Product Introduction

Development of Inverted Front Fork for Small- and Mid-sized Motorcycle

MIYAUCHI Yoshihiko, OZAKI Kosuke

1 Introduction

People's income in the Association of Southeast Asian Nations (hereinafter "ASEAN") region has tremendously increased in recent years. The higher income certainly affects the local motorcycle market. The market has seen a change in the popular category of motorcycle bodies and required motorcycle performance.

The front fork (hereinafter "FF") that connects the body to the wheels contributes to motorcycle stability with its control of vibration input from the road surface, vehicle position control and its presence as a component to provide vehicle strength. The circumstances of the FF have been affected by the higher income of the ASEAN population too. Against the conventional cost-centered product concept, appearance and performance have gained more and more attention.

2 Aim of Development

The conventional popular motorcycles in the ASEAN region were mopeds [Note 1)] and scooters (Photo 1) with an engine displacement of not more than 150cc. The rising income in the region raised the demand for larger-displacement motorcycles. Various motorcycle racing competitions typified by the Asia Road Racing Championship (Photo 2) have also become popular in these countries. With these situations, components for small and mid-sized motorcycles, that are differentiated from conventional products and make customers feel even higher added value, are in demand. As a product group to satisfy the market needs, a new inverted front fork with high salability has been developed.

Photo 1 Example of scooter: Mio Z [Note 2)]
(Source: Yamaha Motor Co., Ltd. Website)

Photo 2 Asia Road Racing Championship
(Source; Yamaha Motor Co., Ltd. Website)

Photo 3 Example of moped: Jupiter MX King150 [Note 2)]
(Source: Yamaha Motor Co., Ltd. Website)

Note 1) The term "moped" used in this article refers to a manual variable speed motorcycle in the shape shown in Photo 3. (In general, the moped often refers to a motorized two-wheeled vehicle with pedals).

Note 2) Mio Z and Jupiter MX King150 are trademarks of Yamaha Motor Co., Ltd.

3 Overview of Development

None of the production sites of KYB Group in the ASEAN region has a track record of producing inverted FFs or offers inverted FFs of a size suitable for small and mid-sized motorcycles. It was then decided to develop an

