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A CONCEPTUAL MODEL FOR SUPPLEMENT BRAKING SYSTEMS IN AUTOMOBILES FOR DEMANDING CIRCUMSTANCES

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Abstract

Supplement braking systems serve as backup or enhancement mechanisms when primary hydraulic brakes face extreme conditions like brake fade, hydraulic failure, or extended heavy braking demands (mountain descents, heavy loads, emergency scenarios). Since the brake system is one of the most crucial control systems in cars, it is not an exception to the periodic advancements in technology. Driving is a complex task that requires the correlation of numerous cognitive aspects, such as observing the state of the road, recognizing it in light of the circumstances, and making a quick and appropriate decision. In addition to the foot-operated brakes used in the current models of automobiles, we suggest an additional mechanism that a co-passenger sitting next to the driver can use to apply the brakes when necessary. The Supplement Braking System (SBS) mechanism, which would be used in a variety of demanding scenarios to boost passenger and vehicle safety, is conceptually modeled and developed in this study. The SBS is primarily useful when the driver is unable to manage the vehicle because of illness, such as when driving uphill and it gives the co-passenger a chance to reduce the causation. This conceptual model prioritizes safety through redundancy while maintaining vehicle controllability under extreme braking demands. The system would require extensive testing and regulatory approval before implementation.

Keywords and phrases: braking system, safety, automotive, emergency brake.

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1. Introduction

Automobiles are the common means of transporting for both cargos and human beings, for long time. Research on this field is more exiting as many dynamic situations arise while driving from one place to another. There are many situations on which researches has focused and as a result the journey has become more comfort and luxurious. Especially the research on steering system, suspension system, braking system, air conditioning, transmission system, chassis design, engine design and safety aspects has brought many changes in automobiles. In spite of all these improvements, the death due to mishaps or injuries is a common issue in daily news. The reason for a mishap is dynamic and varies from one to another mishap. In the present conceptual model, a supplement brake is introduced to take care of the situations while slow moving in up-hills areas or flyover, fatal malfunction of driver, old and physically challenged persons and during parking. Supplemental braking systems enhance vehicle safety and performance beyond conventional braking, particularly in challenging or high-performance scenarios. These systems fall into several key categories:

(a) Automatic Emergency Braking (AEB) systems

AEB systems use multiple sensor technologies that work together to detect crash-imminent situations and automatically apply brakes if the driver has not done so, or apply additional braking force to supplement the driver's braking. The new Federal Motor Vehicle Safety Standard FMVSS No. 127 now makes automatic emergency braking standard in all cars and light trucks.

- Multi-sensor detection (radar, cameras, LiDAR).
- Pedestrian detection capabilities.
- Projected to save at least 360 lives annually and reduce injuries by at least 24,000 when fully implemented.

(b) Integrated braking systems

Modern braking systems are designed for various requirements including conventional drives, hybrid drives, electric drives, and automated driving. For high-performance electric vehicles, carbon ceramic brakes remain crucial for handling high speeds and providing reliable stopping power, complementing regenerative braking systems

(c) Towing and RV applications

For demanding towing situations, supplemental braking systems include breakaway switches that automatically apply the towed vehicle's brakes if disconnection occurs, preventing runaway situations. These systems protect both the towing and towed vehicles from excessive stress during heavy braking scenarios.

- **Emergency situations:** AEB systems for crash avoidance.
- **High-performance driving:** Carbon-ceramic systems for track use and sports cars.
- **Heavy-duty applications:** Enhanced systems for commercial vehicles and towing.
- **Extreme conditions:** Heat-resistant materials for mountain driving or racing.

2. Literature Review

Regenerative braking logic, which strives to maximize energy recovery while braking and reduce wheel locking, hence limiting vehicle instability, should be implemented on fully electric vehicles with front-, rear-, or all-wheel drive and one motor per axle. According to the rationale, a brake-by-wire system should be implemented, meaning that the hydraulic braking system can be engaged without the use of the brake pedal. Actually, when the pedal is depressed, the logic prioritizes the electric motor(s)' braking action, which serves as a generator and maximizes energy recovery while accounting for a number of constraints, such as the wheel locking limit, to maintain the vehicle's stability. Hydraulic brakes, whose contribution seeks to bring the braking towards a condition of ideal braking distribution, are used to integrate braking when the electric motor is unable to meet the regenerative torque request. As a result, the hydraulic systems in the front and back need to be separate and adjustable. Through simulation testing, it was discovered that this logic reduced consumption on the WLTC driving cycle by roughly 30% when compared to the same vehicle without regenerative recovery and by roughly 23% when compared to a logic that is widely used in the market. It saves roughly 24% and 19% on cycle US06, respectively. The self-ruling crisis brake help incorporates forward impact shirking that is generally viable in decreasing frontal crashes by bring down speed. Regardless of the certainties that forward impact is not profoundly successful in the dimness or amid outrageous light introduction and that its productivity sinks with rising rate, it likewise diminishes the braking separation of a vehicle after a crash driving into decrease of setbacks and wounds cause by a vehicle to people on foot. Indeed, even 10% relief at fast may spare human lives and fortify open security [1].

