Analysis of Combined Braking System (CBS) on Two-Wheelers

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ABSTRACT

Brake systems for motorcycles are available in many different designs with different technical solutions. Beginning with a conventional brake system with two independent circuits, a CBS system can be added to improve safety and stability. A combined brake system can be created to enhance safety and comfort by establishing a hydraulic connection between the front brake control and the rear caliper or vice versa. The Motorcycle Integral Brake System MIB, which was introduced to the market in 2006, provides motorcycle manufacturers with the possibility to realize any combined integral functionality characteristic. In addition, the pressure in each brake circuit can be built up actively independently of any rider input, so that the system reacts appropriately in any riding situation. Integral brake functions can be adapted to the philosophy of the motorcycle manufacturer, and many additional functions which were impossible until now can be incorporated. This paper describes the Motorcycle integral Brake system using the controlled braking system (CBS) with the distributed braking forces to increase safety, its operating principles compared with other brake systems, and its various hydraulic and functional possibilities.
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1. **INTRODUCTION**

To provide a front wheel and rear wheel interlocking brake system having a simple structure, which is capable of automatically performing brake control of the front and rear wheels on the basis of the running state of the motorcycle. A front wheel and rear wheel interlocking brake system is provided for a motorcycle in which a front wheel brake and a rear wheel brake, each being hydraulically operated, are provided on a front wheel and a rear wheel, respectively. The brake system includes a front wheel side actuator for applying a hydraulic pressure to the front wheel brake. A rear wheel side actuator is provided for applying a hydraulic pressure to the rear wheel brake. At least one operating member is operated by a driver. An operated amount detecting member is provided for detecting the operated amounts of each brake operating member. A control member is provided for receiving and calculating each of operated amounts detected by each operated amount detecting member. An outputting drive control signals to the front wheel side actuator and the rear wheel side actuator on the basis of the calculated result. In this brake system, the control member performs brake control for single brake control for singly driving either the front wheel brake or the rear wheel brake and interlocking brake control for driving the front and rear wheel brakes in accordance with a specific braking force distribution characteristic, and causes control to switch between single brake control and interlocking brake control on the basis of the operated amounts detected by the first and second pressure.

The reason to this development is the end consumer’s desire for continuous improvements in comfort, riding pleasure, safety and mostly Affordability. Active Brake force Distribution (ABD) is responsible for the appropriate distribution of the rider’s braking command to both wheels. This is carried out in interaction with the brake pressure directly applied by the rider hydraulically via the two actuating controls, whereby the individual distributions, from the hand lever to the rear wheel and from the foot lever to the front wheel are realized using software. The basic characteristic can be based on the ideal braking force distribution and then adapted to suit the situation. Here, input variables such as vehicle speed, as well as signals that describe the rider braking profile are used.
This means that the influence of the rear wheel brake can be reduced at very low speeds in order to achieve ideal handling. For example, looking at the rear brake:

![Graph showing ABD rear-to-front relationship](image)

Vehicle speed, motorcycle and brake system, actual profile

This system can be very impressive and almost perfect but there are possible errors that would include safety if the electric systems malfunction and the price tag of this technology is big for the market.

Therefore, the main aim of this project is to make the ABD system become possible using Controlled Braking System by distributing the pressure that a that is released to the cylinders of the rear and front buy pulling one lever.
2. BACKGROUND

2.1 Combined Braking System

A combined braking system (CBS), also called linked braking system (LBS), is a system for linking front and rear brakes on a motorcycle or scooter. In this system, the rider's action of depressing one of the brake levers applies both front and rear brakes. The amount of each brake applied may be determined by a proportional control valve.

It’s a system that has been in place since the early days of automobile design: simultaneous actuation of the front and rear brakes. However, in motorcycles this is not the case; from early models on to many of today’s most modern machines, the front and rear brakes continue to be actuated by separate controls. For several decades now, Honda has introduced multiple systems that synchronize front- and rear-wheel braking.

2.2 Examples

In most companies that are trying to develop the use of CBS in day to day two wheelers, they have the same aim of developing the brake is to secure a high effect with good control. It is necessary to achieve the goal to improve three areas which are controllability, convenience and confidence for the average rider. With respect to controllability, at first the improvement of conventional brake systems can be cited, which will include the development of a disk brake system for motorcycles for the first time in the world and the development of sintered friction materials. In regards to convenience, the second area, they begun the development of a combined brake system CBS ahead of others and are now tackling the task of an easier way of distributing braking force between the front and rear wheels. This is related to the improvement of controllability mentioned in the beginning. As for the enhancement of the sense of confidence, the third, they aim at preventing wheel lock up.

One example of a company that is aiming high with the development of CBS is Honda and they made a few models were manufactured and put to market in several years.
Combined Braking System Scooter Models From Honda

**Electric**

EV-neo

**50cc**

BeAT, Dio Cesta, Giorno, NFS50 Today, NSC50 Dio, Vison, Scoopy i

**100cc**

SCR100 Seaside 100,

**110cc**

Air Blade, Benly, Benly 110, NCS110 Dio 110, SCR110, SCV110, Zoomer-X

**125cc**

CHA125, CHS125 Fizy, Click, Joying, Lead EX, NHX125 Lead 125, PCX125, PS125i, SC125 Fuma, SCV125, SH125i, Sh-mode, Stream

**150cc**

PES150, SH150i

**300cc**

NSS300 Forza

Honda PCX150 (150cc) using CBS
2.3 **Laws Regarding Necessity of CBS in two wheelers.**

In many countries, the law requires a motorcycle to have two separate braking systems. The justification for Combined braking systems is that, compared to cars, a motorcycle has, proportionately, a higher center of gravity, a shorter wheelbase, a higher power-to-weight ratio, and a smaller tire contact patch area. All these factors lead to a much greater weight transfer to the front wheel on braking, and a greater risk of skidding. But if the rider only brakes with the front or rear wheel, the braked wheel tends to lock up faster as if both brakes would have been applied and a CBS system seeks to further reduce any skid risk.

The Ministry of Transportation and Communication announced amendments to vehicle safety regulations that would make anti-lock braking systems ABS for motorcycles compulsory, starting in 2019. The amendment represented a breakthrough for the ECCT’s Automotive committee as it follows the recommendation made in its position paper based on strong evidence that fitting ABS can improve safety considerably. According to the amendment, starting in 2019, it will be mandatory to fit an ABS to all new models of motorcycles that have an engine displacement greater than 125cc, fit either an ABS or a combined braking system (CBS) to all new models of motorcycles that have an engine displacement equal to or smaller than 125cc. The terms of the amendment are exactly in line with European regulations.

Members of the ECCT’s Automotive committee welcomed the government’s action as an important step that would help to improve traffic safety and reduce traffic accidents and fatalities. The MoTC’s decision was made after reviewing evidence on the effectiveness of ABS from Europe that ABS can reduce motorcycle accidents. Statistics from Spain and Sweden showed that fitting ABS can reduce injuries by between 29% and 42%. The amendment is especially significant for **Taiwan** given the high number of motorcycles on the roads and that motorcycle accidents account for more than 60% of vehicle accident fatalities.
2.4 Matlab

This is a multi-paradigm numerical computing environment and fourth-generation programming language. A proprietary programming language developed by MathWorks. Matlab allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, Fortran and Python.

Matlab is intended primarily for numerical computing and optional toolbox uses the Mu-PAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

It was first used by researchers and practitioners in control engineering, Little's specialty, but quickly spread to many other domains. It is now also used in education, in particular the teaching of linear algebra, numerical analysis, and is popular amongst scientists involved in image processing.

The Matlab application is built around the Matlab scripting language. Common usage of the Matlab application involves using the Command Window as an interactive mathematical shell or executing text files containing MATLAB code.

Variables are defined using the assignment operator. Matlab is a weakly typed programming language because types are implicitly converted.[8] It is an inferred typed language because variables can be assigned without declaring their type, except if they are to be treated as symbolic objects,[9] and that their type can change. Values can come from constants, from computation involving values of other variables, or from the output of a function.
Here is a simple example of how Matlab operates.

```matlab
>> x = 17
x =
17

>> x = 'hat'
x =
hat

>> y = x + 0
y =
104 97 116

>> x = [3*4, pi/2]
x =
12.0000 1.5708

>> y = 3*sin(x)
y =
-1.6097 3.0000
```

Vectors and matrices can also be computed for example

```matlab
>> array = 1:2:9
array =
1 3 5 7 9
```

This defines a variable named array, or assigns a new value to an existing variable with the name array, which is an array consisting of the values 1, 3, 5, 7, and 9. That is, the array starts at 1, increments with each step from the previous value by 2, and stops once it reaches (or to avoid exceeding) 9.

Or

```matlab
>> ari = 1:5
ari =
1 2 3 4 5
```

Matlab functions can accept matrices and will apply themselves to each element. For
example, \( \text{mod}(2 \times J, n) \) will multiply every element in "J" by 2, and then reduce each element modulo "n". Matlab does include standard "for" and "while" loops, but (as in other similar applications such as R), using the vectorized notation often produces code that is faster to execute. This code, excerpted from the function magic.m, creates a magic square \( M \) for odd values of \( n \), Matlab function meshgrid is used here to generate square matrices \( I \) and \( J \) containing \( 1:n \).

For example

\[
\begin{align*}
&[J,I] = \text{meshgrid}(1:n); \\
&A = \text{mod}(I + J - (n + 3) / 2, n); \\
&B = \text{mod}(I + 2 \times J - 2, n); \\
&M = n \times A + B + 1;
\end{align*}
\]

Matlab has structure data types. Since all variables in Matlab are arrays, a more adequate name is structure array, where each element of the array has the same field names. Matlab supports dynamic field names, field look-ups by name, field manipulations. When creating a Matlab function, the name of the file should match the name of the first function in the file. Valid function names begin with an alphabetic character, and can contain letters, numbers, or underscores. Functions are also often case sensitive.

Matlab supports object-oriented programming including classes, inheritance, virtual dispatch, packages, pass-by-value semantics, and pass-by-reference semantics. However, the syntax and calling conventions are significantly different from other languages. Matlab has value classes and reference classes, depending on whether the class has handle as a super-class, for reference classes or not for value classes.

For example, to call classes;

```matlab
classdef hello
    methods
        function greet(this)
            disp('Hello!')
        end
    end
end
```
Since Matlab supports developing applications with graphical user interface (GUI) features, Matlab includes GUIDE (GUI development environment) for graphically designing GUIs. It also has tightly integrated graph-plotting features. For example, the function plot can be used to produce a graph from two vectors x and y which can be used to test the CBS system to check the results.

