Sensotronic Brake Control System Accelerating New Technology

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ABSTRACT

Sensotronic Brake Control- also known as Brakes of the future is appellation given by Mercedes to an innovative electrically controlled brake system which operates more precisely than a conventional hydraulic braking system. Within no time you press the brake pedal and the sensor identify situation in hand, the microcontroller makes an exact calculation of brake force necessary and distributes it between the wheels as per the current scenario. This allows SBC to critically reduce stopping distances [3]. With Sensotronic Brake Control electric impulses are used to pass the driver’s braking commands onto a microcomputer which processes various sensor signals simultaneously and, depending on the particular driving situation, calculates the optimum brake pressure for each wheel. The factor causing burgeon in SBC demand is that it plays a major role in offers even greater active safety than conventional brake systems when braking in a corner or on a slippery surface. With the help of a high-pressure reservoir and electronically controllable valves it is ensured that maximum brake pressure is available much sooner. Moreover, the system offers innovative additional functions to reduce the driver’s workload which include Traffic Jam Assist, which brake’s the vehicle automatically in stop-and-go traffic once the driver takes his or her foot off the accelerator resulting in a comfortable driving experience even for long distances. The Soft-Stop function – another first – allows particularly soft and smooth stopping in town traffic. Taking into account additional safety conditions Mercedes has a backup hydraulic only braking system if due to some malfunctioning SBC fails.

KEYWORDS

Sensotronic brakes; fuzzy logic controller; traffic jam assist; electronic brake proportioning; electronic stability program; dry braking; drive away assist; dry braking

I. INTRODUCTION

For smooth passenger ride and safety, while stopping a vehicle, most drivers slowly press on the brake pedal. Even during an emergency situation, studies have shown that almost all drivers will press only partially on the brake pedal for the first few milliseconds until their brain has time to analyse the situation and then the brake pedal is pressed firmly. This slight delay in braking enables the vehicle to travel several meters further and can cause an accident. There are several other factors that delay the vehicle’s response to a braking situation. Mercedes-Benz is trying to reduce or eliminate as much as possible these factors with
their new brake systems. They call it Sensotronic Brake Control. Sensotronic Brake Control is an electro hydraulic brake system developed by Daimler and Bosch.

With the advent of new technologies, to conquer major share in automobile engineering, in 1999 Mercedes-Benz launched this system under the name Active Body Control (ABC) in the flagship CL coupe, thereby signalling a new era of suspension technology [3]. This electronically controlled suspension system will quickly be followed by the electronic brake system: Mercedes-Benz and Bosch teamed up on this benchmark development project and entered into series production at the Stuttgart automobile brand under the name Sensotronic Brake Control — or SBC for short. It turns the conventional hydraulic brake into an even more powerful mechatronic system. Its microcomputer is integrated into the car’s data network and processes information from various electronic control units. In this way, electric impulses and sensor signals can be instantly converted into braking commands, providing a marked safety and comfort gain for drivers. Counter-attacking different quagmires; Mercedes has been successful in bringing into action, this new brake technology as a benchmark to other automobile companies

II. OPERATIONAL CHARACTERISTICS

In order to achieve more with few attitudes, Mechatronics – a new term is gaining popularity within the automotive industry and is rapidly developing into the catchword of a quiet technological revolution which in many fields stands century-old principles on their head. Mechatronics has played a very crucial role in bringing together two contrasting fields which in many cases were thought to be irreconcilable, namely mechanics and electronics. Working through the technical side though the results seem to be easy achieved, actual mechanism is far more complicated than rest of the braking system with a due consideration as a future demand and needs. For most the vehicles when driver hit the brake pedal, the movement of the foot moves a piston rod which is linked to brake booster and master brake cylinder. Depending on the pedal force, the master brake cylinder builds appropriate amount of brake pressure in the brake lines which then presses the brake pads against the brake discs via wheel cylinders. Considering the fact that brake boosters will not be needed in the future, SBC supersedes the uses of brake booster with a sensor that gauges the pressure inside the master cylinder. Sensors additionally also contribute in measuring the speed with which brake pedal is operated and pass this data to the SBC computer in the form of electrical pulses. Braking operation being the most crucial operation in a car, during braking the entire actuation unit is completely disconnected from the rest of the system and serves the sole purpose of recording any brake command.

