Technology Introduction

Development of High Damping Force Piston Valve for Extra Low Velocity

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1 Introduction

In recent years, the rigidity of suspension frames and vehicle bodies of newly developed vehicles made by automobile manufacturers has been increasing. Tires/wheels are also being made larger, lower, and flatter. These shifts have been increasing the rigidity of vehicles in general.

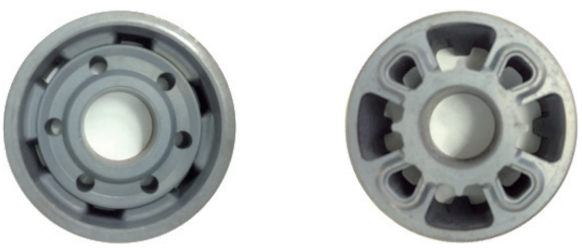
Along with such changes, fine oscillation that used to be absorbed by tires, etc. and did not used to be transmitted to shock absorbers (hereinafter referred to as "SA") have begun being transmitted to SAs. SAs are forced to move in a more detailed and delicate manner in response to the same input from the road surface.

If the above oscillation cannot be controlled, the oscillation is transmitted from the SA to the body through the upper mount, etc. and ultimately leads to discomfort for users. Therefore, securing of the damping force in micro-low velocity and low amplitude as well as high damping force responsiveness in SAs are anticipated more than ever.

In response to such demands, we have developed a piston valve with improved damping force responsiveness, and details were introduced in KYB TECHNICAL REVIEW No. 51 [1)].

In this valve, we modified the inner seat surface shape from the original shape (Fig. 1 (a)) (Fig. 1 (b)), which is a key component, and significantly improved the damping force responsiveness. Not only that, but the leaf valve can now be opened at lower velocity. By further reducing the damping force valve orifices, the damping force for extra low velocity can also be improved (Fig. 2).

In this report, I would like to introduce the development of piston valves that can further improve the damping force for extra low velocity for the valves with improved damping force responsiveness, which was in the previous report.



(a) Conventional valve [Circular seat surface]

(b) Piston valve with improved damping force responsiveness [Independent seat surface]

Fig. 1 Inner seat surface form within the piston

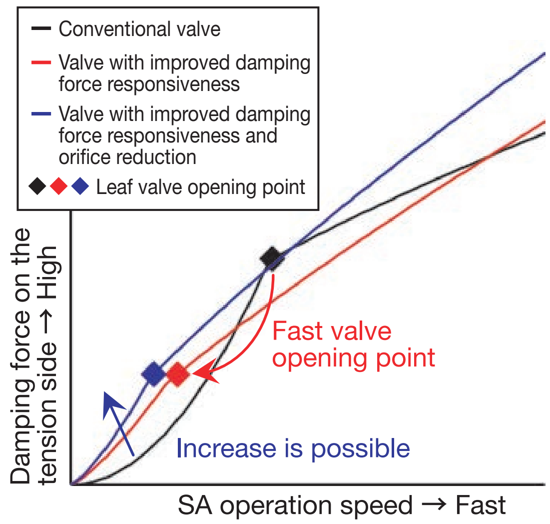


Fig. 2 Comparison image for damping force – velocity characteristics between the conventional valve and the valve with improved damping force responsiveness

2 Development Background

Fig. 3 shows the positioning image of the feeling on actual vehicles in response to SA operation strokes and operation frequency. Stable driving performance can also be described as the responsiveness/tracking performance mainly in response to steering, and texture can also be described as the blocking sense against fine numbing input from the road surface; comfort can also be described as sprung mass damping performance.

While stable driving performance and texture have different domains in Fig. 3, they are both positioned in the same micro-low velocity area when you focus on the operation speed of SAs. This indicates that damping force for extra low velocity greatly affects stable driving performance and texture. We can also say that the damping force in the medium/high velocity area greatly affects comfort.

Through the application of the valve with improved damping force responsiveness, the stable driving performance and texture significantly improved compared to the existing valves. However, automobile manufacturers have further performance improvement demands.