Simple example:

```matlab
x = 0:pi/100:2*pi;
y = sin(x);
plot(x,y)
```

Due to its complexity, Matlab is a proprietary product of MathWorks and can also be used functions as library files which can be used with Java application building environment, future development like the, CBS system which is becoming a Mandatory in most countries for two wheelers, will still be tied to the language.
2.5 BikeSim

BikeSim delivers the most accurate, detailed, and efficient methods for simulating the performance of two-wheeled vehicles. With more than twenty years of real-world validation, BikeSim is universally the preferred tool for analyzing motorcycle dynamics, developing active controllers, calculating overall system performance, and engineering next generation active safety systems.

With manufacturers facing compressed product release cycles, BikeSim provides an intuitive set of tools for engineers to quickly evaluate complete motorcycles, sub-components, and active controllers in complex, simulated driving environments. As more companies and motorsports organizations embrace simulation based engineering, BikeSim provides a system-based modeling approach to help users focus on their area of expertise while keeping the rest of the simulation environment constant.

**Advantages of Using BikeSim**

The main reason why the system calculations were made using Matlab/Simulink in testing the CBS was because BikeSim has a standard interface to MATLAB/Simulink. This means the results could be plugged into the BikeSim and the produce all the data results of the performance of the CBS.

BikeSim is a standalone application. This means that it does not require any other software to perform simulations. Adjustments can be made using the software itself and it brings accurate results of all animations or graphically. It is used extensively by seven of the largest motorcycle OEMs proving it’s reliability.

BikeSim allows users to build complex scenarios and test event sequences. It also can scale Software in the loop, Model in the loop, Driver in the loop And use driver in the loop. BikeSim has an intuitive user interface and powerful analysis tools that make it possible to analyze CBS performance.

We use BikeSim because it includes numerous example vehicles which lets us test the various types of motorcycles using the CBS, roads that allow us to test different braking scenes of day to day driving with the CBS system, and procedures to assist first-time users like the already programed models that can be adjusted also, a help manual that is easy to
understand for the project. BikeSim is economical in comparison to other commercial vehicle dynamics software tools.

Main advantage to the CBS system project is that BikeSim includes Linearization capabilities that can be used with MATLAB to generate Eigenvalues, root locus plots, frequency-response plots. This way, we can produce data from the CBS using Matlab solutions.

This is a basic example of what BikeSim can looks like.
3. METHODOLOGY

Using solid works, a Brake Cylinder will be constructed, and using Matlab, the results will then be used in BikeSim, that will have the rear and the front lever of the motorcycle applying pressure to it. The Front to rear distribution for most motorcycles with this system is 2:1, but the new design will use 1:1 due to the use of hydraulic fluid compared to most systems that use the rear as linked. The 1:1 pressure theoretically is supposed to be 2:1 still due to the difference in size of the disks. The rear the motorcycle has a smaller disk therefore the power of the brake is mostly in the front. C.B.S braking analysis front wheel braking pressure could rise up to 40 bar = 4Mpa
3.1 **SIMULATIONS**

Simulation of **Disk Brake** system with CBS

**Braking force**
- Brake piston area, Front : Rear = 70:30
- \( \text{Force} = \text{Pressure} \times \text{Area} \)
- Given, \( P_f = P_r \)
- Therefore; Braking force,
  - Front : Rear = 70:30

The braking force used in the simulation is more in the front. Balance crucial to a motorcycle’s dynamics, and that’s why most bikes have individual front and rear brake controls. Mostly, it is agreed that roughly 70% of braking effort should go to the front wheel (which uses the hand lever on the right grip), and 30% to the rear (which is operated by the right foot pedal.) Front brakes require more effort because weight transfer from slowing down will shift the bike’s balance from the rear wheel to the front, enabling the front tire to handle more load. When there’s less down force on the rear tire, it becomes much easier to lockup and slide that wheel, resulting in a loss of control.
In the test, the delay function was to avoid a common mistake in Emergency braking. Stopping hard causes a skid. On top of that, enough on the fronts might even lift the rear wheel up. For safety reasons, delay is applied in the test.

**Function of Delay**

- Delay avoid the actuation of front brakes when small amount of rear brake is applied.
- Prevents the nose flipping and improper use of front brake.
- Delay helps provide a proper **70:30** (front : rear) braking force distribution in normal or emergency braking situations.

**Simulation Constraints**

**Type of motorcycles used for analysis:**
1. Big Scooter
2. Sports Bike
3. Cruiser
4. Touring bike

**Braking Method:**
1. **Slow braking:** 50N Rear and 120N Front at 0.2s (no throttle, 4th gear)
2. **Emergency Braking:** 50N Rear and 120N at 5s (no throttle, 4th gear)
The 70:30 braking ratio can shift slightly based on the type of bike being tested. **Cruisers** and **touring bikes** can handle more rear braking because they carry more weight over their rear wheel due to the rearward position of the saddle just like **scooters**, while **sport bikes** can tolerate higher front braking effort since their forks are more vertical and their wheelbases are shorter.
The scooters have the engine and transmission in the rear end and the weight can be balanced by the rider whose weight is by testing regulation 75 Kg. This has a slight effect on the stopping distance on all the motorcycles so various types of motorcycles had to be tested using the BikeSim. This is the reason why the Matlab results will be used on several types of motorcycles, as stated above.

**Big Scooter**

![Big Scooter simulation](image)

This shows the forces being applied on the front and rear tires when braking.
Big scooter pressure

The Blue line shows the pressure that was exerted in the Front brake chamber and the Red line shows the pressure in the Rear brake chamber.
The Blue line shows the Main Frame speed and the Red lines show the rear and front wheel speed.

→ Stopping distance is well about 2.615 seconds.
→ The Rear tire oscillation during braking is very low.
Sports Bike

Sports bike Simulation

![Graph showing force over time for different tire forces.](image-url)
Sports Bike Simulation

![Graph showing pressure and speed over time for a sports bike simulation.](image)

- Pressure in MPa over time.
- Speed in km/h over time.
- Comparison of different braking systems and their effects on pressure and speed.
Cruiser

Cruiser simulation
Touring Bike

Touring Bike simulation
Simulation of DRUM Brake system with CBS

This simulation was done using the drum brake system and the model that was used was a 125cc Scooter to simulate most of the motorcyclist of Taiwan where the roads are mostly occupied by scooters.

This simulation was done using two ratios, **Front: Rear 5:5 distribution**, where the cylinder sends equal amount of force to the master cylinders. The second ratio was **Front: Rear 6:4 distribution** where the cylinder sends 60% to the front and 40% to the rear of the scooter.

A Simulink model was made to show the function of the drum system and the results were produced in a graph form. Then the results are plugged into the BikeSim where the performance of the CBS can be seen.

- Weight taken from front wheel = 39.5kg
- Weight taken from rear wheel = 56.2 kg
- Total length of scooter =1690mm
- By taking mean average of the weight to length, center of mass is assumed to be around 850mm.

→ Scooter simulation with drum brakes
Drum brake Simulink Results

Simulink summary

The maximum brake force that can be generated on application of drum brakes are a compound of the force applied on the lever, the mechanical advantage offered by the connecting linkages and a function of the shoe efficiency. The schematic below shows the setup of drum brakes in motorcycles.

\[ T = T_T + T_L \]

Where:
- \( T \): torque (ft.-lb.)
- \( T_T \): torque for trailing shoe
- \( T_L \): torque for leading shoe
- \( K \): function of the angle of contact
- \( \mu \): coefficient of friction for brake lining
- \( F \): applied force
- \( a \): distance between shoe anchor and wheel cylinder
- \( r \): drum radius
- \( b \): distance between shaft and shoe pins
- \( c \): distance from anchor pin to fulcrum
- \( \theta \): angle of shoe engagement

\[ T_T = \frac{K \mu F a r}{(b + K \mu c)} \]

\[ T_L = \frac{K \mu F a r}{(b - K \mu c)} \]

\[ K = \frac{4 \sin \theta}{(2 \theta + \sin 2 \theta)} \]
Using the Simulink Model in Bikesim simulator, the standard ECE standard were used for Comparison purposes
Rider weight was 75Kg (as per ECE standard)
Brake actuation force = 200N
Initial vehicle speed= 60km/h (as per ECE standard)

**Required stopping distance**
Vehicles with Drum CBS or split service brake systems are laden and lightly loaded conditions due to the size of the drum compared to the light disk brake.

**STOPPING DISTANCE** ($S$), $S \leq 0.1 V + 0.0076V^2 \iff S \leq 33.36m$
Settings for Slow Progressive Braking in BikeSim.

200N on lever increases to 800N to cable and then further distributed as 400N to front and 400N to rear by the CBS system.
The **wheel speed** results were produced by the simulation results of Front: Rear 6:4 in the form of a graph.
CBS distribution of 6:4

The Stopping Distance results were produced by the simulation results of Front: Rear 6:4 in the form of a graph.
Time by distance
Results of CBS distribution of 6:4

Stopping distance = 27.2m
Stopping time = 2.56 sec

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Distance to velocity data table
CBS distribution of 5:5

200N on lever increases to 800N to cable and then further distributed as 400N to front and 400N to rear by the CBS system

Using Same Variables as 6:4

The **wheel Speed** results were produced by the simulation results of Front: Rear 5:5 in the form of a graph

![Wheel speed graph (speed by time)]
The **Stopping Distance** results were produced by the simulation results of Front: Rear 5:5 in the form of a graph.
4. Results

Result of CBS distribution of 5:5 and 6:4

Using brake distribution of 5:5
- Stopping distance = 28.9985 m
- Stopping time = 2.975 sec

Using brake distribution of 6:4
- Stopping distance = 27.2m
- Stopping time = 2.56 sec
5. Conclusion

With conventional motorcycles, one of the core fundamentals of riding is being able to independently control the front and rear brakes in a well-balanced manner. However, this can be more difficult than one might expect. To what extent braking force should be applied to maintain that optimum balance between front and rear wheels largely depends on long hours of actual riding experience. Since the Combined Brake System puts these basics of braking control into astoundingly easy reach. The brakes can be used in a much more relaxed manner.

Keep in mind, however, that rider who start out on bikes equipped with Combined Brake System, and never have much experience riding other motorcycles, may mistakenly take such superb braking capabilities for granted.

The advantage of combined brakes is that the rider can control brake bias between front and rear wheels, within the limits of the system. At speed, combined brakes help balance braking between front and rear, making front trail braking in corners more predictable. At slow speeds, trailing the rear brake helps control speed without bringing the bike to a sudden stop.