This affirms the impact of the braking power on the vessel with the heap while working in the wellbeing braking mode, the most extreme exertion in the link framework is decreased by a factor of three of the powers of normal protection from development of the vessel. Consequently, the braking of the vessel with the heap ought to be considered as a compelling approach to dispense with the dynamic over-burden amid the wellbeing braking on mine raising frameworks in the method of lifting the heap [2].

Furthermore, these strategies are appropriate to improve the virtual condition adaptively to the client by powerfully gathering cerebrum movement and after that utilization it an input to enabling the virtual situation to be adjusted to the client's interactions [3]. The proposed streamlined strategies can be an effective instrument for enhancing the nature of a specialist's work in researching car crashes including engine vehicles net weight up to 3.5 tons and fitted with powerfully determined circle brakes. Its down to earth noteworthiness is in expanding the rightness of a specialist's assessment of the driver's activities in avoidance of car crash thinking about specialized capacity of the vehicle [4]. This venture concentrates on building an easy to understand gadget that spends significant time in distinguishing interruptions other than doing short proximity hindrance discovery [5]. Vehicle wellbeing can be enhanced by reckoning a crash before it happens and in this way giving extra time to convey security advances. Notices can resemble ringer if the driver is moving toward a pothole or any hindrance, driver might be cautioned in cutting edge with respect to what the street involves the undertaking's definitive point in this manner concluded as, one to construct a general, simple to-utilize and adaptable framework that can counteract lethal mishaps. As found in the previously mentioned issue with the convectional brakes, the issue is emerged because of the erosion between at least two rubbing parts [6].

3. Methodology

(a) Braking system

4-wheel braking system is a common phenomenon in the present automobile design, which consists of a master cylinder, slave cylinder, drum brake and/or disc brake, brake line and pedal as shown in Figure 1. Care has been taken about the amount of braking force to be applied to each wheel so as to maintain the stability of the vehicle before coming to rest position. Front brakes take the major role in stopping the vehicle to counter act the car weight imposed on front wheels. The brakes get activated when the driver operates the brake pedal, which pressurizes the working fluid in the master cylinder which is transmitted to slave cylinder through brake lines. According to Pascal's law, the braking force applied by driver is equally distributed to all the slave cylinders by the working fluid in the system. Depending upon the amount of force applied on the pedal, the vehicle may come to rest or decelerate the vehicle speed.

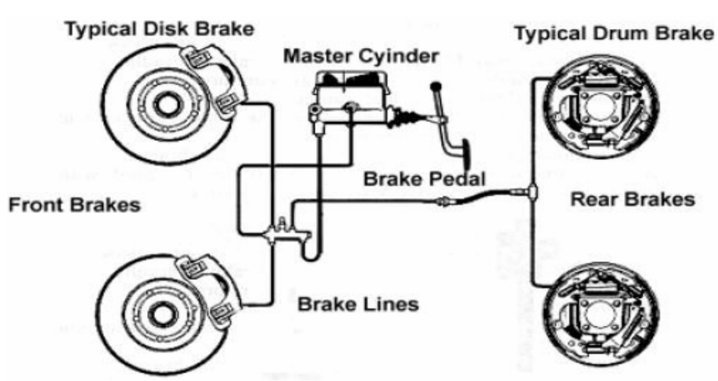

Figure 1. Simple existing hydraulic braking system.

(b) Supplement braking system

A braking system which provides an additional mechanism to operate the brake pedal which acts as a supplement control to co-passenger and driver as well in demanding situations is known as a Supplement Braking System (SBS).

While driving there are situations where the drivers have to operate brake, accelerator and clutch almost with less time gap to operate these pedals. The example for such situation can be journey on up-hills or flyover areas where the vehicle rolls backward due to road slope while the driver has to accelerate the vehicle or change the gear while simultaneously applying the brake in order to stop rolling back of the vehicle. During up-hill drive, the driver needs to have good skill in operating the clutch, accelerator and brake, he needs to vary his foot position from one pedal to another swiftly. If the driver is negligent, then there is a chance that engine may stop and/or vehicle may roll backwards due to slope of road and load. The more serious situation is fatal malfunction of driver, the co-passenger (preferably a driver as well) under such situations will be a mere spectator when the driver is unable to control the vehicle, resulting in injuries or sometimes loss of life.

