DESIGN OF COMBINED BRAKE SYSTEM FOR SCOOTER (MECHANICAL TYPE)

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Abstract : *This paper describes a combined braking system (CBS) where two brake cables are connected to the CBS unit from left hand (LH) and right hand (RH) levers, and two brake cables are connected to the rear & front wheels. The LH brake lever will actuate a link mechanism, and through the mechanism, an appropriate braking force distribution is achieved between the front and rear wheels. Brakes work simultaneously on the front and rear wheels through the mechanism. The operation of the RH lever applies the brakes on the front brake only; in this case, no force is transmitted to the rear brake. The CBS helps in avoiding rear wheel locking and get higher deceleration. A CBS unit was designed for a 125 cc scooter to meet the braking standard IS-14664. A prototype (machined sample) was manufactured, and its working was confirmed on the vehicle. This CBS system will enhance the safety of the rider. Further improvements can be made by reducing the cost of some parts by considering the materials and processes.*

Index Terms - Combined braking system (CBS), Combi-brake, Synchronized brake system (SBS), Scooter brake

1. INTRODUCTION

1.1 BRAKING SYSTEM IN TWO-WHEELERS

Generally, two-wheeler vehicles are provided with independent brakes for decelerating the vehicle. Conventionally, in gearless scooters and mopeds (two-wheelers without clutch lever on left hand (LH) side of the handle bar), such brakes are provided on the handle bar of the vehicle, while in bikes/motorcycles (two-wheelers having a clutch on left hand side of the handle bar) the front brake lever is generally located on right hand (RH) side of handle bar and the rear brake is actuated by means of a foot pedal.

When a user/rider has to decelerate the two-wheeler, generally both the independent brakes, i.e. front and rear brakes have to be applied together in proportion so as to obtain optimum braking effect.
However, there are many demerits of independent braking systems. One such shortcoming is the poor timing of application of the front and rear independent brakes leading to disproportionate braking between the two wheels.
Usually when the rear brake is applied much more than the front brake, the stopping distance increases (the braking effect reduces) and also there will be a possibility of skidding of rear wheel causing hazard to the rider.
On the contrary, if the front brake is applied harder than the rear brake, the braking effect on the front wheel will be very high which may lead to toppling of the scooter/bike or loss of control of vehicle causing hazard to the rider.

Two overcome the problem, it is highly recommended to develop a combined braking system (CBS) by which a rider can apply some defined amount of load for the front & rear brakes so that there will not be any skidding or toppling of the vehicle during braking application.

1.2 EXPLANATION OF VARIOUS CBS DESIGN OPTIONS

Two common design options for CBS are shown in Figs. 1 and 2.

In Scheme 1 design layout, there are two input cables and two output cables. One input cable is from the LH lever, and the other one is from the RH lever. One output cable goes to the front brake, and the other one goes to the rear brake (See Fig. 1)

In scheme 2 design layout, there is one input cable and two output cables. One input cable is from the LH lever, and the other one is from the RH lever.
One output cable goes to the front brake, and the other one goes to the rear brake.
In this layout, one additional cable is required to operate the front brake separately (See Fig. 2).

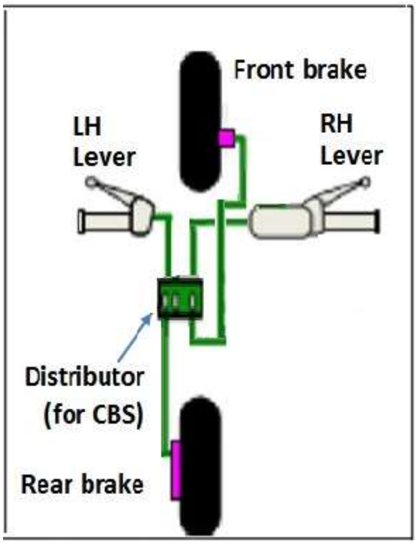

Fig 1. CBS: Scheme 1

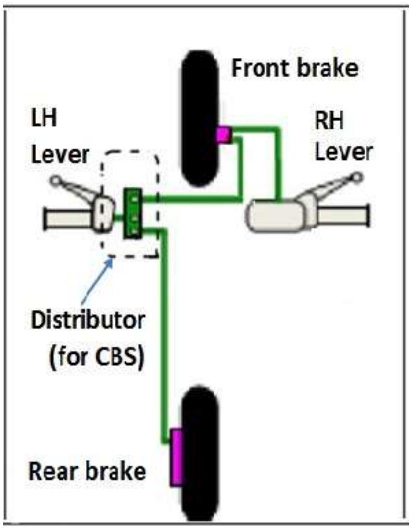

Fig 2. CBS: Scheme 2

1.3 FUNCTIONAL REQUIREMENTS FOR CBS:

i) Should transmit forces to the front and rear brakes in the required proportion to meet the Indian braking regulation IS 14664.
ii) The vehicle with CBS should achieve a minimum deceleration of 5.1 m/s^2.
iii) If the connection to the front brake fails, the linkages should transmit force to the rear brake to provide braking of the vehicle. It should be possible to achieve a deceleration of 2.9 m/s^2 in this condition.
iv) When the front brake is applied using the front brake lever, there should be no force transmission to the rear brake.