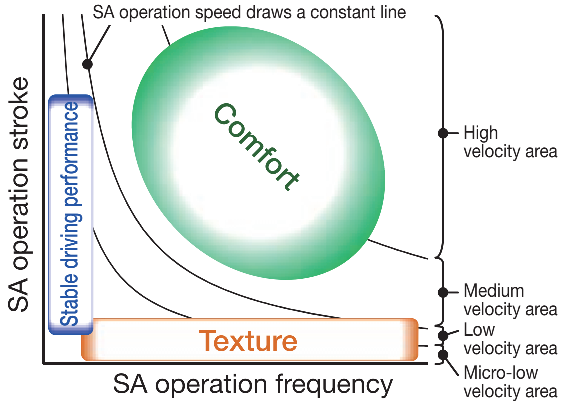


Fig. 3 Impact on the feeling on actual vehicles in response to SA operation

Furthermore, we were unable to only reduce the damping force in the medium/high velocity area due to the characteristics, so comfort still had room for improvement.

In general, ① stable driving performance/texture and ② comfort have a trade-off relationship. SA's damping force tuning means to search for a balance point (greater compromising point) for both ① and ② performance aspects in accordance with the vehicle (weight, suspension system, geometry, etc.) and grade (vehicle characteristics).

Since it was difficult to maintain or improve the ② comfort and further improve ① stable driving performance/texture with damping force tuning alone, we began developing a damping force valve that balances ① stable driving performance/texture and ② comfort at a higher level (Fig. 4).

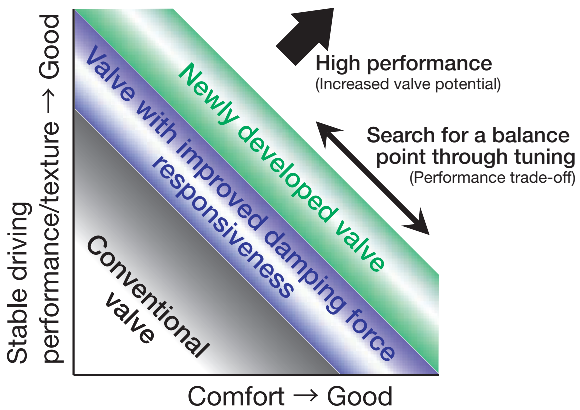


Fig.4 Development direction image for the newly developed valve

3 Development of a New Piston Valve

3.1 Objective of the Development

As previously mentioned, securing of the damping force for extra low velocity by SAs (≈ shift to linear characteristics) contributes to the improvement of stable driving performance/texture. It is considered that control of medium/high velocity area damping force by SAs (≈ shift to saturation characteristics) is effective in improving comfort. There was no valve that simultaneously balanced both of the above characteristics among KYB's existing valves (Table 1).

Table 1 Characteristics of the conventional valve and the newly developed valve

	Damping force in the micro-low velocity area	Damping force in the medium/high velocity area
Conventional valve 1	Low (orifice characteristics)	High (linear characteristics)
Conventional valve 2	Low (orifice characteristics)	Medium (weak saturation characteristics)
Conventional valve 3	Low (orifice characteristics)	Low (super saturation characteristics)
Valve with improved damping force responsiveness	High (linear characteristics)	High (linear characteristics)
Newly developed valve (Objective)	High (linear characteristics)	Low – medium (saturation – weak saturation characteristics)

① Possesses the same level of damping force for extra low velocity as the valve with improved damping force responsiveness.

② Able to control medium/high velocity area damping force and further improve the damping force for extra low velocity without compromising comfort.

③ Possesses the tuning capabilities that can make various changes to the damping force breakpoint, slope, etc. according to the vehicle.