A supplement brake may help the co-passenger to have a chance to control the vehicle during these fatal situations. The third possible situation would be for elderly people who find it difficult to change the position of foot swiftly from brake to accelerator. The fourth possible situation would be during parking, back cameras have been introduced to take care of objects behind the vehicle. But the adjacent sides always have the risk of scratches especially the farther adjacent side. In such situation partial vehicle control to co-passenger in the form of supplement brake would be more helpful. This comprehensive overview demonstrates that numerous supplemental braking technologies already exist and are being continuously refined. The key to successful implementation lies in intelligent integration, system redundancy, and seamless coordination with primary braking systems to enhance overall vehicle safety and performance. In summary, the supplement brake system would be useful in instances where the driver’s visibility is doubtful, when pedals must be used quickly, or when co-passengers need partial control of the car to prevent accidents.

(c) Supplement braking system model constraints

The supplement braking system model development is based on the following constraints.

1. The mechanism should be simple with least modifications of existing brake system.

2. Should be located at a convenient place where both driver and adjacent co-passenger can access.

3. Should operate with minimum force preferably body weight should assist braking force.

4. It should be reliable.

5. The mechanism should suit to all kinds of braking systems, namely, hydraulic, pneumatic, mechanical and automatic.

Table 1. Experiments and comparisons

Brake dynamometer tests: - Fade test: 15 stops from 100-10 km/h at 0.5g - Recovery test: Cooling period assessment - Wear test: 10,000 cycle durability - Temperature mapping: Thermal imaging	Brake fluid specifications (DOT 4/5.1): - Dry boiling point: >260°C - Wet boiling point: >180°C - Viscosity: 1.5 mm^2/s at 100°C - Corrosion protection: Copper strip test
System component power requirements: - ECU and sensors: 50-100W continuous - Electromagnetic actuators: 2-5 kW peak - Hydraulic pumps: 1-3 kW continuous - Communication systems: 10-50W - Total peak demand: 8-15 kW	Wheel speed sensors: - Resolution: 0.1 km/h - Update rate: 100-200 Hz - Accuracy: ±0.5% - Operating temp: –40°C to +150°C
Accelerometers: - Range: ±20g - Resolution: 0.01g - Bandwidth: 0-1000 Hz - Noise: <0.001g RMS	Pressure sensors: - Range: 0-200 bar - Accuracy: ±0.5% full scale - Response time: <5 ms - Temp compensation: ±0.02%/°C
Processing requirements: - CPU Performance: Minimum 1000 MIPS - Memory: 4-16 MB RAM, 32-128 MB Flash - Real-time OS: Deterministic response <1 ms - Communication: CAN, LIN, Ethernet protocols	Heat dissipation requirements: - Continuous: 50-100 kW - Peak: 200-500 kW - Thermal cycling: –40°C to +800°C
Stability requirements: • Maximum yaw rate: ±15°/s before stability intervention • Lateral acceleration limit: 0.8g (dry), 0.4g (wet) • Roll angle limit: ±8° before stability concerns • Pitch angle during braking: Maximum 6-8°	

Mathematical model

$$\Delta Wf = (a \times h \times W)/L \text{ (front axle load increase)},$$

$$\Delta Wr = -(a \times h \times W)/L \text{ (rear axle load decrease)},$$

where

$$a = \text{deceleration } (\text{m/s}^2),$$

h = center of gravity height (m),

W = vehicle weight (N),

L = wheelbase (m).

Kinetic energy conversion

$$E = 1/2\,\mathrm{mv}^2 \text{ (for 1500 kg vehicle at 100 km/h),}$$

$$E = 1/2 \times 1500 \times (27.8)^2 = 578{,}700 \text{ J (578.7 kJ).}$$

(d) Working principle

A SB (Supplement Brake) pedal/knob is firmly fitted to one end of the brake stem rod and a top plate is fitted to another end of the stem. The top plate can move linearly up and down against a spring force while the bottom plate is firmly fixed. One end of the spring is fitted to top plate and another end to the bottom plate. The brake cable is joined to the top plate by a cotter bolt, which passed through the series of rollers with casing arrangement as shown in Figure 2. The other end of the brake cable is joined on the rear side of the main brake pedal such that when the supplement brake pedal is applied, the main brake pedal will move backward and thus a braking force is generated at the master cylinder.

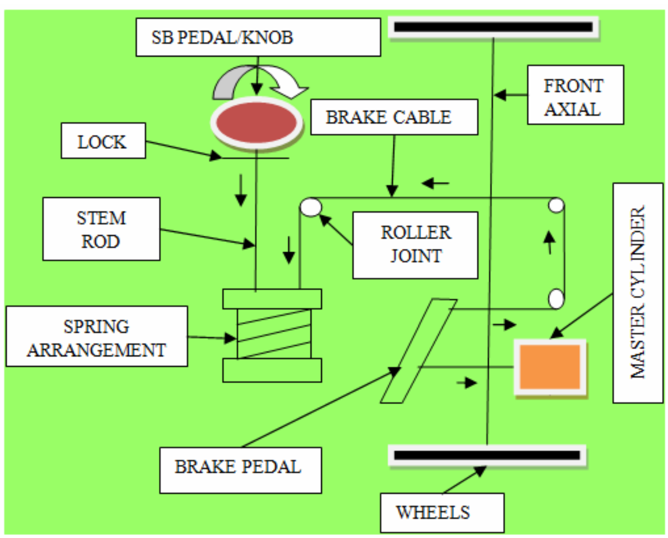

Figure 2. Conceptual SBS block diagram.