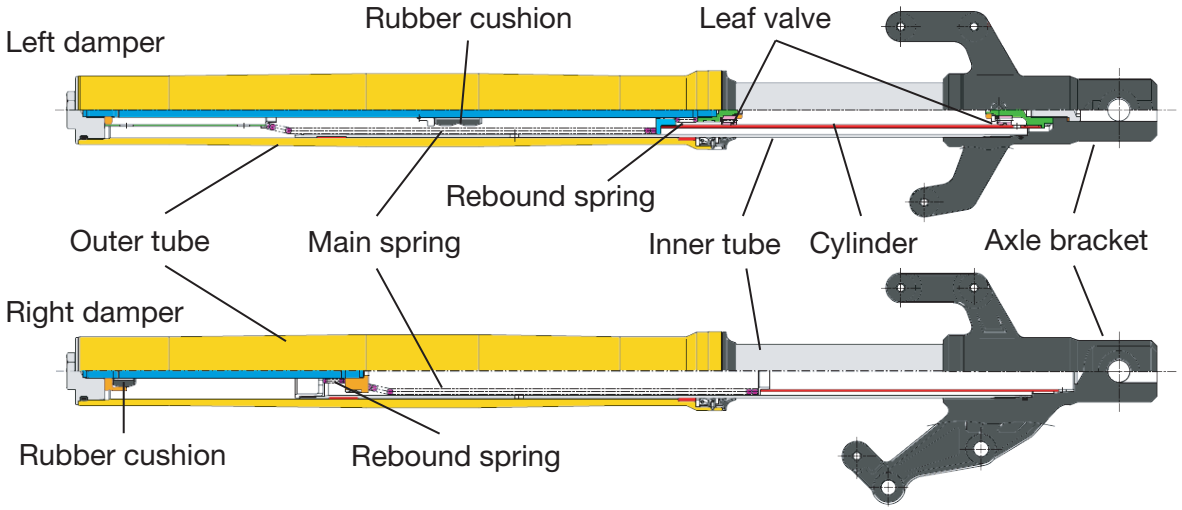

Fig. 1 Structure of ø37 inverted FF

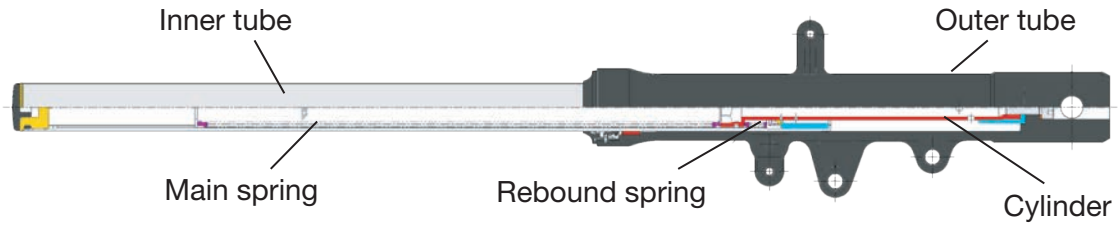

Fig. 2 Example of standard FF

inverted FF with an inner tube diameter of ø37, which was considered to be the best-balanced product for toward the 150cc to 300cc class.

The structure of the newly developed inverted FF is shown in Fig. 1 and the following section:

3.1 Basic structure

The newly developed FF is of inverted telescopic type [Note 3)]. The inverted type has its outer tube up and its inner tube down. Another type in which the outer and inner tubes are arranged on opposite sides is called an standard FF (Fig. 2).

In general, the FF is mounted on the body with the two dampers sandwiching the front wheel. These right and left dampers are joined with an axle and upper and lower brackets. The dampers serve as shock absorbers with their built-in damping force generator and coil spring.

Note 3) The term telescopic type refers to a mechanical structure consisting of several tubes of different diameters to be able to freely expand or contract in the longitudinal direction.

3.2 Specifications of components

3.2.1 Damping force generator

The new inverted FF uses a cartridge type damping force generator that can generate a damping force with its piston assembly containing a leaf valve so as to provide good responsivity even suited to sports driving.

While the ordinary inverted FF has a damping force generator in both dampers, this cartridge type has a damping force generator only in the left damper as it can deliver a sufficiently high damping force with a single generator. As a result, cost reduction can be achieved.

3.2.2 Springs

The new FF has the following spring elements:

① Metal coil springs
② Rubber cushions
③ Air springs

The new FF uses two kinds of metal coil springs. One is a main spring that generates a spring force in the direction of expanding the dampers over the stroke. The other is a rebound spring that is only used to alleviate the shock after the dampers fully expand.

The rubber cushions can alleviate the knocked-up feel during bottom hitting [Note 4)].

The air springs utilize the pressure increase in the enclosed chambers of the dampers when the air is compressed. They mainly contribute to the feel of "go further" in the end of the stroke.

Note 4) The bottom hitting refers to a phenomenon in which the inner tube bumps into the bottom of the outer tube during the full stroke of the FF applied with a strong compressive load by the tires when the motorcycle runs over a step for instance.

3.2.3 Outer tube

The outer tube of the inverted FF uses a tubelized aluminum alloy pipe. The production method for the outer tube was selected by giving considerations to local avail-

ability.

The tube is surface-treated with colored anodized aluminum to possible local work specifications.

3.2.4 Inner tube

The inner tube is one of the important parts that decides the strength and performance of the FF. The relationship between the displacement and inner tube diameter of a motorcycle with an inverted FF is shown in Fig. 3.

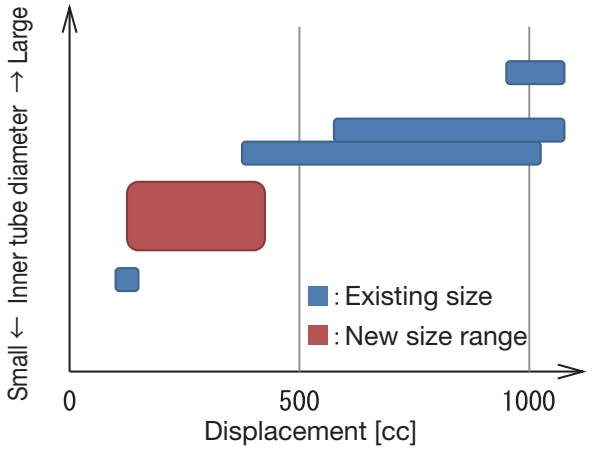

Fig. 3 Inverted FF inner tube size

4 FF Rigidity

The contribution of FFs to motorcycle stability was mentioned in the beginning of the article. Small and mid-sized motorcycles have used an erecting FF with an inner tube sized from ø33 to ø41. In developing this new inverted FF for those motorcycles, it was easily imagined that stability would be substantially affected.

