Development of a Heat-Resistant Power Steering Pressure Hose

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Due to the recent diversification of engine room layouts and operating conditions, engine room and power steering oil temperatures are rising. Koyo has developed a highly heat-resistant power steering pressure hose that can be used in temperatures up to 140℃. This paper presents the specifications, fundamental performance features and performance test results regarding the developed hose.

***Key Words**: power steering, pressure hose, rubber, high temperature*

1. Introduction

In recent years, many automakers have begun placing the engine horizontally adjacent to the front axle in compact cars. For this reason, and also because of these cars' recent higher-output engines, rearward-positioned exhaust systems, the addition of various auxiliary devices, a reduction of engine room space in order to increase passenger room space, etc., the amount of space allotted to the power steering system is being reduced.

Not only have usage environments and conditions become more diverse, in many cases engine room ambient temperatures and power steering system hydraulic fluid temperatures have become higher because of the elimination of coolant piping, etc. for the purpose of cost reduction.

As a result, demands from automakers for power steering hoses better able to withstand heat are on the rise, and in addition, in consideration of recent environmental problems, automakers are demanding superior heat-resistant hoses that do not contain lead from environmental concern.

This paper introduces a low-cost, heat-resistant hose (hereinafter "heat-resistant hose") developed by Koyo for future mass production that is capable of meeting the above-described market requirements.

2. Development Targets

2. 1 Aims of Design

The power steering hoses currently mass-produced by Koyo are ordinary-grade hoses (hereinafter "conventional hoses") that use acrylonitrile-butadiene rubber (NBR) for the inner rubber and chloroprene rubber (CR) for the outer rubber.

The aim of using hydrogenated NBR (H-NBR) for the inner rubber and chlorinated polyethylene (CPE) for the outer rubber in the newly developed heat-resistant hose was to enable it to exhibit sufficient endurance at temperatures 20℃ higher than the upper-limit endurance temperatures of conventional hoses.

Another aim was to use the fittings and crimped area structures of existing mass-production hoses with as little modification as possible in order to reduce costs.

2. 2 Target Performance

Taking vehicle usage environments and conditions into account, we established development targets whereby the hose volume expansion amount, which largely influences noise and vibration, the capability of seals to prevent leakage from hose crimped areas, and other performance features would be comparable to those of mass-production hoses.

Development targets are given in **Table 1**.

Table 1 Development targets of heat-resistant hose

No	Item	Heat-resistant hose	Conventional hose	Remarks
1	Durability · Test pressure, MPa (pump relief pressure, MPa) · Working temperature,℃	 → (→) –40 ~ 140	 0 ~ 11.8 (7.8) –40 ~ 120	 Same level as conventional hose 20℃ higher
2	Noise/vibration · Volume expansion amount, cm^3/m (at 5.9 MPa)	→	11 ~ 13	Conforms to existing hose to prevent reduction of damping characteristics.
3	Sealing performance · Pressure, MPa	→	Min. 8	Because it can cause oil leakage, must be same level as conventional hose.
4	Cost · Rise in cost	Minimal		

3. Heat-Resistant Hose Structure

Hose specifications are given in **Table 2**. As shown in **Fig. 1**, the structure of the developed hose is the same as that of conventional hoses, which enables the same manufacturing equipment to be used.

Table 2 Hose specifications

Item		Heat-resistant hose	Conventional hose
Structure	Inner rubber	H-NBR	NBR
	1st reinforced layer	→	PA66
	Jacket layer	→	CR
	2nd reinforced layer	→	PA66
	Cover rubber	CPE	CR
Dimensions	Inner diameter, mm	φ9.9	
	Outer diameter, mm	φ18.5	
Manufacturing equipment		Same process as existing	

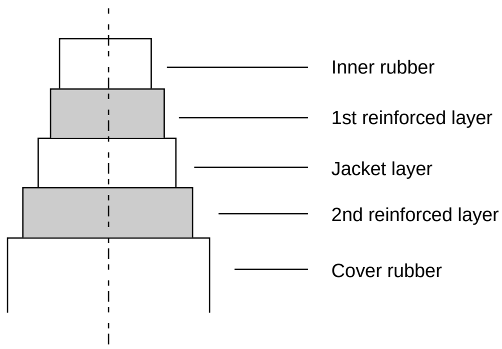

Fig. 1 Structure of heat-resistant hose

The structure of the crimped area is shown in **Fig. 2**. A low-cost double-crimping area with excellent sealing performance has been used.

