A Review on The Mechanical Types of Combine Brake Systems in Motorbike

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ABSTRACT – The operational mechanism of the Combined Brake Systems (CBS) is designed to instantaneously engage the functions of front brake together with rear brake through a unified control input facilitated by a CBS mechanism. The CBS mechanisms employed in high capacity scooters, touring bikes in medium-sized, together with cruisers differ significantly from those used in light motorbikes, which typically utilize a mechanical system. Thus, the primary goal for the recent work is to conduct a comprehensive review of the existing literature on the mechanical types of Combined Brake Systems (mCBS) used in light motorbikes. It was observed that there are five distinct types of layout design for mCBS. This layout is essential for integration with various brake systems and brake actuation controls. This is crucial to obtain the optimum performance of braking and motorbike stability. The mCBS mechanisms, especially those achieving nonlinear force distribution, exhibit promising capabilities for optimizing braking efficiency. Legislative mandates in regions such as the EU, India, Taiwan, and Japan underscore the growing importance and adoption of these systems, emphasizing the need for continued innovation. Future research should focus on developing sophisticated models for nonlinear brake force distribution. Additionally, exploring new technologies to enhance the effectiveness and affordability of these braking systems is essential.

KEYWORDS: Mechanical Types, Combined Brake Systems, Brake Force, Motorbike

1.0 INTRODUCTION

The application of combined braking systems (CBS) effectively reduces crash risks in specific accident scenarios [1]. The CBS functions by simultaneously activating the braking systems of both wheels using a single control actuation. The actuation of a CBS can be operated manually via a lever or pedal. The CBS is connected to both brakes to initiate the braking process. CBS implementation aims to achieve two primary objectives. Firstly, it enhances deceleration and reduces stopping distance. Secondly, it eliminates the rear load transfer [2-5]. This braking system is alternatively referred to as a synchronized brake system, an integral brake system or a linked brake system. The initial development and installation of CBS occurred in 1983 for large touring models [6]. Back then, it was referred to as a single type of hydraulic CBS. The instantaneous braking was achieved solely through controlling the rear brake in this type. The dual CBS (D-CBS) was introduced for the sports model's application ten years later. "Dual" in CBS terminology denotes the input type either the control by lever or pedal. Subsequently, the single CBS with mechanical-type control was developed in 1996. The mCBS was developed specifically for light motorbikes equipped with drum brakes. According to the historical timeline provided, two classifications of CBS have been identified. It is namely as a single CBS and D-CBS, respectively.

For the single CBS, the actuation of both the front and rear brakes of the motorbike is synchronized by engaging the rear control. Meanwhile, the front brake is actuated independently by the front control. Single CBS utilizes the mechanical or hydraulic pressure in the CBS mechanism. Light motorbikes, including small scooters, are equipped with the mechanical type mechanism of CBS (mCBS). It was due to the prevalence of drum brakes on most motorbikes in this category. The mCBS mechanism is operated by a rear brake control, which concurrently activates both brakes through cable linkages.

High-capacity scooters, touring bikes in medium-sized, together with cruisers employ different CBS mechanisms compared to those used in light motorbikes. The new legislation to fit the CBS on light motorbikes was approved by the European Parliament in 2012. Therefore, the CBS is mandated for light motorbikes registered in the European Union (EU) [1]. Followed by India in April 2018. Subsequently, Taiwan and Japan also followed suit. Simultaneously, other countries such as New Zealand, Australia, and Brazil are also contemplating similar regulations. Thus, the primary goal of the recent work is to conduct a comprehensive review of the existing literature on the mechanical types of Combined Brake Systems (mCBS) used in light motorbikes.

