

Development of New Concept Two-Wheel Steering System for Motorcycles

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ABSTRACT

This paper describes the development of a new concept two-wheel steering system for realizing motorcycle motion control. By considering the whole of the main frame as the rear-wheel steering axis, it was possible to move the rear-wheel steering system from the conventional installation position at the rear arm to the head pipe. As a result, the developed two-wheel steering system is both lightweight and compact. This two-wheel steering system was installed in a motorcycle, and starting and stopping tests were carried out with two people riding on the motorcycle. The test results confirmed that the two-wheel steering system is capable of changing the motion characteristics of the motorcycle in actual riding. Furthermore, by calculating the equivalent wheel alignment of this system, this paper also theoretically demonstrates that these changes in motion characteristics are caused by changes in caster and trail.

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INTRODUCTION

Remarkable advances have been made recently in the field of vehicle motion control. Various devices have been developed and commercialized to help enhance active safety performance and to help reduce the number of traffic accidents [1]. Prior to these advances, researchers also examined stability and maneuverability through the development of vehicles installed with four-wheel steering systems [2]. Several examples of such systems were mass-produced from the second half of the 1980s and used for vehicle motion control.

The application of two-wheel steering systems to enhance stability and maneuverability has also been studied for motorcycles [3]. Although research and development using actual motorcycles confirmed the effect of these systems [4], [5], [6], none were actually commercialized. These research motorcycles installed the rear-wheel steering system at the rear arm. However, this installation position increases the divided load on the rear wheel and the unsprung mass, reduces the rear arm stiffness, and so on, thereby reducing capability on rough roads and ride comfort. As a result, it was necessary to make changes to the motorcycle specifications that adversely affect stability and maneuverability.

Therefore, the research described in this paper adopted a new concept for rear-wheel steering as a device to realize the

motorcycle motion control. This concept considers the whole of the main frame as the rear-wheel steering axis, which allowed the rear-wheel steering system to be moved from the rear arm to the rear end of the head pipe. Consequently, the steering systems for the front and rear wheels are concentrated in the head pipe, thereby achieving a compact two-wheel steering system with no adverse effects on stability and maneuverability.

TWO-WHEEL STEERING SYSTEM

This research used a cruiser style motorcycle with an engine displacement of 1,900 cc. to develop the two-wheel steering (2WS) system. [Table 1](#) shows the main specifications of the motorcycle.

As shown in [Fig. 1](#), the rear-wheel steering axis has a large caster λ_r of approximately 60°. This allowed the rear-wheel steering system to be moved from the conventional installation position at the rear arm to the main frame.

[Figure 2](#) shows the details of the steering system. The head pipe is separated from the main frame, re-attached through the bearings to the main frame and provided with a new rotational axis (i.e., the rear-wheel steering axis). In addition, the front- and rear-wheel steering systems are connected to a ball joint through each steering arm and a connecting lever. In this way, the system can determine the

steering angle of the rear wheel proportionally to the steering angle of the front wheel.

Table 1. Main Specifications

Total Length	2580mm
Total Width	1095mm
Total Height	1125mm
Wheel Base	1715mm
Displacement	1854cm ³
Caster	31°
Trail	152mm
Dry Weight	347kg