2. MATERIALS AND METHODS

The steps followed for designing the CBS are as follows.

i) Benchmarking
ii) Exploring new concept
iii) Patent study
iv) Working concept
v) Theoretical calculation
vi) Validation results

2.1 BENCHMARKING

We selected mechanical CBS designs from two standard OEMs, which are already available in the market in the same segment, for benchmarking.

The outcomes of benchmarking are as follows.

a) Both design are based on CBS: scheme 2
b) Free play adjustment should be provided.
c) Cable efficiency plays a very important role in CBS performance.
d) Equalizer ratio should lie in the range of 1.5-2 for most scooters.
e) In both design from Left hand (LH) lever, Rear and front both is operated while from Right hand (RH) only front brake is operated.

2.2 EXPLORING NEW CONCEPT

We have designed a new CBS unit for scooters. This system is based on Scheme-1, where two cables are connected to the CBS unit from LH and RH levers, and the other two cables are connected to the rear and front wheels (See Fig. 3).

When the rider pulls the LH/CBS lever, both front and rear brakes will be activated simultaneously by means of the CBS unit (See Fig. 4).

The operation of RH lever applies the brakes on the front brake only, and no force is transmitted to the rear brake (See Fig. 5).

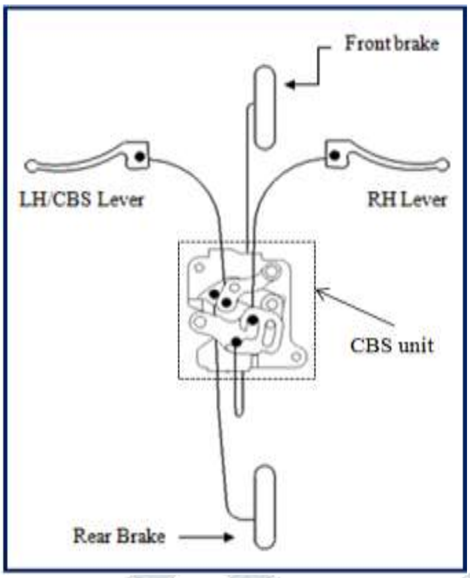

Fig. 3. CBS unit (without lever actuation)

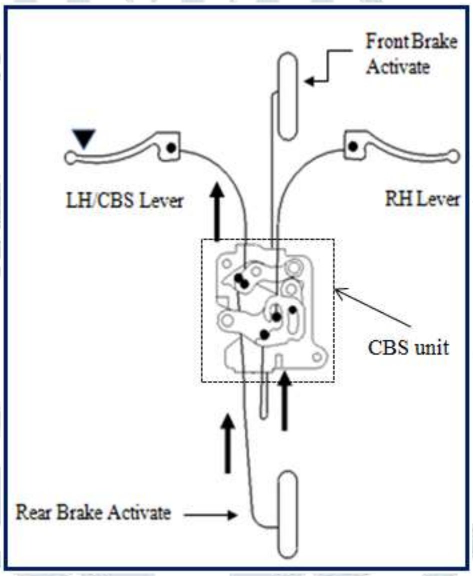

Fig. 4. CBS unit with LH/CBS lever actuation

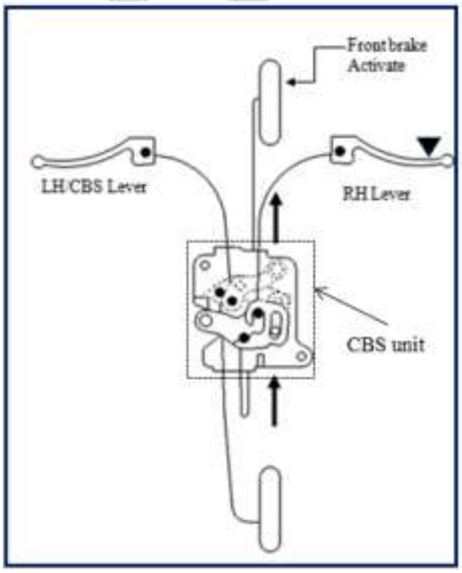

Fig. 5. CBS unit with RH lever actuation

2.3 PATENT STUDY

We have studied the patents on mechanical type CBS for scooters below 125 cc and found that this design is totally different from the present designs of the other OEMs which are already in production. Thus, this CBS design does not infringe with present CBS designs.