2.0 MECHANICAL TYPE OF CBS MECHANISM

Drum brakes can be found on both wheels of a light motorbike, or a hydraulic disc brake can be installed on the front wheel. It is further complemented by a rear drum brake to ensure effective braking control. The operation of the rear brake can be carried out using either a lever that was on the motorbike’s left side (commonly utilized in scooters) or a foot pedal, whereas a hand lever controls the front brake. It is essential to develop various designs of mCBS mechanisms to fit in with various brake systems and brake actuation controls. This ensures maximizing the performance of braking and motorbike stability. It was observed that there are five distinct types of layout design for mCBS, as illustrated in Figure 1. Firstly, it was referred to as a Front Integrated mCBS Mechanism. The mCBS mechanism is intricately integrated into the design of the rear brake control, which facilitates operation through the control of the rear brake. The dual mounting attach slot was intended to coordinate both brakes through cable connections. During rear brake control actuation, both brakes will be activated. This layout is employed for motorbikes equipped with drum brakes. Secondly, the layout employs a similar concept as the first layout. The lever that was on the motorbike’s right side was linked to the front connection cable, rather than being directly connected to the front. This configuration is referred to as an Integrated linked mCBS Mechanism. This is typically employed in motorbikes that were equipped with a hydraulic and a drum brake. The rear brake is promptly triggered by a rear connection cable, initiating braking force on the rear once the rear is activated. The front connecting cable activates a lever that is positioned on the right hand. The generating of the hydraulic pressure will actuate a front braking force during an activation of the lever that was located on the right side of the motorbike.

The rear brake control incorporated in the third layout is known as Direct mCBS Mechanism. It was triggered by the involvement of force exerted on the rear. Subsequently, it synchronizes an activation on dual brakes via a cable connection. This arrangement is made suitable for a motorbike equipped with a drum brake. Fourthly, it was called as Linked mCBS mechanism. This is typically utilized on motorbikes equipped with a drum together with a disc brake. Through activation of a controller for rear braking, the rear connection cable promptly engages the brake at the back and generates a brake force. Instantaneously, the front connection cable actuates the front lever controller. This actuation induces hydraulic pressure through the master cylinder specifically designated for the front brakes. The front brake was subsequently engaged to produce the necessary front braking force. The final outline is referred to as a Dual mCBS mechanism. Actuations of both brakes are controlled over the mCBS mechanism. It accommodates input force originating from either the front or rear control systems. The mCBS mechanism independently triggers the front brake through front activation. Upon the actuation of the rear brake control, both brakes are concurrently engaged. Upon activation of the rear brake control, both braking mechanisms are simultaneously engaged.

