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Motor on drum - A revolutionizing solution for EPB function in modern vehicles.

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Abstract - In today's modern world, vehicles are becoming more & more sophisticated & advanced with cutting edge technologies employing very interesting & useful features for ultimate customer satisfaction & delight. In this feature list one of the most promising feature & selling USP is EPB (Electric/Electronic parking brake) Feature.

As of today, if any OEM intents to provide the EPB feature in any vehicle, it left with no option other than to use disc brake system with EPB only. This is called as MOC (Motor on Caliper) concept. It includes Hydraulic disc brake system with a brake disc & a brake Caliper on which an electric motor is mounted which push the piston mechanically to operate the parking brake. As we know that disc brake systems are always costlier options as compared to drum brake assembly due to more complexities & precise machining.

This paper explores the very innovative & revolutionizing concept of Motor on Drum (MOD) system which is first time in India & redefining Electric Parking Brake (EPB) technology, offering a smarter, more cost-effective, and innovative alternative to the traditional Motor-on-Caliper (MoC) system. As modern vehicles, particularly HEVs and BEVs, demand compact, efficient, and intelligent braking solutions, MoD technology delivers enhanced performance, reduced complexity, and lower manufacturing costs. By integrating the EPB actuator directly into the drum brake, MoD provides simpler arrangement avoiding complexities & also without compromising on any functionality of MOC. This design simplifies system integration, making it an ideal choice for next-generation vehicles.

In this paper MOD smart functionality is explained in detailed also MOD performance is compared with MOC in respect of static performance like holding a vehicle on different gradients, in dynamic condition, parking brake performance in respect of MFDD & stopping distance is also compared. Keeping inline performance, MOD being more affordable and easier to implement. With its strong potential for future mobility solutions, MoD is set to revolutionize EPB technology, making braking systems smarter, more efficient, and future-ready.

I. INTRODUCTION

In today's scenario, EPB feature is an integral part of most of the modern vehicles like HEVs & BEVs. This feature comes with standard arrangement of motor on caliper (MOC) assembly. Disc brake with EPB feature is quite complex & costlier option that is why EPB feature is limited to premium segment vehicles only. This feature is out of reach for mass public. Even today most of the economic range vehicles are fitted with conventional drum brake assemblies at rear axle with parking lever arrangement due to stringent cost targets.

There is a pressing need in market to develop a cost effective yet efficient option to EPB so that this feature can be adopted in economic vehicles also & mass public can enjoy the benefits of EPB feature. An innovative move in this direction is MOD option which is at par in performance compared with MOC yet around 20% cost effective & maintains all the smart functionality of MOC supporting advanced safety features, such as automatic engagement when the engine is turned off, integration with hill-start assist, and the ability to interface with other electronic systems like automatic emergency braking and traction control.

II. LITERATURE SURVEY

Electric Parking Brake (EPB) technology has evolved from conventional cable-actuated systems to electronically controlled mechanisms aimed at improving safety, driver comfort, and system integration. The dominant Motor-on-Caliper (MOC) approach, though widely adopted, presents several limitations in terms of cost, complexity, and packaging. Recent research and development have shifted toward Motor-on-Drum (MOD) systems, especially in the context of electric and connected vehicles where efficiency and integration flexibility are key.

MOC-based EPB systems gained popularity due to their relatively straightforward integration with rear disc brakes and established electronic control logic. Bosch introduced one of the earliest MoC systems, with operational logic and actuator designs detailed in SAE Technical Paper 2004-01-

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2764. Hwang et al. developed control strategies for EPB slope-hold functionality using motor current feedback and vehicle inclination sensing. Their work emphasized real-time control and safety monitoring in EPB systems detailed in "Design of Intelligent EPB Control Algorithm," *Int. J. Automot. Technol.*, 11(6):865–872, 2010.At the VDI Congress (2012), Müller et al. examined the mechanical and thermal stress on MoC actuators during repeated operation, highlighting concerns around actuator longevity in varying environmental conditions [3].