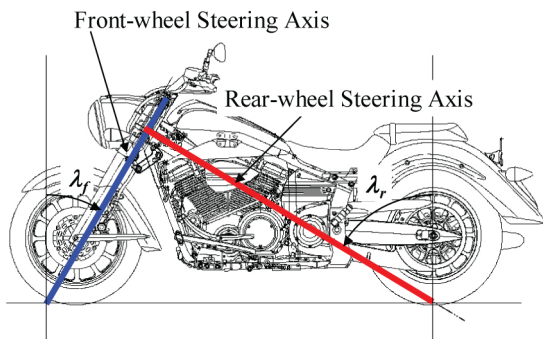


Fig. 1. Outline of Motorcycle with 2WS System

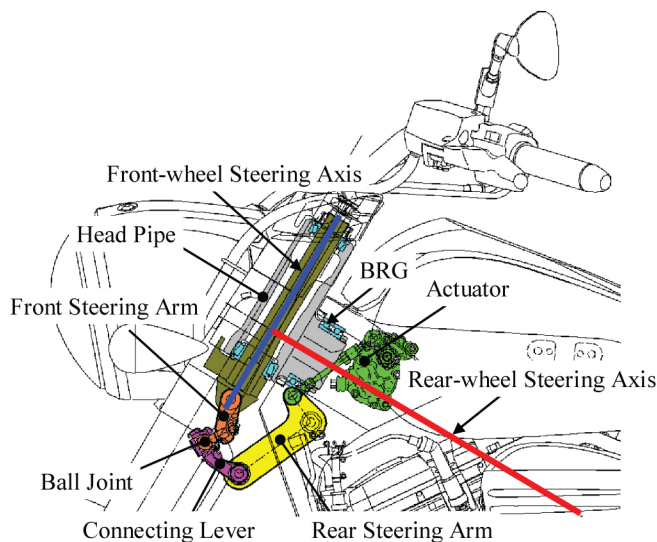


Fig. 2. Details of 2WS System

CONNECTION OF FRONT- AND REAR-WHEEL STEERING

Figure 3 shows a pattern diagram of the steering connection of the front and rear wheels through the link mechanism. The front- and rear-wheel steering axes are almost perpendicular and form the Z_s and X_s axis,

respectively. In the diagram, a and b denote the distances between the ball joint and the front- and rear-wheel steering axis, respectively.

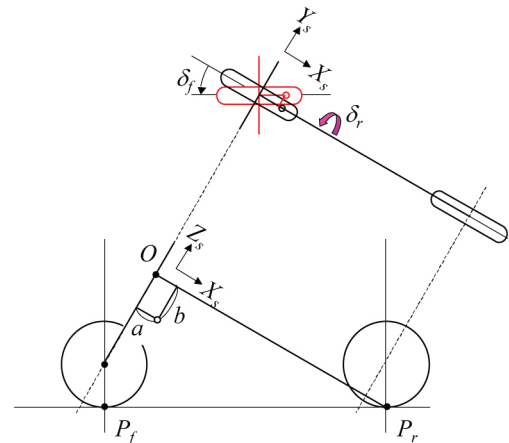


Fig. 3. Pattern Diagram of 2WS System

If the front wheel is steered to the left, generating steering angle δ_f , the ball joint moves by $a \cdot \delta_f$ to the right due to the action of the link mechanism. Then, at the same time, the rear-wheel steering axis also rotates by δ_r . Equation (1) shows the relationship between the front-wheel steering angle δ_f and the rear-wheel steering angle δ_r .

$$a \cdot \delta_f = b \cdot \delta_r \quad (1)$$

Since the steering angles of the front and rear wheels face opposite directions in this coordinate axis, steering ratio k is defined by Equation (2).

$$k = -\frac{\delta_r}{\delta_f} = -\frac{a}{b} \quad (2)$$

As shown in Fig. 4, when the connection point is located behind the front-wheel steering axis (the same condition as shown in Fig. 3), the steering ratio k is smaller than 0, which results in the front- and rear-wheel slip angles facing opposite directions at the ground points. This is referred to as opposite-phase steering.

In contrast, when the connection point is located in front of the front-wheel steering axis as shown in Fig. 5, the steering ratio k becomes larger than 0 because a is smaller than 0. In this condition, the front- and rear-wheel steering angles face in the same direction. This is referred to as same-phase steering.

Furthermore, when the connection point is located on the front-wheel steering axis as shown in Fig. 6, the steering ratio k becomes equal to 0 because a is equal to 0. In this case, no rear-wheel steering angle is generated, in the same way as a conventional motorcycle. This is referred to as neutral steering.