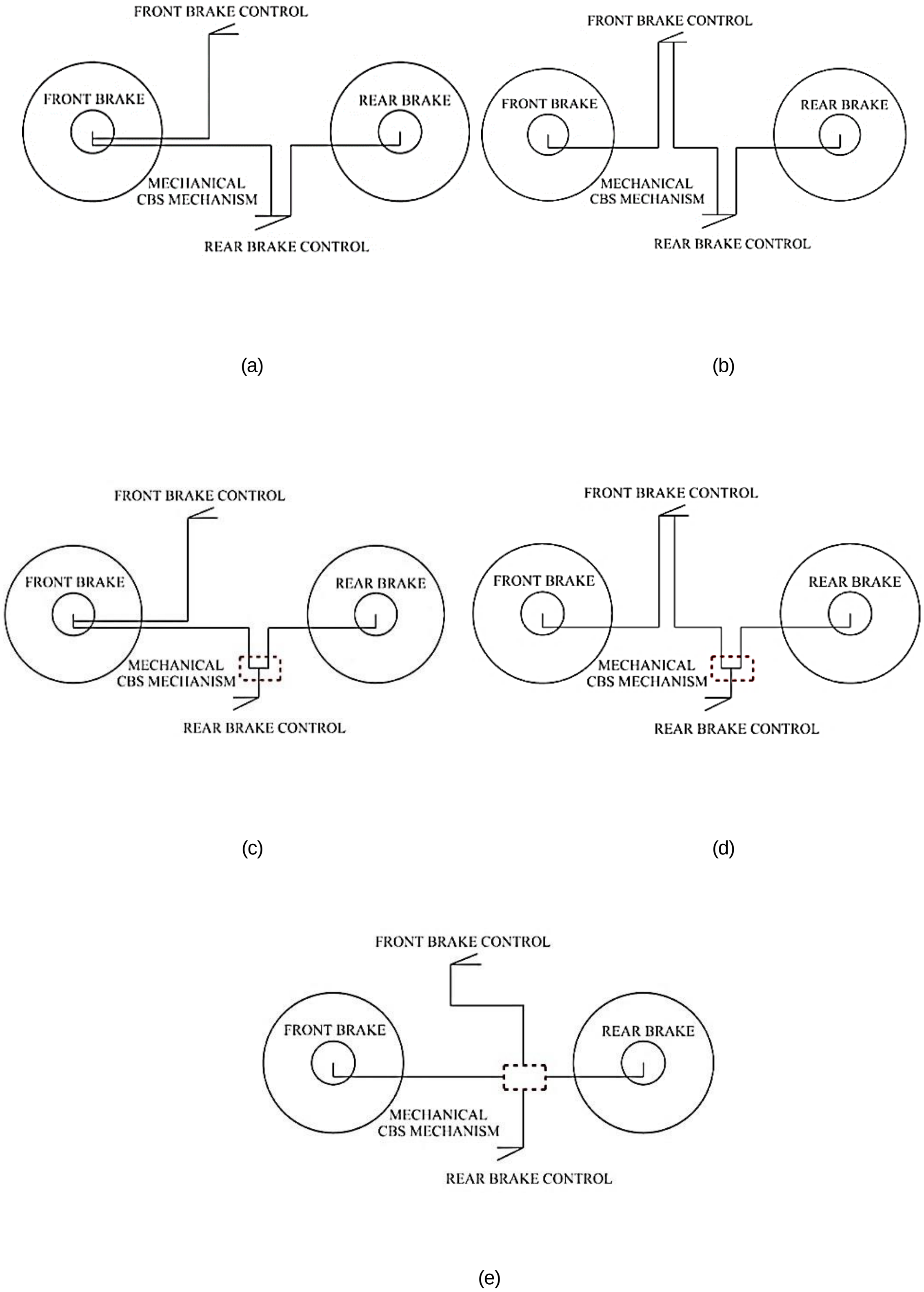

Figure 1. Layout Design of mCBS; a) Front Integrated mCBS Mechanism; b) Integrated linked mCBS Mechanism; c) Direct mCBS Mechanism; d) Linked mCBS Mechanism; and e) Dual mCBS Mechanism

3.0 DEVELOPMENT ON THE MECHANICAL CBS MECHANISM

The mCBS mechanism that was used on the light motorbikes has evolved since 1996. Table 1 presents related studies on the mCBS mechanism. The table provides a detailed overview of the mCBS layout design, categorizes the mCBS mechanism type, and evaluates the force distribution performance of the mCBS mechanism. Previous researchers proposed a mCBS for light motorbikes [7]. Its design facilitates the synchronized operation of braking on both wheels. The brake type on the front and rear motorbike by this system is hydraulic and mechanical, respectively. This system necessitates the individual engagement of the brake lever located on the motorbike's left section. The mCBS mechanism is employed to establish a connection with the brake lever on the left section. Two cables were connected to this mechanism which is rear brake cable and the transmitting cable. The mechanism directly actuates the drum brake. The transmitting brake cable actuates the front brake upon engagement of the brake lever positioned to the motorbike's right section. Thus, both brakes are synchronized. Regrettably, this mechanism results in a purely linear distribution of generated brake force.