The structure of this crimped area has been designed to be optimal for heat-resistant hoses and possesses the strength, durability, sealing performance and other characteristics required in order to satisfy the performance targets. With the exception of the outer diameter, the crimped area's structure is the same as that of conventional hoses, enabling the use of existing manufacturing equipment.

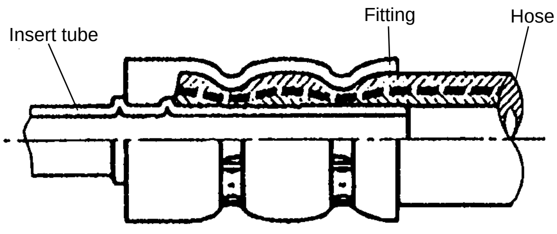

Fig. 2 Crimped area

4. Heat-Resistant Hose Performance

The following performance items were evaluated regarding the developed product.

(1) Durability
(2) Sealing performance
(3) Rubber physical properties
(4) Other performance items

4. 1 Durability

Power steering hose oil leakage, hose breakage, and similar problems often originate in the crimped areas. Accordingly, the durability of crimped area must be thoroughly evaluated when changing to a different rubber hose material.

In order to secure such durability, it is necessary to crimp the area with a force suited to the hose material and structure, and it is very important to use the optimal outer-diameter dimensions. If the area is crimped too strongly, the rubber hose will be damaged during the manufacturing process, which will result in reduced durability. On the other hand, if the area is not crimped with sufficient force, the hose may slide or come out of the area during endurance testing.

In order to determine the optimal fitting outer diameter, therefore, prototype hoses of various diameters were prepared and reliability testing carried out in the form of high-temperature impulse testing. At the optimal area diameter, the heat-resistant hose was determined to be capable of enduring 1 million endurance test cycles at 140℃. In addition, no leaking of power steering fluid or bleeding was observed during the 3-minute pressure resistance test after the endurance testing.

Whereas conventional hoses ruptured after approximately 350 000 cycles during endurance-limit testing at 140℃, the newly developed heat-resistant hoses were able to withstand more than 1.4 million cycles under the same conditions, exhibiting more than four times the durability of conventional hoses.

Conditions of the high-temperature impulse testing are given in **Table 3** and **Fig. 3**. Test results are given in **Figs. 4** and **5**.

Table 3 High-temperature impulse test conditions

No	Item	Conditions
①	Pressure, MPa	0~11.8
②	Pressure waveform	Trapezoid wave
③	Oil temperature, ℃	140
④	Ambient temperature, ℃	140
⑤	Pressurization cycle, min^{-1}	70
⑥	Hose bend radius, mm	R80
⑦	Endurance test cycles, cycles	Min. 1 million

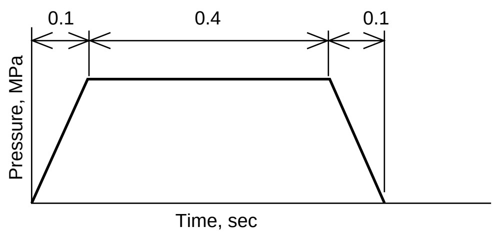

Fig. 3 Pressure waveform

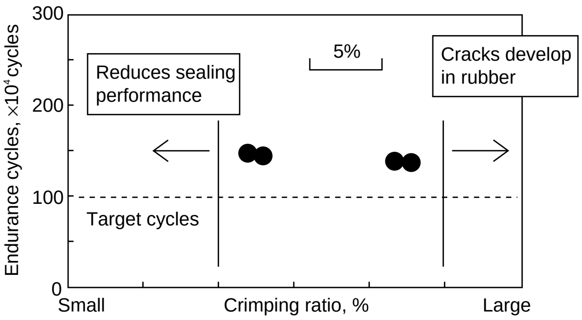

Fig. 4 Crimping ratio and durability

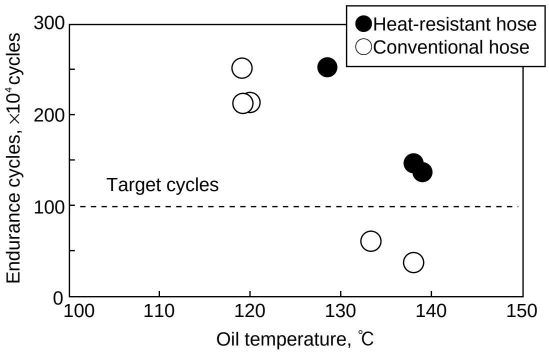

Fig. 5 Test temperature and durability

4. 2 Sealing Performance

In order to eliminate oil leakage and bleeding from around the fitting, it is important that sealing performance between the insert tube and inner rubber be sufficient.