The potential problem with combined brakes; it can promote a dependence on the rear brake. Most all combined brake systems use only a portion of the bike's front brakes when the rear brake pedal is pressed. These days most bikes have multi-piston front brake calipers, such as calipers with two or three pistons per caliper. On the combined brake function, when the rear brake pedal is pressed, usually only one piston of each front brake is applied, no matter how hard the rear brake pedal is applied. This is done to enhance bike stability during braking, especially if the rider tromps on the rear brake. So if the rider only uses the rear brake pedal, or never fully develops the capability to really use the front brake, that rear brake dependency limits the amount of braking capability in an emergency stop. If the bike also has ABS it will do nothing at that point to reduce the stopping distance if the front brakes are underutilized. And with that should be proper skilled use of the rear brake. In a panic or emergency stop, that means using ALL the front brake that traction will allow, and limiting use of the rear brake to maintain bike stability.
References.

https://www.carsim.com/products/bikesim/
http://www.google.com/patents/US5257856#backward-citations
https://www.carsim.com/products/bikesim/
A brake system is disclosed. The brake system includes a front brake, a rear brake, a right brake lever for operating the front brake, and a left brake lever for operating the rear brake. The brake system also includes a brake pedal for operating the front brake and rear brake such that the front brake and rear brake work in an interlocked manner.
The present invention provides a straddle type vehicle brake system that allows the front and rear brakes to work in an interlocked manner and also allows the brakes to be actuated independently.

A straddle type vehicle brake system according to an embodiment of the present invention includes: a front brake; a rear brake; a front brake operating device for operating the front brake; a rear brake operating device for operating the rear brake; and an interlocking brake operating device for operating the front and rear brakes such that the front and rear brakes work in an interlocked manner.

The straddle type vehicle brake system according to the embodiment of the present invention includes, as separate components, a front brake operating device for operating the front brake, a rear brake operating device for operating the rear brake, and an interlocking brake operating device for causing the front and rear brakes to work in an interlocked manner. This will allow the front and rear brakes to work in an interlocked manner and also allow them to be operated independently.

BRIDÉ DESCRIPTION OF THE DRAWINGS

FIG. 1 is a left side view of the overall construction of a motorcycle according to Embodiment 1.

FIG. 2 is a perspective view of the right brake lever and other components as viewed from the side of the vehicle.

FIG. 3 is a schematic view of the overall construction of a brake system.

FIG. 4 is a perspective view of the right brake lever and other components.

FIG. 5 illustrates the brake pedal and other components as viewed from the side of the vehicle.

FIG. 6A is a schematic view of the load application unit.

FIG. 7 illustrates how the load application unit can be operated when the front brake wire is pulled.

DESCRIPTION OF THE EMBODIMENTS

Now, embodiments will be described with reference to the drawings. The dimensions of the components shown in the drawings do not exactly represent the dimensions of the actual components or the size ratios of the components.

In the description below, “front/forward”, “rear/rearward”, “left” and “right” mean directions as perceived by a rider holding the handlebars and sitting on the seat of the motorcycle.

Embodiment 1

In the arrangement described in JP Hei9(1997)-58434A, it is possible to actuate the front brake alone. However, the rear brake may be actuated together with the front brake in an interlocked manner and cannot be actuated alone.

There is a need among riders to actuate the rear brake alone according to road conditions, vehicle travel conditions or the like to control the position of the vehicle or lock the rear wheel. As discussed above, the arrangement described in JP Hei9(1997)-58434A does not allow the rear brake to be actuated alone and thus does not address that need.
The vehicle body 2 includes a body frame 11 (chassis), a body cover 5, handlebars 12 and a power unit 13. The vehicle body 2 further includes a brake system 6, discussed below.

As shown in FIG. 2, the body frame 11 includes a pair of main frames 21, a pair of down frames 22 and a head pipe 23. The head pipe 23 is located in a front portion of the motorcycle 1. The main frames 21 extend rearward and downward from the head pipe 23. The down frames 22 extend downward from a position on the head pipe 23 that is located forward of the main frames 21. In FIG. 2, arrow “F” indicates the forward direction with respect to the motorcycle 1, arrow “R” the rearward direction with respect to the motorcycle 1, and arrow “L” the left direction with respect to the motorcycle 1.

A steering shaft 24 is located in the head pipe 23. Above the steering shaft 24, the handlebars 12 are rotatably connected with the head pipe 23. A pair of front suspension legs 25 (see FIG. 1), located parallel to each other, are connected with the steering shaft 24. As shown in FIG. 1, the front wheel 3 is rotatably attached to the lower ends of the front suspension legs 25.

The body frame 11 with the above arrangement is covered with the body cover 5. The body cover 5 may be made of a resin material, for example. As shown in FIG. 1, the body cover 5 includes a foot board 91 located in a lower portion of the vehicle, a front cover 92 located in a front portion of the vehicle, a handle cover 93 covering the handlebars 12, and the side covers 94 located on the sides of the vehicle.

A front brake 31 including a hydraulic disc brake, for example, is provided on the front wheel 3. The front brake 31 includes a brake disc 32 and a caliper 33. The brake disc 32, together with the front wheel 3, is rotatably supported by the lower ends of the front suspension legs 25. Although not shown, the caliper 33 is attached to portions of the front suspension legs 25 and includes, in its interior, brake pads for pressing together the brake disc 32 in a thickness direction of the disc. The brake pads are pressed against the brake disc 32 by a hydraulic pressure transferred by a hydraulic hose 34 (see FIG. 3). This action generates a braking force for the front wheel 3.

As shown in FIG. 3, the hydraulic hose 34 is connected with a master cylinder 52, discussed below, and transfers to the front brake 31 a hydraulic pressure generated by the master cylinder 52 as the brake pedal 70 or right brake lever 50 is operated, as discussed below.

As shown in FIG. 2, a right grip 12a is provided on the handlebars 12 and is located forward of and to the right of a rider sitting on the seat, while a left grip 12b is located forward of and to the left of the rider. Further, a right brake lever 50 that serves as the front brake operating device is provided on the handlebars 12 near the right grip 12a, while a left brake lever 60 that serves as the rear brake operating device is provided near the left grip 12b.

The right brake lever 50 is rotatably supported on a connection member 51, which is attached to the handlebars 12 adjacent to the right grip 12a (see FIG. 4). Thus, the right brake lever 50 is rotatably supported on the handlebars 12 about a point on one end of the right brake lever 50. The structure of the right brake lever 50 will be detailed below. The left brake lever 60 has a similar structure to that of the right brake lever 50 and thus its description will not be given.

As shown in FIG. 2, a brake pedal 70 (interlocking brake operating device) is attached to one of the down frames 22. The brake pedal 70 may be attached to the one of the down frames 22 that is located at the right foot of a rider sitting on the seat, for example. The brake pedal 70 is rotatably supported on a support member 71 that is fixed to that down frame 22. Although not shown, the brake pedal 70 is located to penetrate the foot board 91 of the body cover 5. In other words, the top of the brake pedal 70 is exposed above the foot board 91.

A front brake wire 74 and a rear brake wire 75 are connected with the brake pedal 70 via a wire coupling member 81 of an equalizer 80, as discussed below (see FIGS. 3 and 5). Thus, the rider may cause the front and rear brakes 31 and 41 to work in an interlocked manner by kicking on the brake pedal 70. The structure of the brake pedal 70 will be detailed below.

As shown in FIG. 1, the power unit 13 is located between the body frame 11 and rear wheel 4. The power unit 13 includes an engine 13a, driving force transmission 13b, and other components. The engine 13a may be a unit-swing engine, for example, where the engine may swing in a top-to-bottom direction together with the rear wheel 4 relative to the body frame 11. The driving force transmission 13b for transmitting to the rear wheel 4 a driving force output from the engine 13a is located rearward of the engine 13a with respect to the vehicle. In other words, in the power unit 13, the engine 13a is located toward the front with respect to the vehicle, while the driving force transmission 13b is located toward the rear with respect to the vehicle. A rear brake 41 is located inward of the driving force transmission 13b as measured in a vehicle width direction, i.e. located inward of a rear portion of the power unit 13 as measured in a vehicle width direction. In the present embodiment, the driving force transmission 13b includes a continuously variable transmission that does not utilize clutch operations.

Similar to the front brake 31 described above, the rear brake 41 includes a hydraulic disc brake, for example. That is, as shown in FIG. 3, the rear brake 41 similarly includes a brake disc 42 and a caliper 43. Together with the rear wheel 4, the brake disc 42 is rotatably supported by a swing arm, not shown. The caliper 43 may have a similar structure to that of the caliper 33 of the front brake 31 and thus its description will not be given.

Next, the structure of the brake system 6 (straddle type vehicle brake system) provided in the motorcycle 1 including the front and rear wheels 3 and 4 will be described in detail with reference to FIGS. 3 to 5 and 6A and 6B. In FIG. 4, arrow “F” indicates the forward direction with respect to the motorcycle 1, and arrow “R” the rearward direction with respect to the motorcycle 1. In FIG. 5, arrow “U” indicates the upward direction with respect to the motorcycle 1, and arrow “F” the forward direction with respect to the motorcycle 1. In FIGS. 6A and 6B, arrow “F” indicates the forward direction with respect to the motorcycle 1, and arrow “B” the rearward direction with respect to the motorcycle 1.

As shown in FIG. 3, the brake system 6 includes a front and rear brakes 31 and 41. The front brake 31 only applies a braking force to the front wheel 3. The rear brake 4 only applies a braking force to the rear wheel 4. The brake system 6 further includes a rear brake lever 50 for actuating only the front brake 31, a left brake lever 60 for actuating only the rear brake 41 and a brake pedal 70 for causing the front
and rear brakes 31 and 41 to work in an interlocked manner. As discussed below, the left brake lever 60 for actuating only the rear brake is located in a position different from that of the brake pedal 70. That is, the left brake lever 60 is located in one of the positions where the rider can operate the vehicle. The brake pedal 70 is located in one of these positions that is different from that of the left brake lever 60.

As shown in FIGS. 3 and 4, a master cylinder 52 is located near the right brake lever 50. More specifically, as shown in FIG. 4, the master cylinder 52 is provided on the handlebars 12 and is located closer to the center of the vehicle than the right brake lever 50. The master cylinder 52 includes a cylinder 52a and a piston 52b located inside the cylinder 52a, both indicated by the broken lines in FIG. 4. The piston 52b of the master cylinder 52 may be configured to move inwardly with respect to the cylinder 52a as the right brake lever 50 is operated, for example. The master cylinder 52 may have a typical structure and thus its detailed description will not be given.

As shown in FIG. 3, the master cylinder 52 is connected with the caliper 33 of the front brake 31 via hydraulic hose 34. In other words, a change in the hydraulic pressure inside the master cylinder 52 is transferred to the caliper 33 of the front brake 31 via the hydraulic hose 34. Thus, when the right brake lever 50 is operated, for example, to push the piston 52b inside the master cylinder 52 inwardly with respect to the cylinder 52a, the change in the hydraulic pressure in the master cylinder 52 is transferred to the caliper 33 of the front brake 31 via the hydraulic hose 34. When the hydraulic pressure increases, the caliper 33 works to press the brake disc 32 together. Thus, the front brake 31 may be actuated by operating the right brake lever 50, for example.