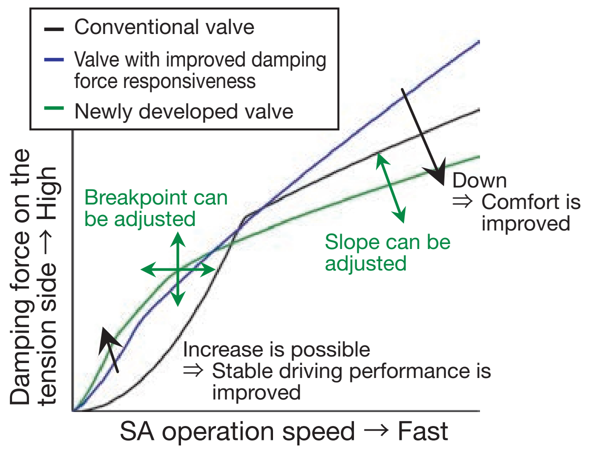


Fig. 5 Image for damping force – velocity characteristics for the newly developed valve

3.2 Design of the Piston Form

In order to shift the damping force for extra low velocity to linear characteristics, separation of the piston seat surface form (as shown in Fig. 1 (b)) is effective. This is due to the fact that the damping force – velocity characteristics become more linear because local opening of the leaf valve is promoted with the pressure applied to the leaf valve in a spot-like manner when the SA operates, causing it to shift from orifice characteristics to valve characteristics at an early stage.

In addition, to shift the medium/high velocity area damping force to saturation characteristics, circularization and enlargement of the valve seat surface is effective. This is due to the fact that they both enlarge the leaf valve opening area, which means that the valve pressure difference is less prone to increasing in response to the increase of operation fluid flow, thus controlling the increase of the damping force.

In order to simultaneously achieve the shift to linear characteristics in the micro-low velocity area and the shift to saturation characteristics in the medium/high velocity area, we designed the inner seat surface form within the piston to have dual seat surfaces, including the independent seat surface and circular seat surface, as shown in Fig. 6.

We also designed the structure so that it can respond to preloads of various load positions and sizes by installing a number of valve supports on the inside of the piston's circular seat surface, aiming to secure a wide scope of damping force tuning characteristics. I will explain the mechanism at a later point.

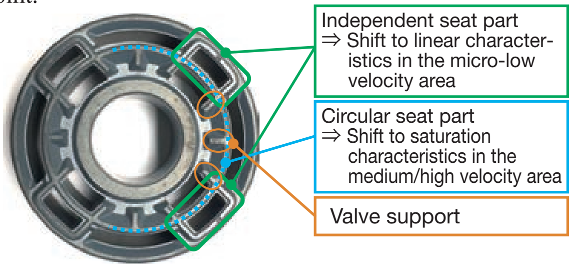
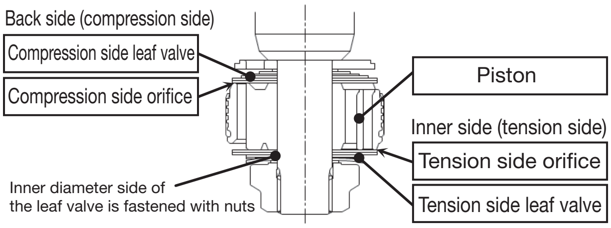


Fig. 6 Inner seat surface form within the piston of the newly developed valve

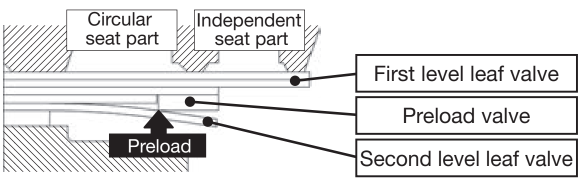
3.3 Structure of the Piston Valve

The cross-section structure of the new piston valve is shown in Fig. 7 (a). The overall structure uses the conventional method of nut fastening to fix the inner diameter side of the laminated leaf valve, but its uniqueness is in the fact that the lamination structure of the leaf valve on the tension side is a two-level structure to match the dual seat surface of the piston (Fig. 7 (b)).