Despite being synchronized through the activation of the rear control which is via a lever that was on the motorbike's left side, the control can also be performed by pressing a pedal brake. This design allows a motorbike with the mechanical type of brakes that are installed on both wheels to actuate concurrently via the rear controller known as the foot pedal. The mCBS mechanism was placed on the foot pedal [8]. The mechanism is anchored to the motorbike frame. It connects to the rear brake through a linking component. A brake cable is used to connect it to the front brake. A bell crank is responsible for managing the operation of three brake cables. The brake cable is responsible for activating the front wheel brake through the bell crank. The front wheel's brake is actuated by the input force, which is transmitted by the third cable, while the first two brake cables serve as inputs. Input to the bell crank comes from the pedal and lever brake. When the right lever is engaged, the bell crank directs force exclusively to the front brake. Meanwhile, the brake foot pedal activates both brakes simultaneously for immediate response. Throughout these operations, the force distribution remains consistently linear, ensuring stable and predictable braking performance.

Table 1. Related studies for mechanical types single CBS

No	Author/Year	The description on mCBS mechanism	CBS Layout design	Force distribution
1	Y. Okazaki et al. (1996) (Okazaki et al., 1996)	Hand Lever mCBS Mechanism	mCBS Mechanism Linked to Front Control	Linear
2	Y.Okazaki (2000) (Okazaki, 2000)	Foot Pedal mCBS Mechanism	mCBS Mechanism Linked to Front Control	Linear
3	Y. Okazaki (2003) (Okazaki, 2003)	Cable-Driven mCBS Mechanism	Dual Input mCBS Mechanism	Linear
4	Y. Okazaki (2004) (Okazaki, 2004)	Swing Supported mCBS Mechanism	mCBS Mechanism Linked to Front Control	Linear
5	O.Uchida et al. (2009) (O. Uchida et al., 2009)	Hybrid Linked mCBS Mechanism	mCBS Mechanism Direct to Front Control	Linear
6	S.Saito et al. (2010) (Saito & Tanaka, 2010)	Single Cable Driven mCBS Mechanism	mCBS Mechanism Direct to Front Control	Linear
7	S. Vinodh et al. (2010) (Vinodh & Arun, 2010)	Two mounting points on the foot pedal	Integrated mCBS Mechanism Direct to Front Brake	Linear

8	S. Ghosh et al. (2014) (Ghosh et al., 2014)	Two Mounting Point Brake Lever	Integrated mCBS Mechanism Direct to Front Brake	Linear
9	W.Yiping (2014) (Yiping, 2014)	Combined rocking arm control by a foot pedal	mCBS Mechanism Linked to Front Control	Linear
10	V. Valli et al. (2014) (Valli et al., 2014)	Brake Lever with Distributor Embedded	Integrated mCBS Mechanism Direct to Front Brake	Linear
11	Y.Uchida et al. (2015) (Y. Uchida et al., 2015)	Window Connected mCBS Mechanism	mCBS Mechanism Direct to Front Control	Linear
12	S.Mohan et al. (2015) (Mohan et al., 2015)	Brake Lever with Reaction-Relay Member	Integrated mCBS Mechanism Direct to Front Brake	Linear
13	K. Tani et al. (2015) (Tani & Nakamura, 2015)	Distributor Link mCBS Mechanism	Integrated mCBS Mechanism Direct to Front Brake	Linear
14	Q.Zeng et al. (2015) (Zeng et al., 2015)	Nonlinear mCBS Mechanism	Dual Input mCBS Mechanism	Variable non-linear
15	S.Mohan et al. (2016) (Mohan et al., 2016)	Enhancement Version of Brake Lever with Reaction-Relay Member	Integrated mCBS Mechanism Direct to Front Brake	Linear
16	T.Horiuchi et al. (2017) (Horiuchi & Saito, 2017)	Brake Foot Pedal with Mechanism Attachment	Integrated mCBS Mechanism Direct to Front Brake	Linear
17	C.Tseng et al. (2017) (Tseng et al., 2017)	Enhancement of Nonlinear mCBS Mechanism	Dual Input mCBS Mechanism	Variable
18	W.Guoxiong (2018) (Guoxiong, 2018)	Hybrid Rocker Type mCBS Mechanism	Dual Input mCBS Mechanism	Linear
19	Y.Lin et al. (2021) (Lin et al., 2021)	Variable mCBS by Swingarm Mechanism	Dual Input mCBS Mechanism	Variable