The structure of the right brake lever 50 and other components will be detailed below.

As shown in FIGS. 3 and 4, a pressing member 53 is provided between the right brake lever 50 and master cylinder 52 for pressing the piston 52b of the master cylinder 52. Similar to the right brake lever 50, the pressing member 53 is rotatably supported on the connection member 51 (see FIG. 4). More specifically, the pressing member 53 is rotatable about a point on the connection member 51 coaxially with the right brake lever 50. Thus, the right brake lever 50 and pressing member 53 may be rotated about a point on the connection member 51, as indicated by the corresponding arrows in FIGS. 3 and 4.

The pressing member 53 includes a supported portion 53a that is rotatably supported by the connection member 51. The pressing member 53 is shaped to extend from the supported portion 53a toward the handlebars 12. In other words, the pressing member 53 extends to cross the handlebars 12. The pressing member 53 includes, toward the end opposite of that with the supported portion 53a (e.g., the end closer to the handlebars 12), a pressing portion 53b for pressing the piston 52b of the master cylinder 52 and a wire connecting portion 53c connected to the front brake wire 74, described below.

As the wire connecting portion 53c is pulled toward the center of the handlebars 12 by the front brake wire 74, the pressing member 53 with the above arrangement is rotated about a point on the supported portion 53a along a vehicle width direction, as indicated by the arrow in FIG. 4, such that the pressing portion 53b presses the piston 52b of the master cylinder 52. This causes a change in the hydraulic pressure in the master cylinder 52 such that this change in the hydraulic pressure is transferred to the caliper 33 of the front brake 31 via the hydraulic hose 34.

Further, the pressing member 53 includes a contact portion 53d for contacting the right brake lever 50 when the right brake lever 50 is operated. The contact portion 53d contacts the right brake lever 50 when the right brake lever 50 is operated. In the pressing member 53, the contact portion 53d is located closer to the handlebars 12 than the supported portion 53a so as to rotate the pressing member 53 about a point on the supported portion 53a. As the right brake lever 50 is operated, the pressing member 53 having the above-described contact portion 53d is rotated about a point on the supported portion 53a such that the pressing portion 53b presses the piston 52b of the master cylinder 52. This causes a change in the hydraulic pressure in the master cylinder 52 such that this change in the hydraulic pressure is transferred to the caliper 33 of the front brake 31 via the hydraulic hose 34.

As such, the front brake 31 may be actuated when the front brake wire 74 is pulled or when the right brake lever 50 is operated.

As shown in FIG. 3, a master cylinder 62 is provided for the left brake lever 60, similar to the right brake lever 50, adjacent to the left brake lever 60. The master cylinder 62 may have a structure similar to that of the master cylinder 52 described above and is connected with the rear brake 41 via a hydraulic hose 44. The structure and operation of the master cylinder 62 will not be given.

A pressing member 63 is provided adjacent to the left brake lever 60. The structure and operation of the pressing member 63 are similar to those of the pressing member 53 described above and thus their description will not be given. The rear brake 41 is actuated when the rear brake wire 75 is pulled or when the left brake lever 60 is operated. That is, at least a portion of an operating force generated as the brake pedal 70 is operated, as discussed below, is transferred to the rear brake 41 via the rear brake wire 75, and an operating force generated as the left brake lever 60 is operated is transferred to this brake. In FIG. 3, character 63a designates a supported portion of the pressing member 63, character 63b designates a pressing portion of the pressing member 63, and character 63c designates a wire connecting portion of the pressing member 63.

Next, the structure of the brake pedal 70 will be described with reference to FIGS. 3, 5, 6A and 6B.

As shown in FIG. 5, the brake pedal 70 includes an arm 70a that is bent in an L shape as a whole, and a pedal 70b provided on one end of the arm 70. The pedal 70b is located above the foot board 91. On the other end of the arm 70a inside the foot board 91 is provided a supported portion 70c that is rotatably supported on a supporting member 71 on a down frame 22. The brake pedal 70 has a bent portion located toward the front with respect to the vehicle and is rotatable about a point on a supported portion 70c supported by the supporting member 71.

A projection 70d that protrudes downward with respect to the vehicle is provided on the other end of the arm 70a, which has the supported portion 70c. A wire coupling member 81 in the equalizer 80, discussed below, is rotatably attached to the projection 70d. On the other end of the arm 70a is provided a connecting portion 70e, which protrudes rearward with respect to the vehicle and to which one end of a spring 72 is attached. The spring 72 is connected with one end of a bracket 73, which has the other end attached to the down
frame 22. Thus, when the brake pedal 70 is operated to rotate forward with respect to the vehicle, the spring 72 biases the brake pedal 70 back to its original position.

[0054] The equalizer 80 (operating force dividing unit) includes the wire coupling member 81, to which the front and rear brake wires 74 and 75 are connected, and a load application unit 82 (timing adjusting unit) provided on the front brake wire 74. The equalizer 80 uses the wire coupling member 81 to divide the operating force received by the brake pedal 70 into an operating force for the front brake wire 74 and an operating force for the rear brake wire 75. The front brake wire 74 causes the master cylinder 52 and pressing member 53 to transfer an operating force in the form of a hydraulic pressure to the front brake 31. The rear brake wire 75 causes the master cylinder 62 and pressing member 63 to transfer an operating force in the form of a hydraulic pressure to the rear brake 41. That is, an operating force provided by the equalizer 80 is transferred to the rear brake 41 via the rear brake wire 75.

[0055] The wire coupling member 81 is a rectangular plate and is rotatably supported on the projection 70a of the brake pedal 70 at a point on the wire coupling member 81 that is closer to one end thereof as measured in a longitudinal direction than the center thereof as measured in a longitudinal direction. The front and rear brake wires 74 and 75 are connected with the respective ends of the wire coupling member 81 as measured in a longitudinal direction.

[0056] In the present embodiment, the front brake wire 74 is located above the rear brake wire 75 with respect to the vehicle. Thus, as the wire coupling member 81 is located to extend in a top-to-bottom direction with respect to the vehicle, the front brake wire 74 is connected with the upper end of the wire coupling member 81 with respect to the vehicle, while the rear brake wire 75 is connected with the lower end of the wire coupling member 81 with respect to the vehicle. The wire coupling member 81 is rotatably supported on the projection 70a of the brake pedal 70 at a point on the wire coupling member 81 that is located downward with respect to the vehicle, center thereof as measured in a longitudinal direction, e.g., located close to its connection with the rear brake wire 75.

[0057] Thus, when the brake pedal 70 is operated to be rotated toward the front of the vehicle, as indicated by the hollow arrow in FIG. 5, the rear brake wire 75, which is connected with a point on the wire coupling member 81 that is located closer to the projection 70a of the brake pedal 70, is pulled as the brake pedal 70 is rotated, as indicated by the corresponding solid arrow in FIG. 5. The wire coupling member 81 is rotated about a point on the projection 70a of the brake pedal 70, as indicated by the broken arrow in FIG. 5, by the reactive force of the front brake wire 74, which is connected to a point on the wire coupling member 81 that is far from the projection 70a.

[0058] The front and rear brake wires 74 and 75 are rotatably attached to the wire coupling member 81. More specifically, an end of each of the front and rear brake wires 74 and 75 has an annular connection, which is rotatably fitted into a circular hole formed in each end of the wire coupling member 81 as measured in a longitudinal direction. Thus, as the wire coupling member 81 is rotated about a point on the arm 70a of the brake pedal 70, the operating force of the brake pedal 70 is transferred to the front and rear brake wires 74 and 75 while the front and rear brake wires 74 and 75 remain in the same position as measured in a top-to-bottom direction and a left-to-right direction with respect to the vehicle.

[0059] The load application unit 82 is provided on the front brake wire 74. The load application unit 82 is configured to apply an initial set load to the front brake wire 74. More specifically, as shown in FIGS. 6A and 6B, the load application unit 82 includes a spirally-wound spring 83 (limiting member) located coaxially with the front brake wire 74 to surround the front brake wire 74. A guide 84 for containing the spring 83, and a piston 85 that is fixed to the front brake wire 74 and can be moved inside the guide 84. FIGS. 6A and 6B each show a cross-section of the guide 84 to show the interior structure of the load application unit 82.

[0060] The guide 84 is a cylindrical member with a bottom, and is located on the front brake wire 74. The guide 84 is fixed to a bracket 86 provided on a down frame 22 at one end measured in a longitudinal direction (see FIG. 5). As shown in FIGS. 6A and 6B, inside the guide 84, the front brake wire 74 extends in a direction of the axis of the cylinder and the spring 83 is located toward the rear of the vehicle. Further, in the guide 84, the piston 85 is fixed to the front brake wire 74 is located forward of the spring 83 with respect to the vehicle. The guide 84 has an opening. This opening is sealed with a plug member 87, wherein a portion of each of the front brake wire 74, the spring 83 and the piston 85 are located within.

[0061] In the load application unit 82 having the above structure, the piston 85 and spring 83 produce a biasing force toward the front of the vehicle for the front brake wire 74. More specifically, the piston 85 attached to the front brake wire 74 is pressed forward with respect to the vehicle by the spring 83. This biasing force by the spring 83 toward the front of the vehicle constitutes the initial set load (constant value) on the front brake wire 74. When the front brake wire 74 is pulled toward the rear of the vehicle, as indicated by the hollow arrow in FIG. 6B, the piston 85 attached to the front brake wire 74 moves toward the rear of the vehicle to compress the spring 83, as shown in FIG. 6B.

[0062] As shown in FIGS. 3 and 4, the front brake wire 74 is connected with the connecting portion 53c of the pressing member 53 provided adjacent to the right brake lever 50. The rear brake wire 75 is connected with the connecting portion 63c of the pressing member 63 provided adjacent to the left brake lever 60.

[0063] Thus, when the brake pedal 70 is operated to be rotated toward the front of the vehicle, as indicated by the hollow arrow in FIG. 5, the operating force is transferred to the front and rear brake wires 74 and 75 via the wire coupling member 81 (the solid arrows in FIG. 5 indicate the direction of pulling). At this point, if the operating force applied to the front brake wire 74 is smaller than the initial set load of the load application unit 82, the wire coupling member 81 is rotated toward the front of the vehicle, as indicated by the broken arrow in FIG. 5, such that only the rear brake wire 75 is pulled. When the rear brake wire 75 is pulled by the brake pedal 70, the pressing member 63 is rotated about a point on the supported portion 63z such that the pressing portion 63b of the pressing member 63 presses the piston of the master cylinder 62. This actuates the rear brake 41.