By installing valve supports on the inside of the piston's circular seat surface (Fig. 6), the volume and position of the preload valve, which is installed in between the first level leaf valve and the second level leaf valve, can be freely adjusted. We aimed to achieve the desired damping force – velocity characteristics by controlling the valve opening point of the circular seat part.



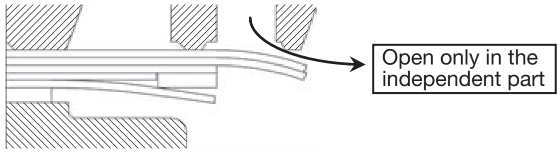
(a) Overall structure/components



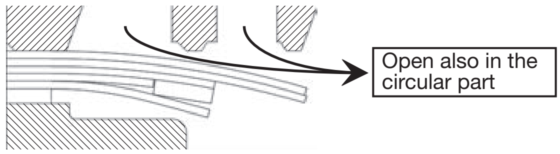
(b) Inner structure details

Fig. 7 Structure of the newly developed valve

Fig. 8 shows a model of the leaf valve opening conditions when the SA is extended. When the SA's operation speed is slow, only the independent seat section opens, only opening the first level leaf valve. The diameter of the first level leaf valve is enlarged as much as possible, and the pressure load is applied in a spot-like manner. Due to this, the leaf valve starts opening in the early stage of SA operation. This allows the valve to make the orifices smaller than the conventional valves, enabling the increase of damping force for extra low velocity.



(a) Micro-low velocity/low velocity area



(b) Medium/high velocity area

Fig. 8 Tension side valve operation model

When the SA operation speed gradually accelerates, the circular seat part that contacts the second level valve opens, suddenly increasing the open area. This controls the increase of the pressure difference against the operation speed, thus controlling the damping force in the medium/high velocity area.

The opening point of the circular seat part can be freely controlled according to the size and diameter of the load from the preload valve. The uniqueness after the opening point is in the fact that adjustments can be made according to the rigidity of the second level leaf valve.

With the summary of the above information, Fig. 9 shows the objective of adjusting the damping force for each tuning element.

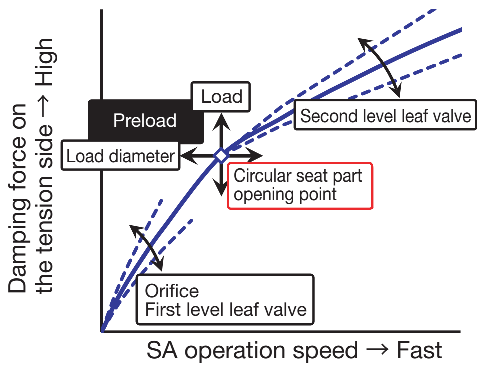


Fig. 9 Objective of each tuning element

3.4 Confirmation of the Damping Force – Velocity Characteristics

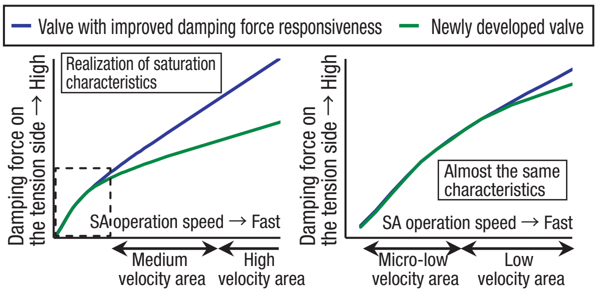
3.4.1 Comparison with the Valve with Improved Damping Force Responsiveness

We used the representative-sized SA (cylinder diameter: ø35, rod diameter: ø22). Fig. 10 shows the comparison result of the damping force – velocity characteristics on the tension side. The damping force in the micro-low velocity area – low velocity area almost has the same characteristics as the valve with improved damping force responsiveness. It also controlled the damping force in the medium/high velocity area, so we were able to achieve the objective.

3.4.2 Confirmation of the Extent of Tuning Freedom

Fig. 11 (a) through (e) show the impact of each of the new valve's tuning elements on the damping force - velocity characteristics and confirmation of the cover range.