Accordingly, after 1 million cycles of high-temperature impulse testing, we drilled holes in two places on the crimped area rubber up to the insert tube surface and checked for the occurrence of oil leakage or bleeding while increasing pressure at low temperature (0℃).

The higher the temperature, the tighter the fit between the hose and insert tube, which enhances sealing performance. Using samples that had completed high-temperature impulse testing, we evaluated sealing performance of the crimped area under low-temperature conditions, where brittleness of the rubber material is a concern.

Fig. 6 shows the low-temperature sealing performance of the heat-resistant hose after 1 million cycles of high-temperature impulse testing at 140℃. When the crimping ratio was too low, the sealing pressure was also too low and did not satisfy the target value of 8 MPa. When the crimping ratio exceeded a certain percentage, cracks developed in the crimped area outer rubber, and sealing performance was reduced. A suitable crimping ratio range was determined based upon these results and the process capability of the manufacturing equipment.

Fig. 7 shows sealing performance in the established crimping ratio range. Sealing performance of the heat-resistant hose after testing at 140℃ was equal to that of the conventional hose after testing at 120℃. Furthermore, no leakage was observed on the developed product during low-temperature impulse testing (–40℃) at surge pressure of 17.6 MPa.

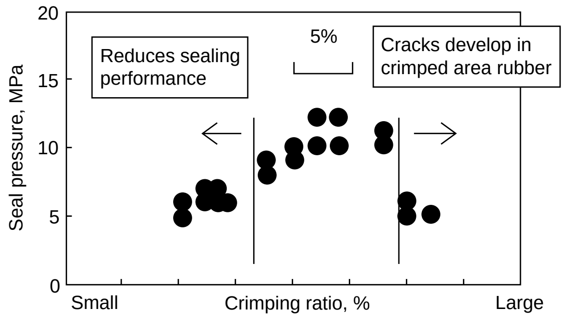

Fig. 6 Crimping ratio and sealing performance (0℃)

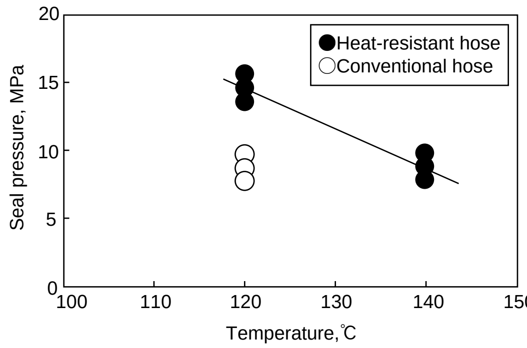

Fig. 7 Test temperature and sealing performance (0℃)

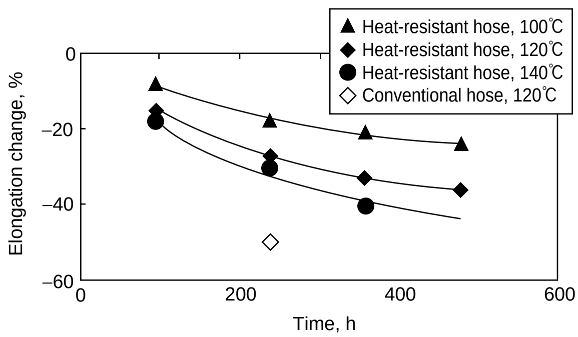

Fig. 8 Elongation change of inner rubber

4. 3 Rubber Physical Properties

Fig. 8 shows the change in rubber physical properties during high-temperature impulse testing.

The elongation change of the heat-resistant hose at 140℃ was less than that of the conventional hose at 120℃, meaning the heat-resistant hose possesses superior durability. Changes in physical properties for the heat-resistant and conventional hoses are shown in **Fig. 9** and **Fig. 10**. The amount of change in rubber physical properties of the heat-resistant hose at 140℃ is less than that of the conventional hose at 120℃.

These results demonstrate that the heat-resistant hose has superior physical properties.