[0064] If the operating force acting on the front brake wire 74 when the brake pedal 70 is operated to be rotated toward the front of the vehicle, as indicated by the hollow arrow in FIG. 5, is equal to or larger than the initial set load of the load application unit 82, the front brake wire 74 moves toward the rear of the vehicle. When the front brake wire 74 is moved...
toward the rear of the vehicle by the brake pedal 70, the pressing member 53 is rotated about a point on the supported portion 53a such that the pressing portion 53b of the pressing member 53 presses the piston 52c of the master cylinder 52. This actuates the front brake 31.

[0065] Thus, in the above structure, operating the brake pedal 70 allows the front and rear brakes 31 and 41 to work in an interlocked manner and also allows the rear brake 41 to begin to be actuated earlier than the front brake 31. That is, in the above arrangement, the rear brake 41 receives an operating force transferred from the equalizer 80 at an earlier time than an operating force is transferred from the equalizer 80 to the front brake 31, as well as an operating force generated by the left brake lever 60. Further, the above arrangement allows the left brake lever 60 and brake pedal 70 to be operated simultaneously.

[0066] In the present embodiment, the brake system 6 includes a front brake 31, a rear brake 41, a left brake lever 50 for operating the front brake 31, a left brake lever 60 for operating the rear brake 41, and a brake pedal 70 for operating the front and rear brakes 31 and 41 such that the front and rear brakes 31 and 41 work in an interlocked manner. This will allow the front and rear brakes 31 and 41 to be actuated in an interlocked manner and also allow these brakes to be actuated independently.

[0067] In the present embodiment, the brake system 6 further includes an equalizer 80 for dividing an operating force received by the brake pedal 70 into an operating force for the front brake 31 and an operating force for the rear brake 41. Thus, the front and rear brakes 31 and 41 may be actuated by operating the brake pedal 70.

[0068] In the present embodiment, the equalizer 80 includes a load application unit 82 for causing an operating force to be transferred to the front brake 31 later than a time at which an operating force is transferred to the rear brake 41. Thus, when the brake pedal 70 is operated, the front and rear brakes 31 and 41 may be actuated at different times. That is, in the above arrangement, by operating the brake pedal 70, it is possible to actuate the rear brake 41 first and then actuate the front brake 31.

[0069] In the present embodiment, the brake system 6 further includes a front brake wire 74 for transferring an operating force from the equalizer 80 to the front brake 31, and a rear brake wire 75 for transferring an operating force from the equalizer 80 to the rear brake 41. The load application unit 82 includes a spring 83 for limiting the displacement of the front brake wire 74 until the operating force acting on the front brake wire 74 is equal to or larger than an initial set load. This configuration allows the front brake 31 to be actuated later than the rear brake 41.

[0070] In the present embodiment, each of the front and rear brakes 31 and 41 is a hydraulic brake including a cylinder and a piston movable within the cylinder, and the equalizer 80 transfers an operating force to the piston of each of the front and rear brakes 31 and 41.

[0071] In the present embodiment, the brake system 6 further includes a footboard 91 on which the feet of the rider may be placed. The brake pedal 70 is located such that a portion thereof protrudes above the footboard 91. The motorcycle 1 includes an equalizer 80 for dividing an operating force received by the brake pedal 70 into an operating force for the front brake 31 and an operating force for the rear brake 41. The equalizer 80 is located below the footboard 91. Thus, the equalizer 80 may be located near the brake pedal 70 such that the operating force of the brake pedal 70 may be efficiently divided by the equalizer 80 into an operating force to be supplied to the front brake 31 and an operating force to be supplied to the rear brake 41.

[0072] In the present embodiment, the motorcycle 1 further includes a footboard 91 on which the feet of the rider may be placed. The brake pedal 70 is located such that a portion thereof protrudes above the footboard 91. The motorcycle 1 includes an equalizer 80 for dividing an operating force received by the brake pedal 70 into an operating force for the front brake 31 and an operating force for the rear brake 41. The equalizer 80 is located below the footboard 91. Thus, the equalizer 80 may be located near the brake pedal 70 such that the operating force of the brake pedal 70 may be efficiently divided by the equalizer 80 into an operating force to be supplied to the front brake 31 and an operating force to be supplied to the rear brake 41.

[0073] In the present embodiment, the brake system 6 includes a front brake wire 74 for transferring an operating force from the brake pedal 70 to the front brake 31, and a rear brake wire 75 for transferring an operating force from the brake pedal 70 to the rear brake 41. The front and rear brake wires 74 and 75 are supported by a body frame 11 and are located forward of the equalizer 80 with respect to the vehicle so as to be movable in a direction in which the wires extend. Thus, in an arrangement where master cylinders 52 and 62 are located near the right and left brake levers 50 and 60, respectively, the length of the brake wires up to the master cylinders 52 and 62 may be reduced. This will reduce the loss in the operating force applied to the brake wires to actuate the master cylinders.

[0074] In the present embodiment, the motorcycle 1 further includes an engine and a transmission for allowing the speed to be varied without the rider operating a clutch. The motorcycle 1 with this transmission will allow the left and right levers to be used for braking and thus is more preferable to realize the arrangement of the present embodiment.

Embodiment 2

[0075] FIG. 7 schematically shows a brake system 100 according to Embodiment 2. This embodiment is different from Embodiment 1 in that a left brake lever 101 serves as an interlocking brake operating device and a brake pedal 102 serves as a rear brake operating device. In the following description, the same components as in Embodiment 1 are labeled with the same characters and their description will not be given, and only the features different from those of Embodiment 1 will be described.

[0076] As shown in FIG. 7, the left brake lever 101 is rotatably attached to the handlebars 12 about a point on one of its ends and is connected with a wire coupling member 111 of an equalizer 110, which has the same structure as the equalizer of Embodiment 1. That is, the left brake lever 101 is connected with the wire coupling member 111 such that the operating force of the left brake lever 101 is transferred to the wire coupling member 111 when the left brake lever 101 is rotated relative to the handlebars 12. More specifically, similar to the wire coupling member of Embodiment 1, the wire coupling member 111 is a rectangular plate, where the left brake lever 101 is connected with a point thereon that is located closer to one end thereof, as measured in a longitudinal direction, than the center thereof as measured in a longitudinal direction. A front brake wire 121 is connected with the other end of the wire coupling member 111 as measured in a longitudinal direction, while a rear brake wire 122 is connected with the one end of the wire coupling member 111 in a longitudinal direction. The connection of the left brake lever
101 with the wire coupling member 111 is closer to the rear brake wire 122 than to the front brake wire 121.

[0077] The front brake wire 121 is connected with the pressing member 53 located adjacent to the right brake lever 50. The rear brake wire 122 is connected with the pressing member 131 located near the brake pedal 102.

[0078] Although not shown, similar to the equalizer 80 of Embodiment 1, the equalizer 110 includes a load application unit located on the front brake wire 121. The operation of the equalizer 110 is the same as that of the equalizer 80 of Embodiment 1 and thus its description will not be given.

[0079] Similar to the pressing members 53 and 63 of Embodiment 1, the pressing member 131 has a supported portion 131a, pressing portion 131b and connecting portion 131c. The supported portion 131a is a portion of the pressing member 131 that is to be connected with the body frame 11 (not shown). The supported portion 131a is rotatably supported on the body frame 11. The pressing member 131 extends from the supported portion 131a in one direction over the master cylinder 123. The connecting portion 131c is located close to the end of the pressing member 131 in a longitudinal direction that is opposite the end with the supported portion 131a. The rear brake wire 122 is connected with the connecting portion 131c. The pressing portion 131b is provided in the pressing member 131 between the supported portion 131a and connecting portion 131c. When the rear brake wire 122 connected with the connecting portion 131c is pulled, the pressing member 131 is rotated about a point on the supported portion 131a such that the pressing portion 131b presses the piston of the master cylinder 123.

[0080] A connecting arm 124 has one end connected with the brake pedal 102 and the other end connected with the pressing portion 131b of the pressing member 131. The brake pedal 102 includes an arm 102a with a bend protruding upward with respect to the vehicle and is rotatably supported on the body frame 11 at the bend of the arm 102a. Thus, when the rider kicks on one end of the brake pedal 102, the other end of the arm 102a is raised upward with respect to the vehicle such that the connecting arm 124 connected with the other end of the arm 102a and pressing member 131 are raised upward. Thus, as the brake pedal 102 is operated, the piston of the master cylinder 123 is pressed by the pressing portion 131b of the pressing member 131.

[0081] In the above arrangement, the rear brake 41 may be actuated by operating the left brake lever 101, and the rear brake 41 may also be actuated by operating the brake pedal 102. In other words, the brake pedal 102 may serve as the rear brake operating device and the left brake lever 101 may serve as the interlocking brake operating device.

[0082] In the present embodiment, the front brake operating device is the right brake lever 50, the rear brake operating device is the brake pedal 102, and the interlocking brake operating device is the left brake lever 101. Similar to Embodiment 1, this arrangement allows the front and rear brakes 31 and 41 to be actuated in an interlocked manner and also allows the brakes to be actuated independently.

Other Embodiments

[0083] Although embodiments of the present invention have been described, the above embodiments are merely examples that may be used to carry out the present invention. As such, the present invention is not limited to the above embodiments, and the above embodiments may be modified as appropriate without departing from the spirit of the invention.

[0084] In the above embodiments, the equalizer 80 or 110 is located near a brake operating device. Alternatively, an equalizer may be located far from a brake operating device.

[0085] In the above embodiments, the equalizer 80 or 110 includes the wire coupling member 81 or 111 and the load application unit 82. However, an equalizer may have any structure that allows the operating force received by the associated brake operating device to be divided among the front and rear brake wires.

[0086] In the above embodiments, the right brake lever 50 implements the brake operating device for the front brake 31, and the left brake lever 60 or brake pedal 102 implements the brake operating device for the rear brake 41. Alternatively, the right brake lever may be used as a brake operating device for a brake other than the front brake 31 and the left brake lever and pedal brake may be used as brake operating devices for a brake other than the rear brake 41. Further, left and right pedal brakes may be provided.

[0087] In the above embodiments, when the interlocking brake operating device is operated, the front brake 31 is actuated later than the rear brake 32. Alternatively, the front brake 31 may be actuated first, or the front and rear brakes 31 and 32 may be actuated simultaneously.

[0088] In the above embodiments, the front and rear brakes 31 and 41 are hydraulic disc brakes. Alternatively, the front and rear brakes 31 and 41 may be brakes of other types.

What is claimed is:

1. A straddle type vehicle brake system comprising:
   - a front brake;
   - a rear brake;
   - a front brake operating device configured to operate the front brake;
   - a rear brake operating device configured to operate the rear brake;
   - an interlocking brake operating device configured to operate the front brake and the rear brake;
   wherein the front brake and the rear brake work in an interlocked manner.