2.4 WORKING CONCEPT

In this CBS, LH brake lever (Link-1) will actuate the link mechanism (links 2, 3, and distributer) through pivot point 1 and pivot point 2. The mechanism distributes an appropriate braking force between the front and rear wheels. The brakes work simultaneously on the front and rear wheels through the mechanism (See Fig. 6).

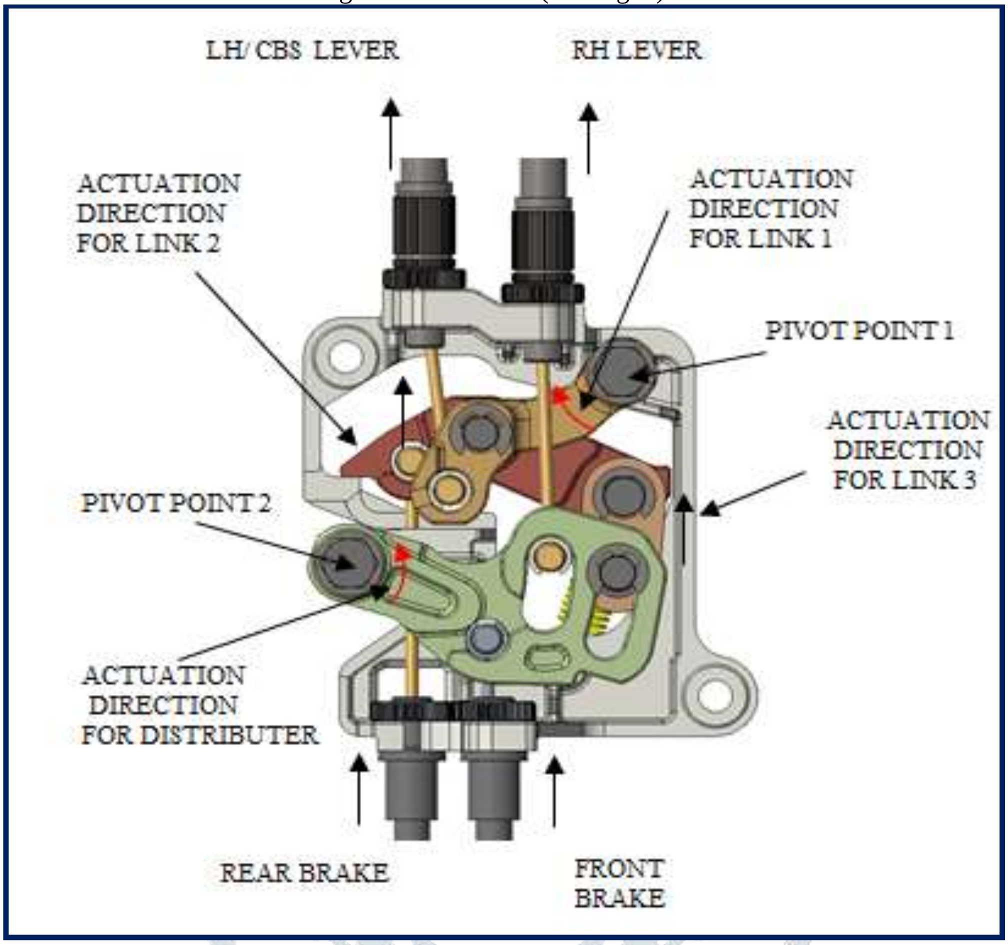

Fig. 6. CBS unit working concept

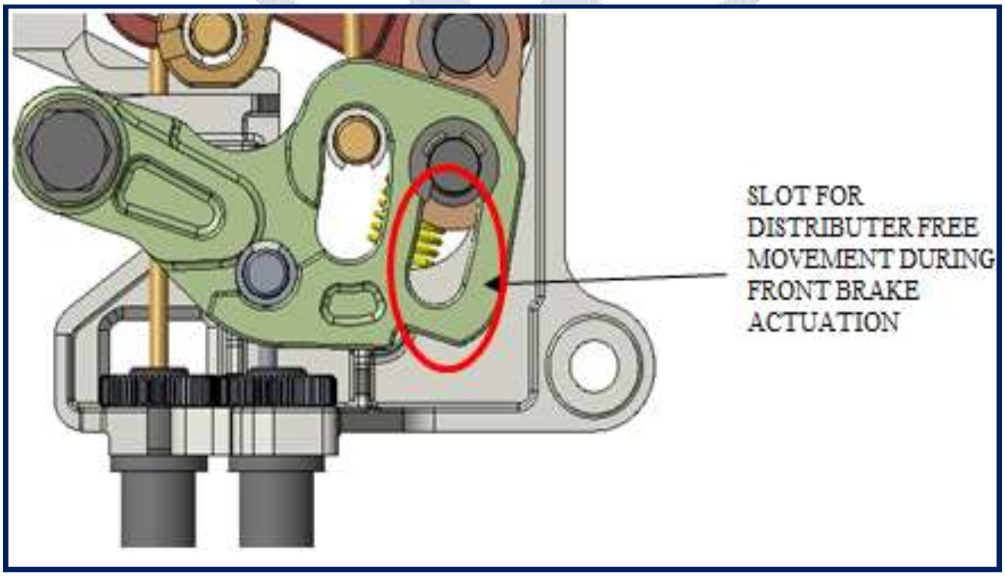

Fig. 7. Slot for front brake operation

The operation of the RH lever applies the brakes on the front brake only. Because of the slot present (See Fig. 7) in the distributer, no force is transmitted to the rear brake.

2.5 THEORETICAL CALCULATION

There are two calculations needed to design the CBS unit:

a) Determination of rear/front braking ratio (equalizer ratio) for a typical scooter.
b) Equalizer ratio calculation.

2.5.1 DETERMINATION OF RATIO FOR A TYPICAL SCOOTER