Despite their widespread use, MoC systems face persistent issues like increased unsprung mass due to the caliper mounted motor & gear box studied in detailed by Singh, A. and Mehta, R., in the SAE paper on "Weight Optimization in EPB Design," SAE Technical Paper 2016-01-0430.A comparative analysis presented by Kaur, S. and Limaye, P. in their paper on "Architectural Optimization of EPB Systems for Future EVs," SAE Technical Paper 2020-01-0402, 2020 confirmed that MoC systems add significant mass and require more complex calibration and diagnostic logic compared to newer EPB designs.

Motor-on-Drum (MOD) EPB systems have been developed to simplify architecture, reduce cost, and improve protection against environmental exposure. These systems integrate the electric motor within the drum brake assembly, using a sealed actuator to engage the brake shoes directly. Brakes India unveiled an indigenous MOD EPB system in 2023 that complies with global performance standards. Though not published in journals yet, the development was showcased at Auto Expo 2023 and covered in industry press [7]. Continental's EPB-Si (Smart Integration) technology, presented at the IZB Supplier Fair 2022, represents a commercial MoD implementation with reduced part count, improved protection, and better energy efficiency. Continental's internal whitepaper highlights reduced brake drag and better cost-effectiveness in EV applications [8]. ZF Friedrichshafen AG also published a whitepaper discussing future EPB trends, identifying MoD as a key enabler for affordable electrified mobility platforms in emerging markets [9]. A comparative hardware and packaging study done in SAE Paper 2020-01-0402 documented a 35% weight reduction and 20–25% cost savings when switching from MoC to MoD, making the latter highly favourable for BEVs and small EVs.

Although MoC systems are well-documented, MOD literature is still emerging. This paper aims to address the gaps like comparative study of MOC & MOD performance tested on physical vehicle in static & dynamic conditions, explained detailed working & explore MOD functions in detailed considering requirements from modern vehicles in respect of advance safety.

III. MOD CONSTRUCTION & WORKING

As shown in below imag1, Actuator is mounted on back plate of brake drum assembly. Actuator contains motor, worm, pinion & short cable. Worm & pinion arrangement converts rotary motion of worm in to linear motion of lead screw which is connected to the pinion. One end of short cable is connected to the lead screw & other end to the parking brake lever. This entire actuator assembly is mounted on the back plate of drum brake assembly. When Motor is rotated in forward direction, Cable pulls the Parking lever to achieve the desired clamp force. When Motor is rotated in the reverse direction, Cable gets released and the clamp force is released.

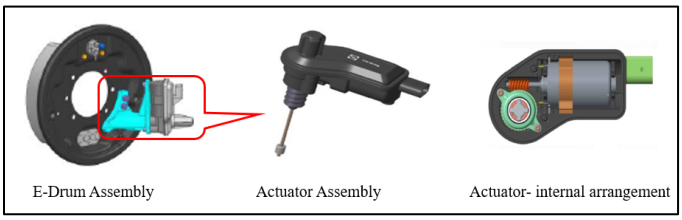

Fig. 1. MOD actuator details

Given below is the process sequence & operation of EPB apply & release function.

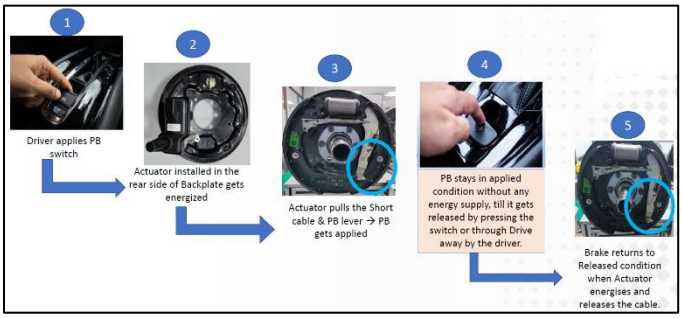

Fig. 2. Step By Step MoD Working

Step-1:- Driver press the EPB switch up provided on central console inside the cabin

Step-2:- Actuator (Motor with worm & pinion arrangement) which is installed on back plate of brake assembly gets energized.

Step-3:- Actuator pulls the short cable which is engaged with parking lever at one end & lead screw pinion arrangement at other end. Thus, parking brake gets applied as lever gets pulled.

Step-4:- once applied, parking brake stays in applied condition without any power supply. Once EPB switch in cabin is pressed down, release function will activate.