2. The straddle type vehicle brake system according to claim 1, further comprising an operating force dividing unit configured to divide an operating force received by the interlocking brake operating device into an operating force for the front brake and an operating force for the rear brake.

3. The straddle type vehicle brake system according to claim 2, wherein the operating force dividing unit includes a timing adjusting unit configured to cause an operating force to be transferred to the front brake after a time at which an operating force is transferred to the rear brake.

4. The straddle type vehicle brake system according to claim 3, further comprising:
   - a front brake wire configured to transfer an operating force from the operating force dividing unit to the front brake;
   and
   - a rear brake wire configured to transfer an operating force from the operating force dividing unit to the rear brake;
   wherein the timing adjusting unit includes a limiting member configured to limit displacement of the front brake wire until an operating force acting on the front brake wire is larger than a predetermined value.

5. The straddle type vehicle brake system according to claim 2, wherein:
each of the front brake and the rear brake is a hydraulic brake including a cylinder and a piston movable within the cylinder; and
the operating force dividing unit transfers an operating force to the piston of each of the front brake and the rear brake.

6. A straddle type vehicle comprising:
a chassis;
a front wheel;
a handlebar configured to control a direction of the front wheel; and
a straddle type vehicle brake system including
a front brake;
a rear brake;
a front brake operating device configured to operate the front brake;
a rear brake operating device configured to operate the rear brake; and
an interlocking brake operating device configured to operate the front brake and the rear brake;
wherein the front brake and the rear brake work in an interlocked manner.

7. The straddle type vehicle according to claim 6, wherein:
the front brake operating device is a right brake lever;
the rear brake operating device is a left brake lever;
the interlocking brake operating device is a brake pedal;
and
the left brake lever and the right brake lever are provided on the handlebar.

8. The straddle type vehicle according to claim 7, further comprising a footboard attached to the chassis and on which a foot of a rider is to be placed;
wherein the brake pedal is located such that a portion thereof protrudes above the footboard;
wherein the straddle type vehicle brake system includes an operating force dividing unit configured to divide an operating force received by the interlocking brake operating device into an operating force for the front brake and an operating force for the rear brake; and
wherein the operating force dividing unit is located below the footboard.

9. The straddle type vehicle according to claim 8, wherein:
the straddle type vehicle brake system includes a front brake wire configured to transfer an operating force from the interlocking brake operating device to the front brake and a rear brake wire configured to transfer an operating force from the interlocking brake operating device to the rear brake; and
the front brake wire and the rear brake wire are supported by the chassis and are located forward of the operating force dividing unit with respect to the vehicle so as to be movable in a direction in which the wires extend.

10. The straddle type vehicle according to claim 6, wherein:
the front brake operating device is a right brake lever;
the rear brake operating device is a brake pedal; and
the interlocking brake operating device is a left brake lever.

11. The straddle type vehicle according to claim 6, further comprising:
an engine; and
a transmission configured to allow a speed to be varied without a rider operating a clutch.

12. The straddle type vehicle according to claim 6, wherein:
the front brake operating device is a left brake lever;
the rear brake operating device is a right brake lever; and
the interlocking brake operating device is a brake pedal.
A motorcycle braking system distributing liquid pressure to a first front brake, a second front brake and a rear brake includes a first master cylinder actuated by a front brake lever and a second master cylinder actuated by a hand brake pedal. The first master cylinder is connected directly to the first front brake and the second front brake. The brake system also employs a pressure controller that distributes liquid pressure from the first and second master cylinders to the second front brake according to the liquid pressure from the second master cylinder. A secondary master cylinder supplies a secondary liquid pressure to the rear brake in response to actuation of the first front brake. The secondary liquid pressure supplied to the rear brake is transformed by a pressure-transformer. Using these components, the braking system implements a braking control method that provides improved control of the motorcycle while braking.
FIG. 4
FIG. 5

IDEAL DISTRIBUTION

OUTPUT LIQUID PRESSURE

P1  P2  P3

INPUT LIQUID PRESSURE
1. Field of the Invention

The present invention relates to a brake system for a motorcycle, in which a common master cylinder is connected with front wheel brakes and a rear wheel brake.

2. Description of Background Art

A brake system is already known in, for example, Japanese Patent Laid-Open No. 319348/1993, wherein the master cylinder is connected with the front wheel brake and the rear wheel brake wherein the liquid pressure from the master cylinder acts directly upon the front wheel brake. As a result, the front wheel is excessively braked even if the brake lever is depressed relatively weakly to slow the speed of the motorcycle making it difficult to control the motorcycle.

SUMMARY AND OBJECTS OF THE INVENTION

The present invention has been conceived in view of such background and has for its object to provide a brake system for a motorcycle, which is able to change the distribution of the braking force at the front wheel side between two states in which the output liquid pressure of the master cylinder is relatively low or relatively high.

In order to achieve the above-specified object, according to the present invention, there is provided a brake system for a motorcycle in which a common master cylinder is connected with front wheel brakes and with a rear wheel brake, characterized in that there is mounted on the front wheel a plurality of front wheel brakes wherein one of the front wheel brakes is connected directly with the master cylinder and the other front wheel brake is connected indirectly with the master cylinder through a pressure controller that changes the liquid pressure transmission ratio in accordance with the output liquid pressure of the master cylinder.

In addition, the pressure controller can be switched between a state, in which it intercepts the liquid pressure transmission when the output liquid pressure of the master cylinder is lower than a predetermined level, and a state in which it transmits the liquid pressure when the output liquid pressure of the master cylinder is equal to or higher than the predetermined level.

One of the front wheel brakes is equipped with a secondary master cylinder for establishing a liquid pressure in response to a brake reaction caused by the action of the front wheel brake. The secondary master cylinder is also connected with the rear wheel brake.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferential embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinafter and the accompanying drawings which are given by way of illus-
second master cylinder $M_p$ is connected directly with the liquid pressure chamber $S_p$ of the rear wheel brake $B_p$ and the liquid pressure chamber $S_o$ of the first front wheel brake $B_{fp}$, and through pressure controller $P$ with the liquid pressure chamber $S_p$ of the rear wheel brake $B_p$, the second master cylinder $M_p$, the central piston $P_{cc}$ of front brake $B_{fp}$, and the central piston $P_o$ of front brake $B_{fp}$ (via pressure controller $P$).

With additional reference to FIG. 3, the secondary master cylinder $M_s$ has its cylinder body 9 formed into a cylindrical shape having an output port 10 in its one closed end. In cylinder body 9, there is slidably fitted a piston 12 to define cylinder M, has its cylinder body 9 formed into a cylindrical cylinder body 9 and one end of the piston 12. In the output liquid pressure chamber 11 between one end of the cylinder body 9 and the piston 12, there is compressed a return spring body 9. On the outer circumference of the piston 12, there is formed a cover 21 that forms a reserving chamber 20. In the output liquid pressure chamber 11, there is coaxially and integrally extended a rod 19 which intercept the communication between the reserving chamber 20 and the output liquid pressure chamber 11. Thus, the piston 12 has its intermediate portion radially reduced at its outer circumference to form an annular chamber 14 between itself and the inner circumference of the cylinder body 9. On the outer circumference of the piston 12, there are fitted first and second cup seals 15 and 16 which define the annular chamber 14 therebetween.

The first cup seal 15, located between the annular chamber 14 and the output liquid pressure chamber 11, is in sliding contact with the inner circumference of the cylinder body 9 and permits communication of the working liquid from the annular chamber 14 to the output liquid pressure chamber 11 when the pressure in the output liquid pressure chamber 11 is lower than that in the annular chamber 14. First cup seal 15 obstructs the communication of the working liquid from the output liquid pressure chamber 11 to the annular chamber 14. The second cup seal 16 is in sliding contact with the inner circumference of the cylinder body 9 to obstruct the communication of the working liquid with the side opposite to the output liquid pressure chamber 11.

In the open end of the cylinder body 9, there is fitted a stop ring 17, by which is slidably fitted a disc-shaped push plate 18 in the cylinder body 9 while being obstructed from coming out. The push plate 18 is in coaxial contact with the other end of the piston 12. From the push plate 18, moreover, there is coaxially and integrally extended a rod 19 which extends away from the piston 12.

On the outer circumference of the cylinder body 9, there is fixed a cover 21 that forms a reserving chamber 20 between cover 21 and the outer circumference of the cylinder body 9. The cylinder body 9 includes a primary port 22 formed in the side wall of the cylinder body 9 for opening the output liquid pressure chamber 11 into the reserving chamber 20 when the piston 12 is in the position that maximizes the volume of the output liquid pressure chamber 11 (as shown in FIG. 3) and a secondary port 23 that allows the annular chamber 14 to communicate with the reserving chamber 20 at all times.

As shown in FIG. 2, the caliper 6, of the first front wheel brake $B_{fp}$, is equipped with a connection arm 26 which is associated with and connected to the rod 19. By the brake reaction acting upon the caliper 6, when the first front wheel brake $B_{fp}$ is actuated, the connection arm 26 pushes the rod 19 upward so that the piston 12 reduces the volume of the output liquid pressure chamber 11. Thus, the piston 12 reduces the volume of the output liquid pressure chamber 11, even after the first cup seal 15 passes the primary port 22 to intercept the communication between the reserving chamber 20 and the output liquid pressure chamber 11, so that the liquid pressure is outputted from the output liquid pressure chamber 11 via output port 10.

Output port 10 is connected through a conduit 24 with the pressure-transforming device 7. Conduit 25 connects the reserving chamber 20 with the liquid pressure chamber $S_p$ of the rear wheel brake $B_p$, the second master cylinder $M_p$, the central piston $P_{cc}$ of front brake $B_{fp}$, and the central piston $P_o$ of front brake $B_{fp}$ (via pressure controller $P$).

As shown in FIG. 4, the pressure-transforming device 7 is equipped with a proportional pressure-reducing valve 27 and pressure-reducing unit 28. The proportional pressure-reducing valve 27 has a housing 29 formed with a first spring housing hole 30 having one end thereof opening into a first sliding hole 31 which is radially reduced from and coaxial to the first spring housing hole 30. A second sliding hole 32, radially enlarged from the first sliding hole 31, has one end coaxially extended with the first sliding hole 31. A second spring housing hole 33, radially enlarged from the second sliding hole 32, has one end coaxially leading to the second sliding hole 32 and the other end opened.