The vehicle data for a typical scooter of 125 cc are shown in Fig. 8 and Table 1.

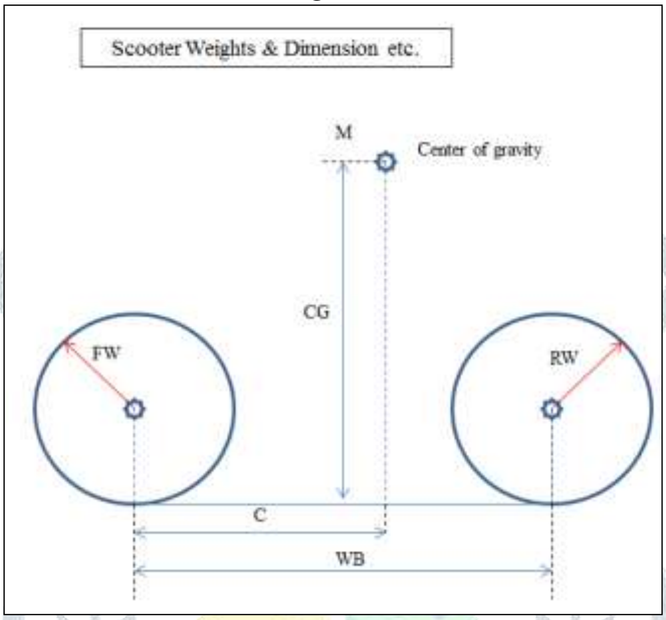

Fig. 8. Layout related to vehicle data

Symbol	Unit	Value	Remarks
M1	kg	187	1 refers to vehicle + driver
C1	mm	814	
CG1	mm	650	
WB1	mm	1270	
M2	kg	262	2 refers to vehicle + driver + passenger (pillion)
C2	mm	883	
CG2	mm	734	
WB2	mm	1260	
FW	mm	217	
RW	mm	217	

Table 1. Vehicle data

From the vehicle data, the dynamic front and rear wheel loads were calculated for a deceleration of 5.1 m/s^2. The equalizer ratio was adjusted to obtain this deceleration without having rear wheel locking condition. A tyre-road friction value of 0.9 was considered as per the regulation.

A value of **1.2** was obtained for the equalizer ratio to meet the above conditions with a certain margin of safety.

2.5.2 EQUALIZER RATIO CALCULATION

The calculation to find out the equalizer ratio is given below.