(a) Due to the orifice area change, a sufficient scope of damping force variables is achieved in the micro-low velocity



(a) Entire velocity area (b) Micro-low velocity/low velocity area (Enlarged image of the broken line part in the left figure)

Fig. 10 Comparison of damping force – velocity characteristics

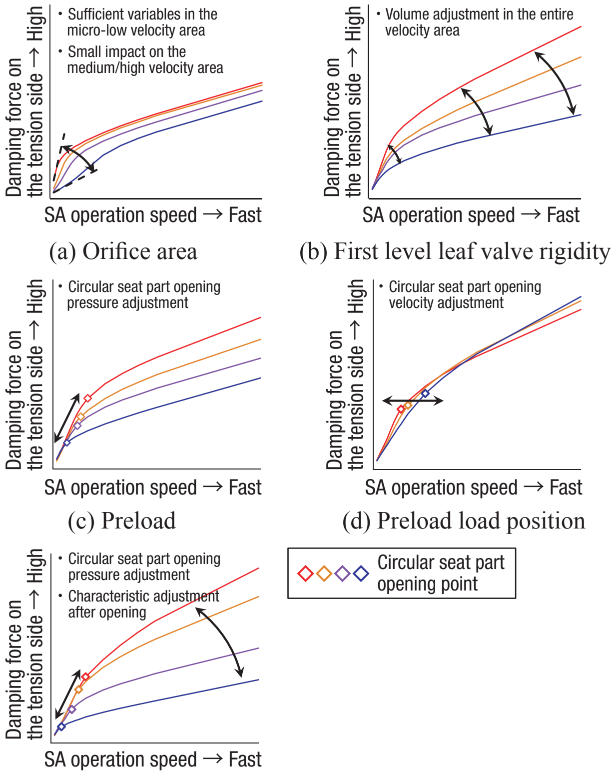
area. In addition, even if the damping force in the micro-low velocity area is significantly improved through the effect to control the damping force in the medium/high velocity area, the damping force changes in this area is controlled to be relatively small. We consider that this is achieving a good balance with comfort.

(b) By changing the rigidity of the first level leaf valve, adjustment of the damping force volume in all velocity areas is made possible. The fact that the damping force starts to change in the micro-low velocity area also indicates that the leaf valve starts to open at an extremely early point.

(c) By adjusting the load of the preload by selecting the preload valve level, the opening pressure in the circular seat part can be changed. At the velocity near the opening point, the damping force goes up and down in an offsetting manner.

(d) Adjustment of the load diameter for the load of the preload through selection of the preload valve outer diameter enables fine tuning of the opening speed for the circular seat part.

(e) Changes to the second level leaf valve rigidity enables adjustment of the opening pressure of the circular seat part as well as the damping force slope after the opening point.



(a) Orifice area (b) First level leaf valve rigidity (c) Preload (d) Preload load position (e) Second level leaf valve rigidity

Fig. 11 Impact/effect of each tuning element on the damping force – velocity characteristics

4 Utilization Status

The mass production of this newly developed piston valve started in December of last year, and the trend still shows that it is going to be utilized in a wide variety of vehicles. We are promoting its application development. As with the recent piston valve with modified damping force responsiveness, we intend to promote this valve's deployment as our new main valve by positioning it as a value-adding valve that is distinctly different from common valves. We expect that both the number of vehicles in which this valve is used and production volume will increase.

5 In Closing

We have developed a new item to overcome the weaknesses of the recently developed valve by focusing on the improvement of the damping force for extra low velocity and control of the damping force in the medium/high velocity area. Thanks to this, we can achieve a balance of stable driving performance and comfort at a higher level and provide end-users with comfortable vehicles.

Finally, I would like to express my sincere gratitude for everyone involved who has provided us with guidance and cooperation in the course of this development.

Reference

1) "Development of Valve with Improved Damping Force Responsiveness," KIMISHIMA, YAMANAKA, YAMAMOTO, KYB TECHNICAL REVIEW. No. 51 (Oct. 2015).

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