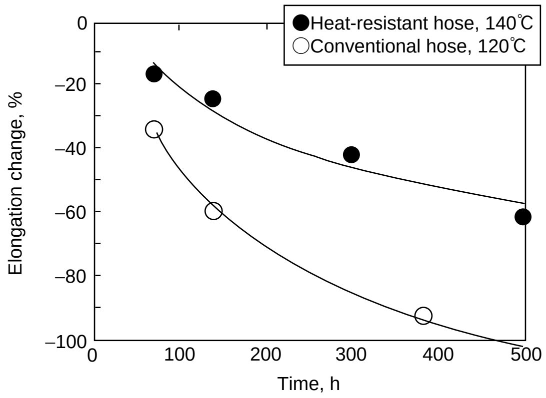

Fig. 9 Elongation change of outer rubber

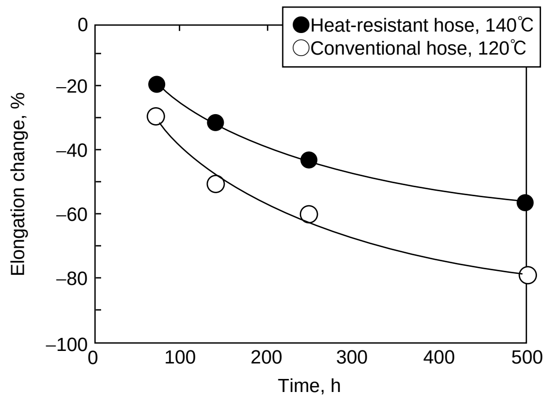

Fig. 10 Elongation change of inner rubber

4. 4 Other Performance Items

Power steering hoses are required to have performance of suppressing noise and vibration created by the power steering system.

Hoses with increased volume expansion amount and good damping characteristics are effective in reducing noise and vibration. However, increasing the volume expansion amount increases the amount of hose expansion and contraction during the previously mentioned high-temperature impulse test, which lowers durability as well as response. If the only features being sought are high durability and good response, it is better to have a small volume expansion amount.

Because good response was included as a development target for the heat-resistant hose this time, the volume expansion amount was made the same as that of conventional hoses.

The pulse damping characteristics of the heat-resistant hose are shown in **Fig. 11**. As shown in the figure, there is no difference in the pulse damping characteristics of the heat-resistant and conventional hoses, indicating that a heat-resistant hose comparable to conventional hoses in regard to pulse damping characteristics was successfully developed.

It was confirmed that the heat-resistant hose satisfies the specifications required by automakers and the JASO M326 type 1 no.1 10.3 MPa specifications[1)] shown in **Table 4**.

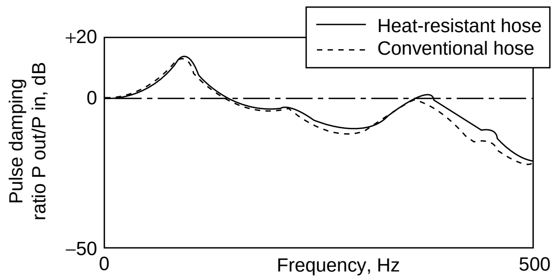

Fig. 11 Pulse damping characteristics

Table 4 Other test items

Hose assembly	Hose
①Pressure resistance test	①Volume change test
②Burst pressure resistance test	②Fluid resistance test at low temperature
③Tensile strength test	③Pressure resistance test
④High-temperature impulse test	④Burst pressure resistance test
⑤Low-temperature impulse test	⑤Tensile strength test
⑥Bending resistance test	⑥Low temperature resistance test
⑦Crimping resistance test	⑦Adhesion resistance test
⑧Sealing test	⑧Ozone aging resistance test

4. 5 Cost

Because the developed heat-resistant hose possesses the same hose dimensions, hose fittings and crimped area structures as conventional hoses, it can be manufactured on existing equipment and use common fittings, etc., enabling a cost benefit to be realized. Through these and other means, the overall cost increase of the newly developed hose was kept to be a minimum.

Use of the newly developed heat-resistant hose will allow oil cooler piping to be shortened or eliminated, likely offsetting any cost increase associated with adoption of this new power steering hose.

5. Conclusion

It was confirmed that the developed heat-resistant hose possesses sufficient performance even at temperatures up to 140℃.

Automakers consider cost reduction and weight reduction to be priority items, and we will therefore continue researches aimed at satisfying these requirements.

Reference

1) Japanese Automobile Standards Organization: Japanese automobile standards "Power Steering Hose and Hose Assemblies for Automobiles" JASO M326.