Step-5:- When EPB switch is pressed down, actuator gets energized & pinion turns in reverse direction & cable gets released & thus lever comes to home position & parking brake gets released.

IV. COMPARATIVE ANALYSIS: MOD VS MOC SYSTEM

A. Design and Complexity

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MoC systems require the integration of electric motors onto each brake caliper, adding to the system's complexity and weight. In contrast, MoD systems centralize the actuator mechanism within the drum brake, streamlining the design and reducing the overall number of components. This simplification not only enhances reliability but also facilitates easier maintenance and assembly processes.

B. Weight and Space Considerations

The compact nature of MoD systems contributes to significant weight savings. Modern drum brake design has achieved a mass reduction of approximately 35%, additionally, the elimination of traditional handbrake levers frees up valuable cabin space, a critical advantage in the design of modern vehicles.

C. Performance and Efficiency

MoD systems offer superior clamping efficiency and reduced residual torque compared to MoC systems. The inherent design of drum brakes ensures minimal residual torque, which is beneficial for maximizing the range of EVs and BEVs, Furthermore, the enclosed nature of drum brakes protects against corrosion, maintaining consistent performance over time.

D. Cost Implications

The reduction in component count and simplified assembly processes translate to lower manufacturing costs for MoD systems. Modern MoD brake system exemplifies this cost-effectiveness, being up to 20% cheaper than traditional MoC-based EPB systems. This affordability makes MoD technology an attractive option for widespread adoption across various vehicle segments.

Following table shows summarised comparative analysis of MOD Vs MOC

TABLE 1: SUMMARISED COMPARATIVE ANALYSIS OF MOD VS MOC

Parameter	MoC System	MoD System	Improvement with MoD
Component Count	High	Lower	Simplified design
Unsprung Mass	Higher due to caliper motor	Reduced	~35% lighter
Cost per Unit	Higher	Lower	~20% lower
Environmental Protection	Moderate (exposed motor)	High (sealed drum)	Improved corrosion resistance
Holding Force	Sufficient	Equal or better	Higher at lower motor torque
Thermal Sensitivity	Higher due to disc exposure	Lower due to enclosed system	Stable across temp ranges
Maintenance Frequency	Moderate	Low	Less prone to debris-related issues
Connectivity Compatibility	High	High	Equal, supports ECU features

V. MOD FUNCTIONS

In MOD all the functionality of MOC is maintained without compromise. Advance safety features like auto vehicle hold, hill hold assist, comfort & convenience features like auto apply & release, drive away assist etc. can be easily integrated within MOD. In addition to this MOD hardware & software is Compatible with other vehicle ECUs, like Adaptive cruise control. EPB Can function based on commands received from any other ECUs in vehicle if needed. Thus, MOD has capabilities of integration with modern Evs, BEVs & connected vehicles by collaborating with the vehicle's Electronic Control Unit (ECU). MOD functions are categorized as safety, comfort & servicing/maintenance functions.

A. MOD Safety Functions

MOD Safety functions are summarized & explained in below table-2

TABLE 2: SUMMARY OF MOD SAFETY FUNCTIONS

Static mode	Dynamic Mode	Ignition off mode	Limp home mode
Switch Apply/Release:- Basic Parking brake function On/OFF manually when EPB switch is pulled/pressed	**Electronic controlled deceleration (ECD):-** In dynamic mode, service brake will get applied if anybody pull the parking switch. Provided accelerator pedal is not pressed	**Switch apply: -** In ignition -off mode, EPB can be applied by switch also. **Child Lock: -** unless ignition is on & service brake pedal is pressed, EPB release function will not happen.	**Dynamic standstill detection:-** If no ECD & RWU function works then EPB will take signal from G-sensor & apply the parking brake
Roll away detection:- Adjust the clamp load & re-clamp if wheel movement is detected after initial parking	**Rear wheel unlocker (RWU): -** In dynamic mode if service brake fails & driver applies parking, it will decelerate the vehicle without rear wheel locking.		**Fall back for G-sensor signal failure:-** If G sensor also fails then it will apply the EPB function automatically.

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Engine stall logic: - Avoid Rolling back of vehicle while ascending the slope. Apply is automatic & Release is manual.			

