. 7**).

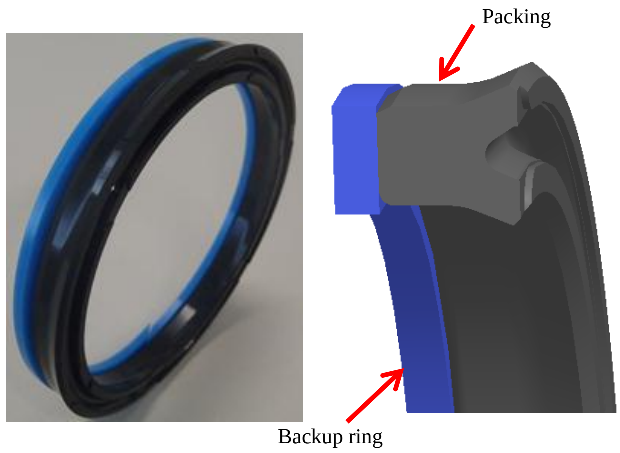


Fig. 7 Appearance of rod packing

3.3 Use of a Contact-Surface Seal with Enhanced Heat Resistance

For a notion equivalent to that used in the rod packing mentioned above, the material for the O-ring was changed to a heat resistant material, while the material for the backup ring was changed from Teflon to Nylon (**Fig. 8**).

The O-rings in tube joints continue to use the conventional material because the tube joints are anchored by bolts and there are no clearances for extrusion.

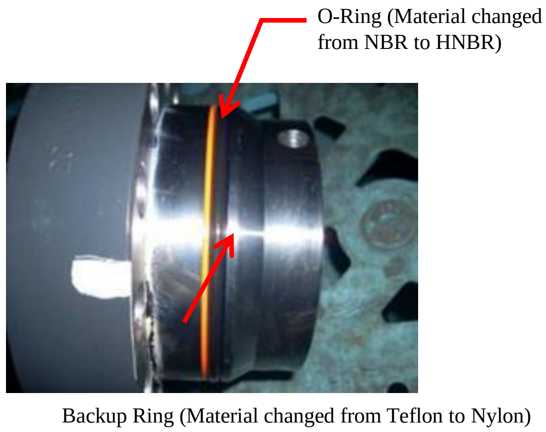


Fig. 8 Application example (Cylinder head contact surface)

3.4 Change in Material of Piston Rod

Material strengths are generally determined by carbon equivalents of the materials. Accordingly, by substituting elements whose prices are skyrocketing, materials were developed that maintain equivalent tensile strength, hardness and impact value. The prices of the steel materials themselves remain very high. However, the costs of the object elements have gone down and these materials are not yet used with piston rods.

Photo 2 Piston rods

3.5 Change in Heat Treatment of Piston Rod

The strength required for piston rods is roughly halved, for buckling and piston fastening parts. The raw material cost was also restrained by changing and adding heat treatment conditions.

Strengths that are one class higher were secured for the buckling strength by increasing the thickness of the hardened layer and maintaining the bending strength of piston rods and for the piston fastening parts by adding heat treatment to the conventional material strength. Conditions for hardening and tempering were established for heat treatment, allowing heat treatment by an induction coil. (**Figs. 9** and **10**).