The bonnet is the central control unit known as the centerpiece of the electrohydraulic brake which mainly consists of microcomputer, software, sensors, valves and electric pumps with all together lead to a high dynamic brake management [3]. In order to improve this data to a greater extent the electronic assistance systems like antilock braking system (ABS) provides information about the wheel speed with electronic stability program (ESP) providing the data from its steering angle, turning rate and transverse acceleration sensors to SBC computer in the form of sensor signals. The complex calculations made in order to calculate the current driving range leads to perfect driving stability and optimum deceleration. Further briefing about the system comes the high pressure reservoir which contains brake fluid that enters the system at pressure from 140 to 172 bar. The SBC computer controls the electric pump which is connected to the reservoir and results in a shorter response time than conventional breaking system.
Another important component of this braking system is the hydraulic unit which comprises of four pressure modulators which control the brake pressure for each tyre separately as a result slowing them down as monitored by each pressure sensor.

The main performance characteristic of SBC include extremely high dynamics during pressure build up and exact monitoring of driver and vehicle behavior using sophisticated sensors. Brake force control plays a very important role while deciding the braking principle. Keeping this in mind Mercedes has programmed the system in such a way that when slowing down from a high speed the larger part of the brake force continues to act in font axle which prevents hazardous over braking of rear axle. At low speeds or during partial braking the system automatically increases the brake force share at the rear axle to improve brake system response. During the research in Daimler Chrysler’s Berlin driving simulator it has been propounded that almost two third of all drivers are startled when ABS pulsation sets in or they do not increase the brake force further thereby lengthening the stopping distance of their vehicle by an average distance of 2.1 meters during ABS braking from 60km/hr. Sensotronic brake control applications include the Mercedes cars like E-class, CLS-class, SL-class, SLR and May Bach. High precision and reliability are most desired functions in modern sensor design. The conversion of pressure in specific case into an electrically measurable value is performed through piezoresistive elements implanted on the surface of silicon chips.

![Fig 1. Schematic of Braking System](image-url)
III. SENSORS AND ELECTRONIC UNIT

Field of mechatronics has created promising opportunities to the Mercedes engineers not only in terms of comfort and safety but in a considerable way to the realization of their long term objectives. For such vehicle guidance, the experts need a computer controlled brake system which automatically acts on the instructions of an electronic autopilot and stops the car safely. In order to replace the mechanical components with a view to enhance functioning of the braking system, detailed and precise designing of high performance microcomputers and electronically controlled actuators plays a very important role.

Design features of a modern sensor include multi functionality, flexibility and reliability for any wire application. With a view to achieve these factors it is necessary to conceive a silicon micro machined piezo-resistive pressure sensor chip with higher and lower sensitivities each having a specified pressure range. Digital electronics is considered out of price for pressure sensors but still till today they are used to implement monitoring and correction strategies in the sensor. Activities are carried out for failure analysis at design level. The most common evaluation method of these errors is by self-test which correct them without outside intervention.

Sensor design requires a good deal of experience and simulation techniques. The transducer chip design is mainly carried out by the European Aerospace Defense and Space Company. For chip design one of the main difficulties faced were the correspondence between transducer response and applied pressure. Latest tests have shown the results that proper positioning of the piezo-resistive elements on the chip membrane with a 90-degree profile has been reducing the previously described risk by significantly showing the stress distribution changes after the mechanical contact[3].

Thus it will not be wrong to conclude that the design of electronic should be maintained at low level of complexity in order to avoid unnecessary over dimensioning of the components that would further increase the costs. Instead a volatile memory for storing the calibration parameters and non-volatile one for programming of self-tests should be planned while designing.

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Fig 2 Role of Electronics in Braking

IV. WHAT MAKES SENSOTRONIC BRAKES-BRAKES OF THE FUTURE?

Electrohydraulic backup plays a very important role in improving the brake assist performance. Prefilling is a process in which SBC recognizes the drivers rapid movement and with the help of high pressure reservoir the system increases the pressure inside the brake lines and instantly presses the pads on the brake discs as a result to get a tight grip with the assist of brake pedal. This overall functioning leads to a shorter brake distance compared to others up to 3% [2]. The electronic stability program (ESP) keeps on the vehicle safety by creating braking impulses at wheels by reducing engine speed as a result offering
benefits of greater dynamics and precision. The high pressure reservoir gives faster braking impulses which thus results in easy and comfortable stabilizing of the vehicle which is about to brake.