Another proposed mCBS mechanism is designed for motorbikes equipped with a lever brake that is controlled via hand for both brakes. For this development, the mechanism is connected to both hand lever brake controls through brake cable linkage [9]. In this cable-driven mCBS mechanism, the attached cable actuates a brake that controls both wheels of the motorbike. The said mechanism achieves concurrent brake engagement towards all wheels during the activation of the lever brake placed to the left section of the motorbike. The control of the front side was triggered by an action of the right lever pulling the brake cable. This cable was actuated via the joint member that connected the brake cable control as well as the front brake cable. Now, the disengagement of the mechanism is facilitated by the elongated hole embedded with joint member's design. Therefore, this action deactivates the brake on the rear section and activates a braking action towards front side individually. Given that the point of pull on the mechanism is kept in a stationary position, the proportion of brake force distribution stays unchanged. An additional design was developed to achieve a linear force distribution [10]. It represents an enhanced version, incorporating a bell crank mechanism. Here, the synchronization of braking action between the rear and front brakes is achieved by a swing-supported mCBS mechanism. The mechanism actively engages the rear brake arm to facilitate operation.

These rear brake arms are responsible for controlling the expansion of the shoe brake that is contained within the mechanical brake hub. The rear brake arm is activated through a brake connecting link when the brake foot pedal is operated. As a consequence of this motion, the drum brake found on the rear wheel is activated. The bell crank is operated by the swing-supported mCBS mechanism through the brake cable in conjunction with this response. The activation of the front wheel brake ensures that both wheels are interlocked in their braking action.

The introduction of the hybrid operation of the mCBS mechanism represents an innovative development in braking systems [11]. The mechanism's design is integrated into the hydraulic master cylinder, enabling simultaneous operation of the brakes. The operation of this hybrid apparatus is managed by the brake lever which is positioned on the right side of the motorbike. This lever activates both the hydraulic and mechanical brakes concurrently. At this moment, the mechanism within the hybrid device draws the rear brake cable and actively presses against the hydraulic master cylinder. This operation was achieved through the integrated knocker design. In the meantime, the brake on the front is solely regulated by the brake lever that easily accesses the right section of the motorbike. Even with this configuration, the suggestion of a hybrid rocker-type mCBS mechanism has been put forward [12]. The system that has been proposed encompasses components such as the rocker arm bracket, cylinder body, pushrod, rocker arm, and piston. Both hydraulic oil inlet and outlet ports are featured on the cylinder body. Utilizing the cylinder body, hydraulic pressure is transferred from the master cylinder to the front brake caliper whenever the right lever is pulled. Subsequently, the system solely applies the brakes to the front of the motorbike. Nevertheless, the engagement of the rear drum brake is initiated by the actuation of the lever for rear control, which is located on the left section of the motorbike. This is accomplished through the brake cable mechanism. Concurrently, the rocker arm that is attached to the cylinder body is responsible for activating the pushrod, which results in the generation of hydraulic pressure within the cylinder body. This pressure is then directed to the caliper of the front brake system for application. Activating the rear brake at this point simultaneously engages the front brake. However, both hybrid types are still unable to achieve nonlinear force distribution due to the use of a fixed mechanism in this design.