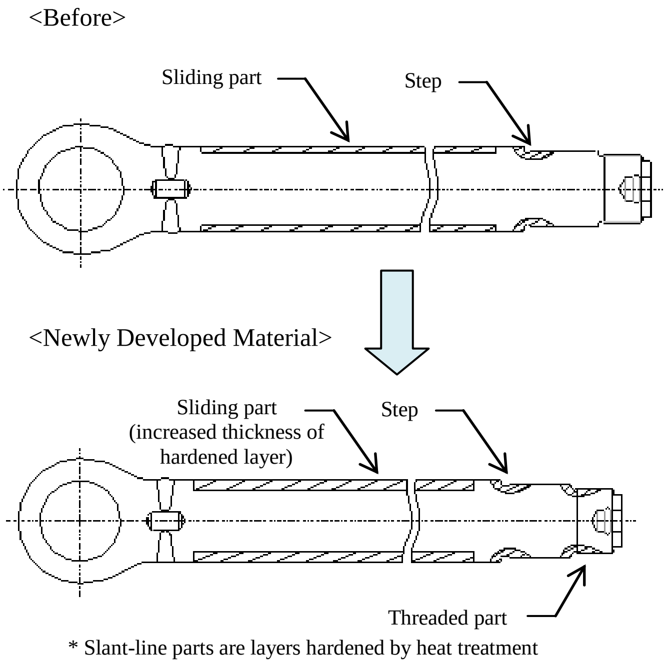


Fig. 9 Schematic depiction of the heat treated parts of rods

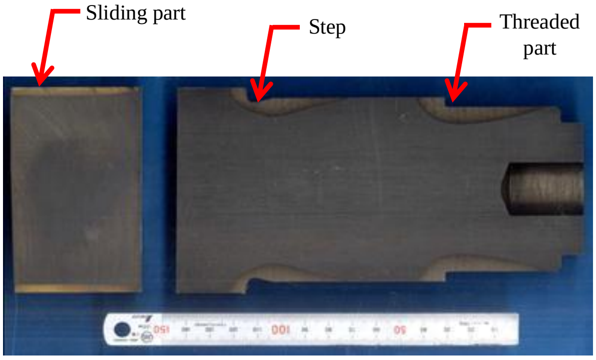


Fig. 10 Macroscopic photo of developed part after heat treatment

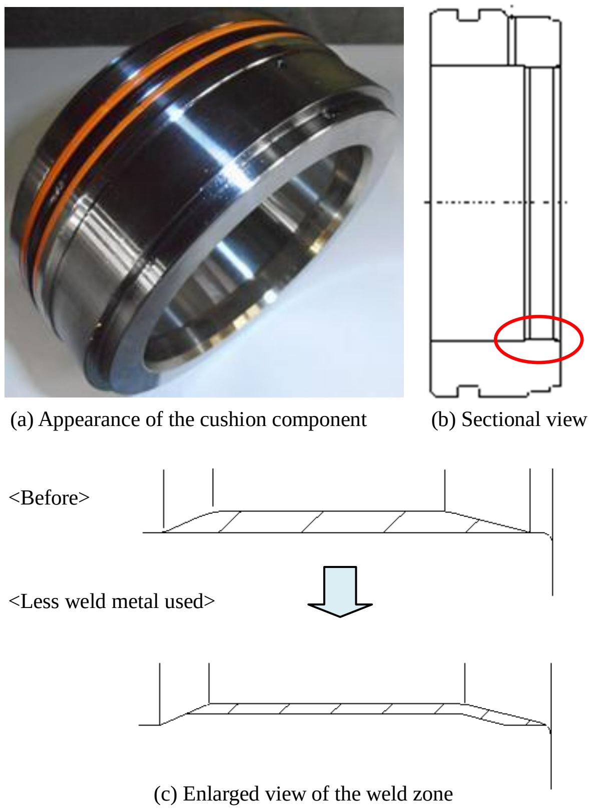
3.6 Change in Material of Cylinder Steel Tube

From Model PC200-3 onward, Komatsu started to use electric welded tubes as steel tubes of hydraulic cylinders, instead of the seamless tubes previously used, ahead of other machine manufacturers. Initially, 540 N/mm^2 high tensile strength steel was used, but 735 N/mm^2 high tensile strength steel has since been used from PC200-7 to achieve thin wall thickness and light weight. A method to control residual stress without changing the wall thickness of steel tubes was developed and equivalent strength was maintained with 620 N/mm^2 high tensile strength steel.

Photo 3 Appearance of the hydraulic cylinder

3.7 Other Change

The cushion component of the cylinder with a cushion slides under high pressure of 80 MPa and a copper alloy is welded onto the sliding part of the cushion component to prevent galling. The weld metal was reduced by examining the wear of machines after many hours of operation and changing the thickness to the required and suitable level (**Fig. 11**).



(a) Appearance of the cushion component (b) Sectional view

(c) Enlarged view of the weld zone

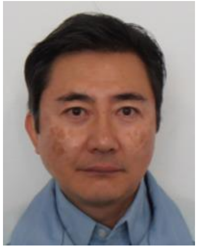
Fig. 11 Cushion component

4. Conclusion

No direct suggestion for improvement to meet the Tier4 emission regulation was made. Nevertheless, cost improvement to restrain the skyrocketing steel price and quality improvement could be achieved for conventional cylinder.

In recent years, the demand for hydraulic excavators has shifted to emerging economies, centering on China. The newly developed cylinder will be installed in machines destined for these regions and it is hoped that the new cylinder will win high acclaim of users worldwide.

Introduction of the writers



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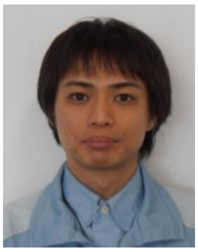

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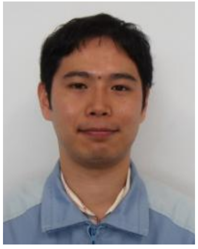

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[A few words from the writers]

The mainstay cylinder could be completed successfully thanks to the cooperation of manufacturers of steel, seals and other products to meet the hurdles of quality, cost and delivery time (QCD) that are present for each model change. The writers thank them for their cooperation.