The soft-stop function primarily focuses on comfortable stopping of the vehicle resulting in the smooth braking action. Dry braking function is activated in order to dry the water film on the brake surface formed while travelling on the wet surface. Traffic jam assist function is activated while there is not car motion. It contributes as a unique feature for the drivers as they only need to use the acceleration pedal. When they take their foot off the accelerator, SBC slows down the car to a standstill at a steady rate of deceleration. Drive-away assist function prevents the car from rolling backwards and forwards on steep slopes thus adding a safety feature [3].

As a result with fined grained control of pressure SBC offers a unique basis in order to implement skid protection and traction control. Furthermore development in this braking system leads to improvement in the metering of required brake pressure which contributes to a precisely controlling each wheel. Electronic Braking Proportioning (EBP) allows proper proportioning of front to back and side to side [1]. There is no pedal vibration during its operation resulting in eliminating distraction to the driver during the critical moments. Involvement of the mechatronics in this system leads to a faster response to brake request inputs [1]. Pressure reduction at standstill reduces stress on the components.

Though the above advantages stated may be in technical terms and can be challenged, we cannot deny the fact that accident rate has dropped by 15% especially due to standard SBC in Mercedes cars keeping the car on course with less difficulty. The major factor contributing to the decline in the number of accidents is the safety provided due to variable brake force distribution which actively influence the cars compliance steer.

![Fig 3. Detailing of the Parts](image-url)
V. FAILURE AND CURRENT IMPLICATIONS

Mercedes based on its customer feedbacks decided to discontinue its SBC system following a number of problems which has led to significant recalls. By the year 2004 over 2 million vehicles were recalled due to defects [2]. Problems with SBC include premature switching to hydraulic emergency backup due to problem with wiring. According to Mercedes, vibrations within the connector plug affect the electrical contacts and provide safe braking to which the driver is not used to. Instead of using any mechanical connection there are electronic control units connected to the brake pedal which results in complete disconnection from the rest of the system. This may prove to be advantageous or disadvantageous depending on the current driving conditions.

Unfortunately although the intent was good the execution was not up to the expectations. The main cause for its deterioration was the failure in the wiring system. We cannot rule the possibilities of computer and pump failure which leads to an increase in the driver effort and simultaneous pressure rise compensation for the reservoir. In comparison to its advantages though the disadvantages may not seem to cause a concern but still some features like high maintenance, costly electronic parts to replace and noise from the SBC hydraulic motor add to people’s concern regarding its future implementation[2]. This Mercedes braking system has led to an advent of an astonishing era but still Mercedes is finally getting tired of trying to convince the consumers of the benefits of SBC system. Although this technology is pure advancement in field of automobile engineering the poor design and lack of tests are ultimately leading to its downfall. The steady growth of road transportation is an increasing issue as a result of number of heavy vehicles the braking performance needs to be improved to avoid the number of crashes. The Highly Automated Vehicles for Intelligent Transport (HAVE it) brake wire technology of Volvo industries are aiming at improving safety on the basis of research work at University of Stuttgart(Germany) to reach zero accident vision. Further developments are made in SBC with the aid of video cameras, proximity radar and advanced telematics. Another automobile company has accepted the challenge with a new fixed type calliper braking system which is lighter in design and responds very quickly which improves the acoustics of the brake. The MK-C1 coil present in the braking unit proves fruitful in reducing the weight and further increases the pressure dynamics requirements for advanced driver assistance systems. The “power on demand” principle of braking also reduces the energy requirements and noise emission level with the use of Electronic Speed Control (ESC) multi piston and electric vacuum pumps.

Fig 4. Mercedes Sensotronic Brake
VI. WHAT DO WE THINK COULD BE DONE FOR EFFECTIVE BREAKING

Fuzzy logic is a form of many-valued logic that deals with reasoning that is approximate rather than fixed and exact. Fuzzy Logic Controller (FLC) based on fuzzy logic provides a means of converting linguistic control strategies into automatic control system. The dynamic braking resistor is a very effective device for stability control of any car. FLC plays a very important role in improving this brake resistor control unit by using Fuzzy Logic toolbox in Matlab and PID controller [8]. This technology if used in the microcomputer will definitely increase its advancement in the future as a result completely nullifying the problems arising due to malfunctioning of the system.