The mCBS design has undergone further refinements, resulting in enhanced functionality and streamlined complexity. The elimination of the bell crank device has been proposed to simplify the working framework. In the proposed system, individual control of the drum brake for the front is facilitated through a right-section lever that controls the brake activation of motorbike, which utilizes a dedicated brake cable for operation. Meanwhile, the brake lever placed on the left section performs synchronous front-to-rear braking via a single cable-driven mCBS mechanism [13]. The rear drum brake is actuated by one brake cable, whereas a separate brake cable engages the front brake, ensuring synchronized braking performance. In this design, two brake cables were connected to the front brake for enhanced control and efficiency. The enhancement of the front brake arm was implemented to optimize performance. To position two front brake cables, two elongated holes were made. The reciprocal sliding action of one brake wire was made easier by the extended hole, which was also responsible for the tensioning of another brake cable. The distribution of force on all brakes for this design is constrained to linear distribution. In addition to this, a new single cable-driven mCBS mechanism has been designed [14]. This mCBS mechanism includes a window that connects to the mechanism case, ensuring distinctiveness in its design. The mCBS mechanism integrates a sizable, rectangular window that enhances external visibility of the system. This design feature allows observers to directly observe the intricate workings of the mCBS mechanism. Additionally, the modified version of arm for front brake is characterized by two elongated apertures, contributing to its improved functionality. Upon the brake lever that was on the motorbike’s right side activates, it causes the front-connected cable to tension the modified brake arm. Simultaneously, the other cable is able to slide freely through the elongated aperture. Activating the system, which subsequently transmits forces through a cable to both brakes, is accomplished by pressing the lever that was on the motorbike’s left side. This coordinated action ensures a linear force distribution across both wheels during braking.

The utilization of an improved front brake arm, featuring two elongated holes, represents an economical and straightforward design approach for mCBS systems. Remarkably, this concept has been successfully implemented in other mCBS designs as well. The modified brake arm is directly connected to the brake foot pedal via a cable linkage, facilitating simultaneous activation of both brakes. An additional connection cable linked to the modified brake arm connects to the brake lever located on the right side of the motorbike, allowing for the activation of the front brake independently. Furthermore, an alternative mCBS design incorporating a modified brake arm and utilizing a dual mounting point hand brake lever has been introduced. Similar to the conventional braking system, this design allows for the individual front brakes to be activated when the brake lever located on the right side of the motorcycle is pressed. However, simultaneous brake activation occurs when the brake lever that was on the motorbike's left side is engaged. The brake lever on the left section of the motorbike, equipped with two mounting points, offers an effective configuration for brake activation [15]. One connection point is attached directly to the rear brake, while the other end is linked to the modified brake arm. Both proposed designs incorporate a modified brake arm with two fixed actuation points. This design limitation precludes achieving nonlinear force distribution. Regardless of utilizing the modified brake arm, a new design featuring a movable arm with linkages has been proposed to address the issue [16]. The rear brake arm and modified front brake arm are connected by the linkages. In light of this, pressing the foot pedal for the brakes causes the interlock braking mechanism to become active. The actuation of the brake lever that was located on the right side of the motorbike achieves individual braking action on the front brake. The braking actuation of the motorbike, which is equipped with drum brakes on both wheels, is synchronized by the proposed system. In this system, both brakes activate simultaneously when force is applied to the brake foot pedal. One end of the mechanism is connected to the rear brake transmission member, while the other end is connected to the front transmission member. The brake pedal is connected to the mechanism, allowing braking actuation on both wheels concurrently. The setup utilizes a modified brake arm for front brake activation, enabling interlocked action when the brake pedal is pressed and allowing single activation of the front brake when operated by the brake lever on the motorbike's right side.