B. MOD Comfort Functions

MOD comfort functions are summarized & explained in below table-3

TABLE 3: SUMMARY OF MOD COMFORT FUNCTIONS

Static mode	Ignition off mode
Drive Away Assist: - Vehicle is on, driver moves out- parking brake gets applied automatically. Driver comes back, press the accelerator- parking brake gets released automatically.	**Auto Apply: -** EPB will be applied automatically when ignition is off **Auto Adjust: -** parking Cable adjustment is done automatically in liner wear condition.
Gradient dependent apply (GDA)- Clamping force magnitude for applying the parking brake is automatically decided by EPB. Not dependent on drivers input like in manual parking brake.	
External apply/release: - Compatible with other vehicle ECUs, like Adaptive cruise control. EPB Can function based on commands received from any other ECUs in vehicle if needed.	

C. MOD Servicing/Maintenance Functions

MOD servicing/maintenance functions are summarized & explained in below table-4

TABLE 4: SUMMARY OF MOD SERVICE/MAINTENANCE FUNCTIONS

Static mode	Limp home mode
Liner change mode: - This is done by diagnostic tool while doing any servicing & maintenance activity on vehicle. This function will disable the EPB function	**Switch release:-** No wheel speed signals required for EPB release function
Diagnostics: - Diagnostic tool is used to check the functions externally, find out faults & for trouble shooting if any.	

VI. VEHICLE TEST SET UP & TEST RESULTS

For vehicle testing, various instruments like IMC data logger, GPS (global positioning system), speed sensors, pedal effort sensors, pedal travel sensor, were installed on vehicle. Parking brake trials & pedal feel trials were conducted in laden condition.

Vehicle trials were conducted back to back on two vehicles of same make & same model. One vehicle was fitted with MOC where as other was fitted with MOD system. Below trials were conducted back to back in different test condition & performance of MOD was compared with MOC.

Test conditions

1. Static Parking brake test on different gradients to check gradient dependant apply/release function.
2. Dynamic Parking brake test at different speeds to measure mean fully developed deceleration (MFDD) & stopping distance.
3. Dynamic service brake test to compare the pedal feel (pedal effort & pedal travel) when switched from MOC to MOD

Test results of condition 1 & 2 are summarized in below table-5

TABLE 5: VEHICLE TEST RESULTS SUMMARY OF PARKING BRAKE TRIALS

Parameters	Vehicle Level Targets	MOC System	MOD System
Static Parking Brake test			
Parking at 12.5% Gradient Roll away distance - Nose up/ Nose down	≤ 100 mm	0	0
Parking at 18.2% Gradient Roll away distance - Nose up/ Nose down	≤ 100 mm	0	0
Parking at 26% Gradient Roll away distance - Nose up/ Nose down	≤ 100 mm	0	0
Dynamic Parking Brake test			
MFDD at 30-0 km/h	≥ 2 m/s2	4.2	4.1
Stopping distance at 30-0 km/h	≤ 20 m	16	19
MFDD at 100-0 km/h	≥ 4 m/s2	5.4	4.7

In static parking brake test it is evident that EPB function of gradient dependent apply feature is comparable in MOC &