Slip condition in the braking is of cardinal importance which must be kept as minimum as possible. For this purpose Anti-Fuzz brake controller has been designed for each vehicle. Difference between torques of both sides of wheels is calculated by this controller in order to reduce the difference between actual and the desired slip angle for any car in any driving situation. Combination of three dimensional modeling for chassis and one dimensional modeling for each wheel along with Matlab or Simulink simulation will validate the actual functioning of this electronic mechanism in order to calculate the actual slip angle difference [7].

It is true that to replace the vacuum braking system this electromechanical braking system was brought in use by Mercedes by superseding the hydraulic parts by electronic parts. Many times the coding part of the microcomputer was changed. With respect to these changes and studying other brake systems it is easy to conclude that the Integrated Brake control system is being undertaken everywhere which enhances performances and enables features like the automatic emergency braking. German electronics specialist Siemens has developed new braking technology in the form of the electronic wedge brake, which the company claims new innovations taking braking to a new level of growth. Focusing on either electronics or mechanics is not the ultimate aim in achieving growth, but designing a braking system which can economically satisfy all the functions of a braking system.

Thus it is our personal opinion that Mercedes must take SBC to the next level in the form of EDIB (Electric Driven Intelligent Brake) as it controls the regenerative brake and friction brake to support both of these requirements. Further, it also controls the reactive force from the pedal in order to unify the feeling when stepping down on the pedal and the sense of deceleration. The field of braking is vast with a view for further scope for innovation. The “Premium Compact” braking system is to be undertaken in 2015 in order to fulfill the above stated advantages. Programmable Logic Controller design using the ladder diagrams is the latest trend undertaken in field of electronics for developing any new system. Tests like crash analysis works like mirror in determining efficiency in functionality of brakes when actually in operation. The different design of these brake concepts poses new challenges for the automotive industry with regard to availability and fallback levels in comparison to standard conventional brake systems. This contribution focuses on the development of appropriate fallback level concepts. Hardware-in-the-loop (HIL) techniques and field trials will be used to investigate the performance and the usability of such systems.

With due considerations of our personal overview regarding the competition in field of automotive engineering, to lead and prove to be the best is the main spirit with which each and every company works.
Thus we think that the main challenge for the future of automobile companies is to find the right trade-off between cost and performance and try to work with a definite methodology.

VII. CONCLUSION

In simple words we can conclude that the Sensotronic Braking Technology is system of interdisciplinary interactions of mechanics and electronics which provides its benefits to a greater extent. The microcomputer, software, sensors, valves and electric pumps together allow a totally novel, highly dynamic brake management. Considering the disadvantages it is not correct to conclude that Mercedes will entirely scrap SBC system [4]. It will surely continue to develop and improve braking system with less prone conditions to malfunctioning. Taking into consideration the future needs Mercedes will try to drop the SBC system and will substitute with an Adaptive brake new system which is the first facelift model [2]. The fact cannot be neglected that the additional advantages of Sensotronic braking system provide uncompromising quality, stability and longevity. Combination of manage ride and handling with driving safety provided by the braking system in a sustainable and calculable way differentiates it with other braking system in a lucrative way. Mercedes engineers are exploring new and promising avenues beyond just comfort and safety. With SBC, engineers have also taken another large step towards their goal of guiding the automobiles of tomorrow fully automatically around town and country. The basis of development in the field of braking Sensotronic Braking Control System has proved to be the foothold in automobile engineering due to its efficiency and reliability over conventional systems.

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ACKNOWLEDGEMENTS

Inspiration and guidance are invaluable in every aspects of life, especially in the fields of academics, which we have received from my respected review paper guide. We would like to thank him as he was responsible for the complete presentation of my seminar and also for his endless contribution of time, effort valuable guidance and encouragement he has given to me. Last but certainly not the least; we would also to thank my friends for their inspiration and motivation and also those who helped me directly or indirectly in my seminar work.