In the first sliding hole 31, a liquid-tight and slidable-fitted regulation piston 36 is formed at an intermediate portion of the first sliding hole 31 with a flanged portion 36a that abuts against a stepped portion 34 between the first spring housing hole 30 and the first sliding hole 31. A regulation spring 39 is compressed between the flanged portion 36a and a spring receiving member 38 which is supported by a stop ring 37 fitted in the open end portion of the first spring housing hole 30. Thus, the end face of the regulation piston 36 facing the second sliding hole 32 is flush with a stepped portion 35 (that is between the first and second sliding holes 31 and 32) when the flanged portion 36a of regulation piston 36 is in abutment against the stepped portion 34.

In the second sliding hole 32, there is slidably fitted a pressure-receiving piston 41 that forms an output liquid pressure chamber 40 between itself and the stepped portion 35. In the annulus of pressure-receiving piston 41 there is a liquid-tight and relatively slidable spring receiving piston 42 which defines an input liquid pressure chamber 43 between the pressure-receiving piston 41 and the spring receiving piston 42.

Thus, the housing 29 is formed with an input port 44 that receives liquid pressure from the secondary master cylinder $M_s$ via conduit 24. The input port 44 communicates with the input liquid pressure chamber 43. The housing 29 also includes an output port 46 which communicates with the output liquid pressure chamber 40 via a liquid pressure passage 45. A conduit 47 connects the output port 46 with the liquid pressure chambers $S_o$ and $S_p$ of the rear wheel brake $B_p$ as shown in FIG. 2.

In the open end portion of the second spring housing hole 33, a stop ring 48 is fitted. This stop ring 48 supports a spring receiving member 49 that abuts the end portion of the spring receiving piston 42 at the side opposite to the input liquid pressure chamber 43. A pressure-regulating spring 50 is compressed between the spring receiving member 49 and the pressure-receiving piston 41. Moreover, the pressure-receiving piston 41 is made axially shorter than the distance between the stepped portion 35 and the spring receiving member 49 so that the pressure-receiving piston 41 can axially reciprocate between the stepped portion 35 and the spring receiving member 49.

The end portion of the pressure-receiving piston 41 at the side of the output liquid pressure chamber 40 is axially formed with a guide hole 51 and a valve hole 52 leading to the output liquid pressure chamber 40 and also includes a tapered valve seat 53 with the valve hole 52 opened at its...
In the input liquid pressure chamber 43, there is housed a valve body 54 which can be seated on the valve seat 53. A closing spring 55 is compressed between the valve body 54 and the valve seat 53. From the valve body 54 there is a valve opening rod 56 which protrudes from valve body 54 and which is loosely fitted in the valve hole 52 and is in abutment against the regulation piston 36.

The pressure-reducing unit 28 shares the housing 29 with the proportional pressure-reducing valve 27 and is equipped with a stepped pressure-reducing piston 59 which is slidably fitted in the housing 29 and has one end facing a liquid pressure chamber 58 formed midway in the liquid pressure passage 45 that joins the output liquid pressure chamber 40 of the proportional pressure-reducing valve 27 with the output port 46. Spring 60 urges the pressure-reducing piston 59 so as to reduce the volume of the liquid chamber 58. Between the outer circumference of an intermediate portion of the pressure-reducing piston 59 and the housing 29, there is formed an annular liquid pressure chamber 61 for applying the liquid pressure so as to increase the volume of the liquid chamber 58.

The housing 29 is formed with a smaller-diameter sliding hole 62 having one end thereof leading to the liquid chamber 58; a larger-diameter sliding hole 63 radially enlarged with respect to the smaller-diameter sliding hole 62 and having one end thereof coaxially leading to the other end of the smaller-diameter sliding hole 62; and a third spring housing hole 64 radially enlarged with respect to the larger-diameter sliding hole 63 and having one end thereof coaxially leading to the other end of the larger-diameter sliding hole 62 and the other end thereof opened.

The pressure-reducing piston 59 is formed with a smaller-diameter portion 59a which is liquid-tight and slidably fitted in the smaller-diameter sliding hole 62 having its one end facing the liquid chamber 58 and a larger-diameter portion 59b which is liquid-tight and slidably fitted in the larger-diameter sliding hole 63 and which is coaxially extensive with a tapered, pressure-receiving stepped portion 59c and a smaller-diameter portion 59d.

The annular liquid pressure chamber 61 is formed in the annulus that is between the smaller-diameter sliding hole 62, the larger-diameter sliding hole 63, and the pressure-receiving stepped portion 59c of the pressure-reducing piston 59. Furthermore, the annular liquid pressure chamber 61 extends so as to communicate with the input port 44.

The pressure-reducing piston 59 includes a flanged portion 59d which can abut against a stepped portion 65 that is between the larger-diameter sliding hole 63 and the third spring housing hole 64. The spring 60 is compressed between the flanged portion 59a and a spring receiving member 67 which is supported by a stop ring 66 fitted in the open end portion of the third spring housing hole 64.

The pressure-transforming device 7 thus constructed has pressure-transforming characteristics, as illustrated in FIG. 5. Specifically, the proportional pressure-reducing valve 27 is left open before the liquid pressure inputted to the input port 24 reaches level P1, so that the output liquid pressure from the output port 46 increases in proportion to the input liquid pressure, as indicated by a straight line joining point 0 and point A.

When the input liquid pressure exceeds the level P1, the pressure in the output liquid pressure chamber 40 causes pressure-receiving piston 41 to move against the spring force of the pressure-regulating spring 50 so that the valve body 54 seats on the valve seat 53 to intercept the communication between the input liquid pressure chamber 43 and the output liquid pressure chamber 40. This movement of pressure-receiving piston also increases the volume of the output liquid pressure chamber 40.

As the liquid pressure of the input liquid pressure chamber 43 further rises, the pressure-receiving piston 41 moves so that the valve body 54 leaves the valve seat 53 to restore the communication between the input liquid pressure chamber 43 and the output liquid pressure chamber 40. This movement of pressure-receiving piston 41 also reduces the volume of the output liquid pressure chamber 40. Thus, the pressure-receiving piston 41 axially reciprocates according to the rise of the input liquid pressure to open and close the valve hole 52 interruptedly, so that the rising rate of the output liquid pressure decreases, as indicated by a straight line joining point A and point B in FIG. 5.

When the input liquid pressure further rises to level P2, the liquid pressure acting upon the regulation piston 36 overcomes the spring force of the compressed regulation spring 39 so that the regulation piston 36 moves to further compress the regulation spring 39. As a result, the valve opening rod 56 of the valve body 54 is seated against the valve seat 53 to interrupt the communication between the input liquid pressure chamber 43 and the output liquid pressure chamber 40. As a result, when the input liquid pressure reaches the level P2, the output liquid pressure is held at a constant level, as indicated by a straight line joining point B and point C in FIG. 5.

When the input liquid pressure further rises to exceed level P2, the liquid pressure acting on the pressure-reducing piston 59 overcomes the spring force of the spring 60, and the pressure-reducing piston 59 moves so as to increase the volume of the liquid chamber 58 and thereby decrease the output liquid pressure.

Thus, the characteristics of distributing the braking pressure between the front and rear wheels close to the ideal characteristics represented by the ideal distribution curve of FIG. 5 can be achieved by the pressure-transforming device 7.

As shown in FIG. 6, the pressure controller 8 has a housing 70 that includes an input port 71, a cylinder hole 73, a partition 72 interposed between the cylinder hole 73 and the input port 71, and a threaded hole 74 all of which are coaxially formed in the received order. The partition 72 includes a communication hole 75 coaxially joining the input port 71 and the cylinder hole 73. A bolt 76 is driven into the threaded hole 74.

In the cylinder hole 73, there is slidably fitted a piston 79 which defines not only an input liquid pressure chamber 77 leading through the communication hole 75 to the input port 71 between piston 79 and partition 72 but also an output liquid pressure chamber 78 between piston 79 and bolt 76. Moreover, a spring 80 is compressed in the output liquid pressure chamber 78 between the bolt 76 and the piston 79 that urges piston 79 towards the input liquid pressure chamber 77.

Mounted on the outer circumference of the piston 79, there is an O-ring 81 on the end facing the input liquid pressure chamber 77 and a cup seal 82 on the end facing the output liquid pressure chamber 78. O-ring 81 and cup seal 82 are spaced apart from each other in the axial direction of the piston 79. The cup seal 82 is mounted on the piston 79.
such that the working liquid between the cup seal 82 and the O-ring 81 is allowed to flow to the output liquid pressure chamber 78 in response to the drop of liquid pressure in the output liquid pressure chamber 78.

The housing 70 is provided with a connection hole 84 in a side portion thereof to which is connected a conduit 83 leading from the primary master cylinder M1, which outputs liquid pressure in response to the actuation of the brake lever 2. A primary port 85 and a secondary port 86 lead to the connection hole 84 and open in the inner face of the cylinder hole 73. When the piston 79 is positioned to minimize the volume of the input liquid pressure chamber 77, (as shown in FIG. 6), the primary port 85 opens in the inner face of the cylinder hole 73 independent of the axial position of the piston 79.

To the input port 71, there is connected a conduit 87 from the second master cylinder M2 which outputs liquid pressure to input port 71 in response to the actuation of the brake pedal 4.

Between a head 76a of the bolt 76 and the cylinder body 70 there is clamped a hose mouth piece 90. Washer 88 is interposed between hose mouthpiece 90 and head 76a. Washer 89 is interposed between hose mouthpiece 90 and cylinder body 70. A hole 91 leading to the hose mouthpiece 90 communicates with the output liquid pressure chamber 78 via a communication passage 92 formed in the bolt 76 and is connected with the liquid pressure chamber S2 of the second front wheel brake B2P, as shown in FIG. 2.

The ratio of the liquid pressure transmission by the pressure controller 8 is varied with the output liquid pressure of the second master cylinder M2. Specifically, when the liquid pressure that urges the piston 79 so as to increase the volume of the input liquid pressure chamber 77 is lower than the opposing spring force of spring 80, the connection hole 84 communicates with the output liquid pressure chamber 78. In this state, the liquid pressure transmission between the second master cylinder M2, and the liquid pressure chamber S2, of the second front wheel brake B2P is intercepted. Also in this state, the first master cylinder M1 communicates with the liquid pressure chamber S1, of the second front wheel brake B1P.

When the liquid pressure of the input liquid pressure chamber 77 exceeds a predetermined level so that the liquid pressure that urges the piston 79 so as to increase the volume of the input liquid pressure chamber 77 overcomes the opposing spring force of spring 80, the piston 79 moves to increase the volume of the input liquid pressure chamber 77 and reduce the volume of the output liquid pressure chamber 78. The liquid pressure that is outputted from the output liquid pressure chamber 78 is in accordance with the reduction of the volume of the output liquid pressure chamber 78.

In short, when the liquid pressure of the input liquid pressure chamber 77 exceeds the predetermined level that overcomes spring 80, the output liquid pressure of the second master cylinder M2 is transmitted via piston 79 to the liquid pressure chamber S2 of the second front wheel brake B2P.