First of all, it should be noted that the inverted FF is clamped to the vehicle body with its outer tube and the erecting FF is clamped to the vehicle body with an inner tube that is different in size from the outer tube. This generally means that the inverted FF has high rigidity and the erecting FF has low rigidity. A high-rigidity FF will help stabilize the motorcycle position during braking, high-speed running or turning. Even during quick steering such as slalom riding, the rider can cut the handle with excellent responsiveness.

However, it may be inconvenient in some cases to use the inverted FF on a vehicle that uses an erecting FF because of its quick responsiveness. The rider may feel too responsive, or even unstable compared to the existing erecting FF. This difference in rider feel was the most difficult part of the development. Some measures to integrate the inverted FF, which has inherently different properties from the erecting FF, into the vehicle were needed.

Then, a new attempt was made to create a 3-dimensional (3D) model of FFs and determine the rigidity through the finite element method (FEM) analysis. The analysis model is shown in Fig. 4.

Different rigidity levels of the erecting and inverted FFs were derived from the analysis and compared with each other. The component profile affecting the rigidity was changed in different ways to achieve integration. As a result, the inverted FF has been successfully adjusted to have a rigidity level suitable for small and mid-sized motorcycles on an analysis basis.

Actually, the determined rigidity was verified with sensory evaluation using an actual motorcycle equipped with a prototyped FF. The sensory evaluation will be described in the following section.

On the other hand, the decrease in the higher rigidity of the inverted FF means lower strength. The analysis has verified that the absolute strength of the FF and the strength balance between the vehicle body and the FF have no problem. In this way the specifications have been reviewed with few redos by using the FEM analysis.

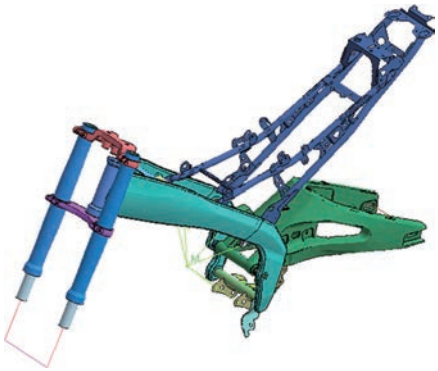

Fig. 4 FEM analysis model

5 Sensory Evaluation by Actual Vehicle

In addition to the analysis-based integration of the inverted FF described in the previous section, a prototyped FF was mounted on an actual vehicle to carry out sensory evaluation by the vehicle according to customer evaluation criteria. Several items including vehicle stability and riding comfort were evaluated.

The rigidity stated in the previous section is a property related to vehicle stability and particularly affects the steering feel upon quick steering during slalom riding as well as the vehicle stability during acceleration, braking or cornering. Since the shape determination through analysis resulted in the accurate adjustment of the rigidity, the prototyped FF was able to be smoothly set in the actual vehicle for sensory evaluation.

6 Cost Reduction and Local Procurement

We actually visited the site to work on determining a cost reduction solution in collaboration with local staff at the site. We discussed possible local manufacturing methods and component availability, and determined an

optimal design with these points taken into account. Finally, we achieved almost 100% local procurement, leading to cost reduction.

7 Product Situation and Future Outlook

The newly developed product started to be manufactured in volume in March 2017 and is being applied to other vehicle models for sales expansion. This standard inverted FF for small and mid-sized motorcycles is also planned to be developed as one of the company's key products. Production is expected to increase and the product will probably be used in more and more motorcycle models.

8 In Closing

The recent market of small and mid-sized motorcycles of less than 400cc has dramatically changed. European motorcycle manufacturers, who have mainly manufactured large-displacement motorcycles for developed countries, are now entering the small and mid-sized motorcycle market as well. These motorcycles use inverted FFs of a size equivalent to that aimed by KYB with its motorcycle suspensions. The market of motorcycles of this displacement range is currently overheated with the additional participation by European manufacturers. We cannot take our eyes off the market situation.

We are proud that the newly developed product has been used in the motorcycle model shown in Photo 4. We will make further efforts to have a stronger presence in the market.

Photo 4 YZF-R15 [Note 5)] equipped with ø37 inverted FF
(Source: Yamaha Motor Co., Ltd. Website)

Note 5) YZF-R15 is the trademark of Yamaha Motor Co., Ltd.

Finally, we would like to cordially thank all those in the related departments who extended support in product development.

Author

OZAKI Kosuke

Joined the company in 2006.
Engineering Dept., KYB Motorcycle Suspension.
Engaged in design and development of motorcycle suspensions.

MIYAUCHI Yoshihiko

Joined the company in 2009.
Engineering Dept., KYB Motorcycle Suspension.
Engaged in design and development of motorcycle suspensions.