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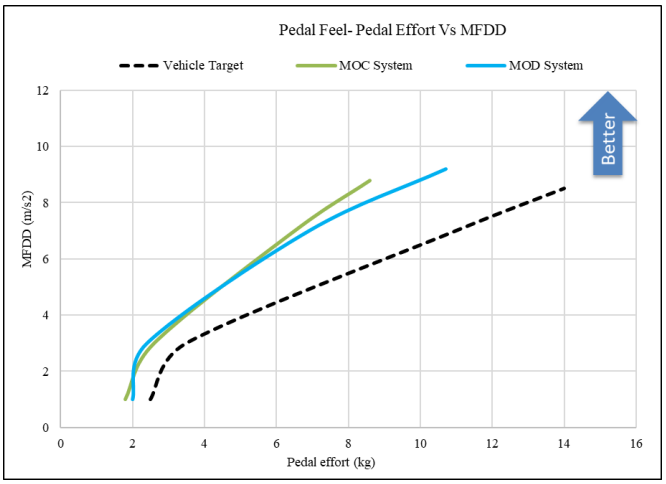
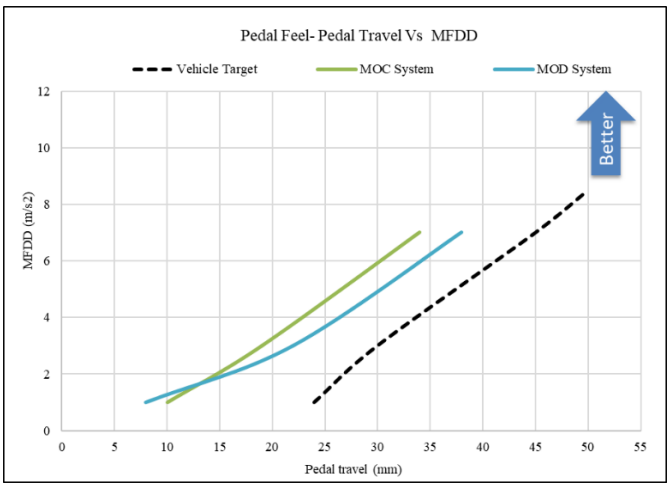
MOD. There is no roll away distance observed in both nose up & nose down condition on different gradients.

In dynamic parking test, mean fully developed deceleration & stopping distance with MOD is comparable with MOC & meeting the vehicle level targets.

Test results of condition 3 are summarized in below graphs



Graph 1: Pedal Effort Vs MFDD



Graph 2: Pedal Travel Vs MFDD

From above graphs it is evident that there is no drastic change in pedal feel in terms of pedal effort & travel if one switch from MOC to MOD system on vehicle. This test is necessary as shifting from disc brake system to drum brake system needs critical evaluation of brake performance & pedal feel characteristic. If there is perusable difference in pedal feel & performance by the driver this may result in customer dissatisfaction. From above test results, it is evident that performance & pedal feel of MOC & MOD is comparable.

VII. ADVANTAGES OF MOD OVER MOC

A. *Space Efficiency /Compact Integration*

MOD systems are better for integration in smaller space (smaller wheels), Actuator/Motor integration is more easy & simple compared to MOC

B. *Cost-Effectiveness*

Drum brakes, in general, are less expensive to than disc brakes. MOD systems can be a cost-effective option for economical range of vehicles.

C. *Durability and Longevity*

Drum brakes are better protected from dirt, moisture, and debris compared to disc brakes. This can lead to longer-lasting performance in certain environments

D. *Parking Brake Functionality:*

Drum brakes are traditionally used for parking brake functionality. So the MOD system can be easily integrated directly into the drum brake assembly

E. *Reduced Noise:*

Drum brakes generally produce less noise compared to disc brakes. The motor-on-drum system can maintain this quieter operation

F. *Enhanced Brake Force Distribution:*

Drum brakes can provide more gradual and uniform brake force distribution, which can be advantageous for certain driving conditions and load distributions.

VIII. FUTURE OUTLOOK

The trajectory of automotive innovation points towards increased adoption of MoD systems. As manufacturers strive for more efficient, cost-effective, and intelligent braking solutions, MOD technology stands out as a promising candidate. Ongoing research and development efforts are expected to further enhance the performance and integration capabilities of MOD systems, solidifying their role in the future of automotive braking technology.

IX. CONCLUSION

From test data, it is evident that MOD performance is in line with MOC performance in both static as well as dynamic conditions. Inspite of that, MOD arrangement is cheaper & light weight as compared to MOC. In addition to these distinct benefits, MOD can take care of all the advance safety functionalities similar to MOC without any compromise.so it can be concluded that Motor-on-Drum technology represents a significant advancement in Electric Parking Brake systems,

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offering a smart, cost-effective, and efficient alternative to traditional Motor-on-Caliper system.

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XI. DEFINITIONS/ABBREVIATIONS

MOD	Motor on drum
MOC	Motor on caliper.
EPB	Electric parking brake
HEV	Hybrid electric vehicle
BEV	Battery electric vehicle
MFDD	Mean fully developed deceleration
ECD	Electronic controlled deceleration
RWU	Rear Wheel unlocker
GDA	Gradient dependent apply
ECU	Electronic control unit

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