Next, the operation of this embodiment will be described.

When the brake lever 2 is solely actuated, the liquid pressure generated in the primary master cylinder M1 is applied directly to the liquid pressure chambers S1 and S2 of the first front wheel brake B1P and the liquid pressure chambers S3 and S5 of the second front wheel brake B2P and further to the liquid pressure chamber S6 of the second front wheel brake B2P, because the connection hole 85 and the output liquid pressure chamber 78 are held in communication with each other by the pressure controller 8.

Moreover, the liquid pressure established in the secondary master cylinder M2, in accordance with the braking action of the first front wheel brake B1P, acts upon the liquid pressure chambers S3 and S5 of the rear wheel brake B2R through the pressure-transformer device 7 to brake the rear wheel WR. At this time, the output liquid pressure of the secondary master cylinder M2 rises with the increase in the braking force of the front wheel WR, the braking force close to the ideal distribution characteristic is established in the rear wheel WR, by the pressure-transforming characteristics of the pressure-transformer 7, as shown in FIG. 5.

When the brake pedal 4 is solely actuated, on the other hand, the liquid pressure generated in the second master cylinder M2, acts directly upon the liquid pressure chamber S5 of the rear wheel brake B2R and the liquid pressure chamber S6 of the first front wheel brake B1P. Furthermore, the braking action of the first front wheel brake B1P causes liquid pressure to be generated in the secondary master cylinder M2, which acts indirectly on the pressure liquid pressure chambers S5 and S6 of the rear wheel brake B2R through the pressure-transformer 7. Thus, the front wheel WR and the rear wheel WR are braked.

Incidentally, when the liquid pressure from the second master cylinder M2 is lower than a predetermined level, the liquid pressure is not transmitted to the liquid pressure chamber S6 of the second front wheel brake B2P because of the action of the pressure controller 8 so that the second front wheel brake B2P is left unactuated.

When the liquid pressure from the second master cylinder M2 exceeds the predetermined level, on the contrary, the pressure controller 8 transmits the liquid pressure to the liquid pressure chamber S6 of the second front wheel brake B2P to actuate the second front wheel brake B2P. Specifically, when the depression of the brake pedal 4 is less than a predetermined value, the first front wheel brake B1P is actuated, but the second front wheel brake B2P does not actuate. When the depression of the brake pedal 4 exceeds the predetermined value, both the first and second front wheel brakes B1P and B2P actuate. As a result, if the brake pedal 4 is relatively weakly depressed to adjust the running speed of the motorcycle V, the front wheel WR is not excessively braked.

If the brake pedal 4 is relatively intensely depressed to raise the output liquid pressure of the second master cylinder M2 to a relatively high level, the braking force of the front wheel WR can be set to a relatively high value by the actuation of both front wheel brakes B1P and B2P.

Moreover, when the brake lever 2 and the brake pedal 4 are simultaneously actuated, all the brakes B1P, B2P, and B2R are actuated to brake the front wheel WR and the rear wheel WR.

Now, let it be assumed that the brake pedal 4 is depressed while the brake lever 2 is braking. In the pressure controller 8, the piston 79 is initially in the state that minimizes the volume of the input liquid pressure chamber 77. Piston 79 stays in this initial state until the pressure from the master cylinder M1 overcomes the sum of the liquid pressure in the output liquid pressure chamber 78 from the first master cylinder M1 and the spring force of the spring 80. After the output liquid pressure of the second master cylinder M2 rises so that the piston 79 moves to close the primary port 85, the pressure controller 8 is brought into the state in which it transmits the liquid pressure from the second master cylinder.
der $M_p$ to the liquid pressure chamber $S_p$ of the second front wheel brake $B_{72}$.

When the brake lever 2 is actuated while the brake pedal 4 is being depressed sufficiently hard so as to cause piston 79 to block primary port 85, on the other hand, the output liquid pressure of the first master cylinder $M_p$ is applied to the output liquid pressure chamber 78 by the action of the cup seal 82 when the output liquid pressure of the first master cylinder $M_p$ is higher than the liquid pressure of the output liquid pressure chamber 78. As a result, output liquid pressure of the first master cylinder $M_p$ urges the piston 79 in the direction that reduces the volume of the input liquid pressure chamber 77. Also, the output liquid pressure of the second master cylinder $M_s$ urges the piston 79 so as to increase the volume of the input liquid pressure chamber 77, so that the output liquid pressure of the first master cylinder $M_p$ acts upon the liquid pressure chamber $S_p$ of the second front wheel brake $B_{72}$ after the piston 75 is moved so as to reduce the volume of the input liquid pressure chamber 77 and thereby open the primary port 85 by the rise of the output liquid pressure of the first master cylinder $M_p$.

As has been described hereinbefore, there is mounted on the front wheel a plurality of front wheel brakes of which the front wheel brake is connected directly with the master cylinder. The other front wheel brake is connected with the master cylinder through a pressure controller that changes a liquid pressure transmission ratio in accordance with the output liquid pressure of the master cylinder. As a result, the front wheel braking force distribution can be changed according to the output liquid pressure from the master cylinder.

In addition, the pressure controller can be switched between a state, in which it intercepts the liquid pressure transmission when the output liquid pressure of the master cylinder is lower than a predetermined level, and a state in which it transmits the liquid pressure when the output liquid pressure of the master cylinder is equal to or higher than the predetermined level. As a result, a necessary braking force can be obtained by rendering the other front wheel brake unactuated to thereby weaken the front wheel braking force, when the output liquid pressure of the master cylinder is relatively low and by actuating all the front wheel brakes when the output liquid pressure of the master cylinder is relatively high.

Furthermore, one of the front wheel brakes is equipped with a secondary master cylinder for establishing a liquid pressure by a brake reaction that is generated in response to the action of the front wheel brake. The secondary master cylinder is connected with the rear wheel brake through a pressure transforming device. As a result, the rear wheel brake can be associatively actuated in response to the braking action of the front wheel brakes.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

We claim:

1. A brake system for a motorcycle having a first master cylinder and a second master cylinder comprising:
   - a first front wheel brake connected directly with the first master cylinder;
   - a second front wheel brake having a first piston connected directly with the first master cylinder and a second piston connected indirectly with the first master cylinder;
   - a pressure controller connecting the first and second master cylinders to the second piston of said second front wheel brake, said pressure controller changing a liquid pressure transmission ratio supplied to the second piston of said second front wheel brake by the first and second master cylinders in accordance with an output liquid pressure of the second master cylinder to selectively provide the output liquid pressure from the second master cylinder to the second piston of said second front wheel brake.

2. The brake system according to claim 1, wherein said liquid pressure controller is switchable between a first state and a second state:
   - wherein said liquid pressure controller is in the first state when the output liquid pressure of the second master cylinder is lower than a predetermined level, in the first state said liquid pressure controller intercepts a liquid pressure transmission from the second master cylinder to said second piston of said second front wheel brake and provides liquid pressure from the first master cylinder to said second piston of said second front wheel brake;
   - wherein said liquid pressure controller is in the second state when the output liquid pressure of the second master cylinder is equal to or higher than the predetermined level, in the second state said liquid pressure controller transmits the liquid pressure from the second master cylinder to said second piston of said second front wheel brake.

3. The brake system according to claim 1, wherein said first front wheel brake includes a secondary master cylinder establishing a liquid pressure in response to a brake reaction caused by action of said first front wheel brake and wherein said secondary master cylinder is connected with a rear wheel brake.

4. The brake system according to claim 3 further comprising:
   - a liquid pressure transformer receiving input liquid pressure from said secondary master cylinder and supplying a transformed output liquid pressure to the rear wheel brake.

5. The brake system according to claim 4 wherein said liquid pressure transformer includes a proportional liquid pressure valve having:
   - a first liquid pressure transmission ratio when the input liquid pressure is between zero and a first predetermined value,
   - a second liquid pressure transmission ratio when the input liquid pressure is between the first predetermined value and a second predetermined value, and
   - a substantially constant output liquid pressure when the input liquid pressure is between the second predetermined value and a third predetermined value.

6. The brake system according to claim 5 wherein said liquid pressure transformer further comprises:
   - a liquid pressure reducer reducing the output liquid pressure when the input liquid pressure exceeds the third predetermined value.

7. A brake control system for a motorcycle having a first front brake; a second front brake; a first master cylinder establishing a first output liquid pressure that is supplied to the first front brake and a rear brake; and a second master cylinder establishing a second output liquid pressure that is supplied to the first front brake and the rear brake, comprising:
   - a liquid pressure controller controlling the first and second output liquid pressures from the first master cylinder...
11. The brake system according to claim 7 wherein said liquid pressure transformer includes a proportional liquid pressure valve having:
(a) a first liquid pressure transmission ratio when the input liquid pressure is between zero and a first predetermined value,
(b) a second liquid pressure transmission ratio when the input liquid pressure is between the first predetermined value and a second predetermined value, and
(c) a substantially constant output liquid pressure when the input liquid pressure is between the second predetermined value and a third predetermined value.

12. A method of distributing brake fluid pressure between a first front brake, a second front brake and a rear brake of a motorcycle in response to actuation of a front brake actuator or a rear brake actuator comprising the steps of:
(a) applying fluid pressure from a first master cylinder to a first front brake actuator when the first front brake is actuated;
(b) applying fluid pressure from a first master cylinder to the second front brake when the fluid pressure from the second master cylinder is equal to or higher than a predetermined level, the fluid pressure from the second master cylinder to the second front brake is transmitted and the second front brake receives fluid pressure from the second master cylinder when either the rear or front brake actuators are actuated such that when the fluid pressure from the second master cylinder is lower than a predetermined level, the fluid pressure from the second master cylinder to the second front brake is blocked and the second front brake receives fluid pressure only from the first master cylinder and when the fluid pressure from the second master cylinder is equal to or higher than the predetermined level, the fluid pressure from the second master cylinder to the second front brake is transmitted and the second front brake receives fluid pressure from the second master cylinder.

13. The method of claim 12 further comprising the steps of:
(a) establishing a secondary liquid pressure with a secondary master cylinder when the first front brake is actuated, and
applying the secondary liquid pressure to the rear brake.

14. The method of claim 13 further comprising the step of transforming the secondary liquid pressure applied to the rear brake.

15. The method of claim 14, said transforming step 5 having:
   a first liquid pressure transmission ratio when the secondary liquid pressure is between zero and a first predetermined value,
   a second liquid pressure transmission ratio when the secondary liquid pressure is between the first predetermined value and a second predetermined value, and
   a substantially constant output liquid pressure when the secondary liquid pressure is between the second predetermined value and a third predetermined value.
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