During demanding situations, when the supplement brake knob is applied, the braking force pushes the stem rod downward against the spring force. This downward motion of SB knob pulls the supplement brake cable which operates the main brake pedal as shown by the arrows in Figure 2. Once the main brake pedal/knob is operated, the piston inside the master cylinder applies the pressure on the working fluid and brake is applied as discussed in earlier section.

Under normal working conditions when the driver is having full control of the vehicle, he himself will operate the main brake pedal; during this operation, the brake cable of SBS will sag as the cable cannot operate in reverse direction (i.e., the cable cannot push the top plate against the spring force).

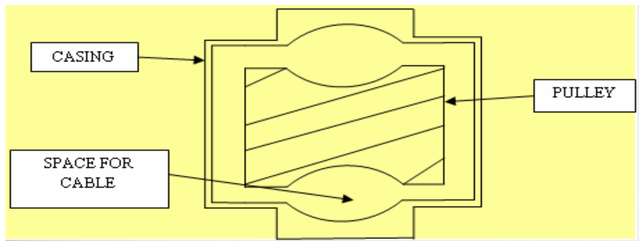

Figure 3. Side view of pulley with casing.

The problem with sagging brake cable is that the brake cable may not locate exactly in the roller/pulley groove or it may slip from the roller groove while operating the main brake pedal. In order to overcome this problem, the rollers are provided with a casing such that the cable may be allowed to sag or bulge near the roller but when the driver releases the load on the main pedal, the brake cable of SBS will come back to working position.

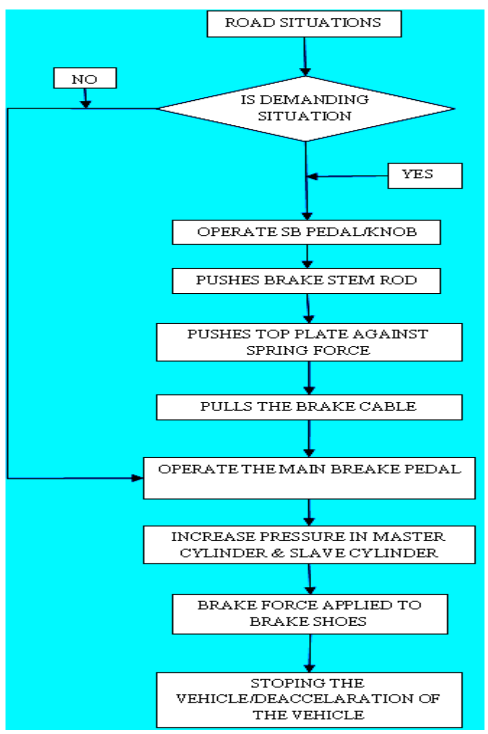

Figure 4. Structural approach: proposed concept model.

When the driver is completely aware of the situation and has complete control over the car, he can choose not to give the co-passenger partial control by using the locking mechanism at the SB knob. The locking mechanism is simple rotation type such that the co-passenger can take control over the SBS at the demanding situations.

4. Conclusion

A Supplement Braking System (SBS) would be very useful when the driver is unaware of situation or unable to control the vehicle and the co-passenger is well conscious and ready to take control of the vehicle. In the existing models, apart from main brake, we also have hand brake or parking brake which could have been used instead of SBS. The authors find two major problems in using hand brake as supplement brake. First, the hand brakes in some design are used to lock propeller shaft which will be more fatal when engaged during running condition. Secondly, even if the hand brake is connected to brake drum, the brake has to be applied against the gravity, while the foot operated pedals like acceleration, brake and clutch pedal will be operated in line with gravity. Practically, it is very difficult to operate one limb in line with gravity and other limb against it.

Apart from these brakes, SBS is also provided which is used for entirely different purpose. Considering these facts, a Supplement Braking System (SBS) would be helpful at least for the said situations. The supplemental braking system represents a critical advancement in automotive safety technology, providing enhanced stopping performance during demanding situations. Success depends on intelligent integration of multiple technologies, robust control systems, and seamless interaction with existing vehicle safety systems. The framework presented here provides a comprehensive foundation for developing practical, reliable, and effective supplemental braking solutions that can significantly improve vehicle safety across various operating conditions.

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