Legends (See Fig. 9)

F1- Load applied from LH lever to Link 1
F2- Load transfer to Pivot 2 of Link 1
F3- Load transfer to rear brake
F4- Load transfer to Link 3
F5- Load transfer to front brake
F_D - Load of delay spring

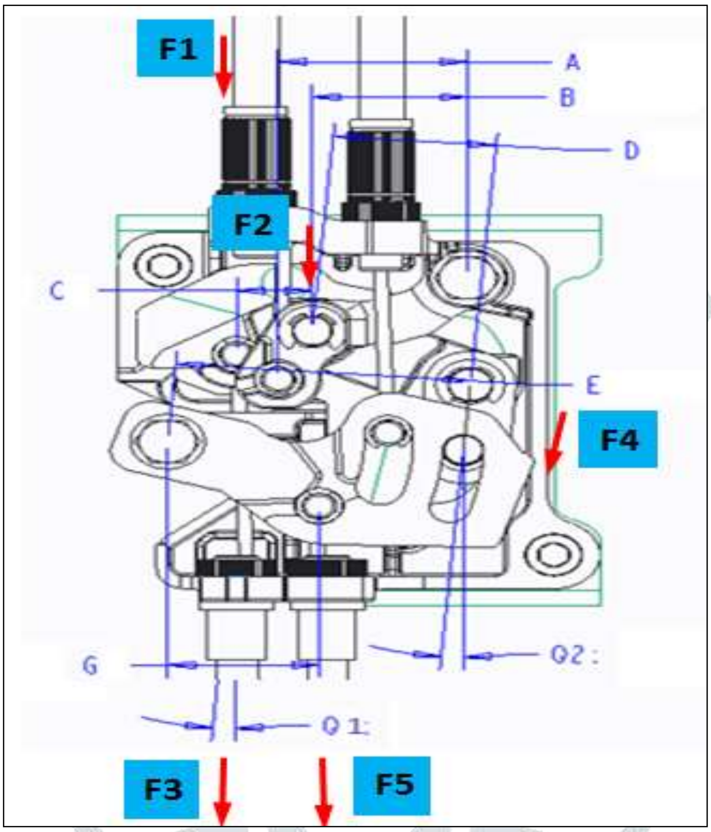

Fig. 9. CBS unit layout

F2 = F1*(A/B) (1)

F3. COS (Q1) + F4. COS (Q2) = F2

F3 * C = F4 * D

Hence, F3 = F4 * D / C (2)

F4. COS (Q1) * D / C + F4. COS (Q2) = F2

F4 = F2 / [COS (Q1) * D / C+COS (Q2)] (3)

F3 = F4 * D / C

F5 * G = F4 * E

Hence, F5 = (F4-F_D)* E / G (4)

Rear/front ratio = F3 / F5 (5)

We performed calculations as per equations. 1 to 5 based on the dimensions of the CBS unit. The dimensions were adjusted to obtain a value of **1.2** for the rear/front ratio which is required to meet the regulation.

2.6 VALIDATION TEST

We prepared a prototype (CNC machined sample) of the CBS unit based on the above design. The unit was mounted on the vehicle and braking tests were conducted on a level road as per the regulation. The results of brake performance tests are presented in Table 2.

Braking test results on typical scooter 125cc with CBS					
Sr. No.	**Test Detail**	**Unit**	**Limit as per IS 14664**	**Average stopping distance**	
				Low friction brake liners	**High friction Fr. Brake liners**
A	**CBS operation :-**				
	With rider only (lightly loaded condition)	m	33.4	26	25
	with rider + pillion (fully loaded condition)	m	34.4	29	27.5
B	**Front failed condition :-**				
	With rider only (lightly loaded condition)	m	53.9	35.5	34
	with rider + pillion (fully loaded condition)	m	53.9	38	36
C	**Only front brake operation :-**				
	With rider only (lightly loaded condition)	m	37.3	35.2	28.5
	with rider + pillion (fully loaded condition)	m	37.3	36.4	33
Note :- 1. All the tests were done at 60 km/h on a flat road at Pune. 2. There was a significant improvement in front brake performance with high friction liner. 3. The brake regulation is met with a comfortable margin with the improved brake liner.					

Table 2. Results of brake performance test

3. RESULTS AND DISCUSSION

The deceleration of 5.1 m/s^2 could be achieved without any locking of the rear wheel. The deceleration of 2.9 m/s^2 in the front brake condition could also be achieved without locking of the rear wheel.
The results show that the CBS unit designed by us can meet the Indian regulation, and thus enhance the safety of the rider.

4. CONCLUSIONS

The CBS unit that we designed and developed is working properly, and meets the functional requirements of CBS as mentioned in IS 14664.The rear/front ratio for braking force distribution was calculated based on the vehicle data, and a value of 1.2 was obtained. The dimensions of the links were adjusted to obtain the above ratio at the CBS output. A prototype of the unit was manufactured and tested to verify the braking performance. The test results showed that the regulation requirements are met comfortably with the above CBS unit.

The application of this design in scooters can significantly enhance the safety of the rider. Further improvements will be considered in future by reducing the cost of the product.

5. ACKNOWLEDGMENTS

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