The refinement of the earlier mCBS concept, which employs two mounted brake levers to coordinate brake activation. In the new configuration, a brake lever featuring an integrated distributor connects to a modified brake arm [17]. Conversely, an alternative mCBS system with a similar concept was introduced, employing a brake lever equipped with a reaction-relay member instead of the distributor-embedded lever [18]. Subsequently, an enhanced version of the brake lever featuring the reaction-relay member was proposed [19]. Notably, the actuation point in both designs remains fixed during operation, resulting in a limited linear distribution of brake force across both wheels. The distributor-linked mCBS mechanism system comprises several key components: the foot pedal, distributor link, delay spring, master cylinder, and two pressure-input brake calipers [20]. When the brake lever that was on the motorbike's right side is actuated, hydraulic pressure is produced within the front master cylinder and conveyed to the front brake caliper, resulting in the independent activation of the front brake. Conversely, by pressing the brake foot pedal, actuation of the brakes is achieved in a synchronized manner. When pressure is exerted on the pedal, the rear drum brake lever is actuated by the brake rod, triggering the activation of the rear brake. The delayed spring controls the timing of brake actuation, ensuring that the rear brake engages before the front brake. Further depression of the brake foot pedal generates hydraulic pressure in the master cylinder, which is then transmitted to the front brake caliper, resulting in interlocking brake action. The experimental analysis carried out on an identical motorbike indicates that this CBS system notably enhances the performance of braking. The CBS system achieves a stopping distance of 27.3 meters, which signifies a reduction of 34% in comparison to the stopping distance of 41.4 meters by the non-CBS once the solely pressed of foot pedal. However, it is important to note that this arrangement continues to produce a linear distribution of the brake force. Existing studies predominantly focus on fixed mCBS mechanisms for synchronizing brake actuation between the front and rear wheels, resulting in limited linear brake force distribution from this design.

Zeng introduced an innovative mCBS mechanism characterized by nonlinear brake force distribution [21]. When the brake lever on the left section activates, this system seamlessly synchronizes braking actions while dynamically adjusting the ratio between both wheel's brakes. The device comprises six essential components: a front lever, swing rear lever, swing arm, rear lever, roller, and spring. The front lever features a strategically designed elongated aperture, enabling precise single-point actuation of the front brake while simultaneously ensuring coordinated movement across the entire front brake assembly. Specifically, the cable control for front brake connects to this lever on one side, while the actuation front cable is meticulously attached to the opposite side. Meanwhile, the rear brake control cable is connected to the swing rear lever, and the roller is responsible for securing the opposite end of the cable. A spring that has been thoughtfully attached to the roller shaft makes the retraction process even more smooth. While this is happening, the rear brake cable that is used for actuation is connected to the rear lever, which is still attached to the swing arm. Upon the brake lever on the left section of the motorbike is engaged, the control cable for the rear brake exerts tension on the rear's swing lever. As a result, the surface of the swing arm is smoothly glided upon by the roller, resulting in the activation of the swing arm itself. This dynamic force transmission ensures effective activation of both brakes located on the front and rear motorbike.

Continued operation of the brake lever on the left section of the motorbike results in the movement of the swing arm's actuation point converging to the point where the activation of the front brake occurred. Consequently, the activation ratio on the front-to-rear brakes shifts, enabling the distribution of nonlinear brake forces. The automatic control of the front-to-rear brake ratio is regulated via the movement of the lever brake which is positioned on the motorbike's left section. The design of the swing arm specifically its slope and height plays a significant role in determining the distribution forces. Tseng (2017) proposed an enhancement to this nonlinear mCBS mechanism, which enables a wide range of variable brake ratios. Notably, the operational principles of this enhanced device remain consistent with those described in the initial nonlinear mCBS mechanism [22].

4.0 CONCLUSION

The study was conducted by reviewing the mechanical type of combined brake system (mCBS) for light motorbikes. It consists of mCBS layout, evolution, and performance. Since 1996, CBS mechanisms have evolved into single CBS and Dual CBS (D-CBS). It was observed that there are five distinct types of layout design for mCBS. These layouts include integrated front brake mechanisms and dual input methods controlling both brakes. Integrating a distinct brake system and actuation control requires this arrangement layout. This mechanism is designed to optimize the performance of the motorbike in terms of stability and wheel stop during braking events. However, many designs of mCBS mechanisms are limited to linear brake force distribution. The best braking force distribution of the motorbike necessitated a nonlinear configuration. Recent developments showed that the mCBS mechanism was capable of varying the brake force ratio. Thus, the braking force distribution with a nonlinear configuration could be managed effectively. Legislation in the EU, India, Taiwan, and Japan emphasizes the need for innovation and the growing relevance of these systems. Future research should focus on developing sophisticated models for nonlinear brake force distribution and exploring new technologies to enhance the effectiveness and affordability of these braking systems.

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