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Sensotronic Brake Control

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Abstract : Sensotronic Brake Control, is an 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 identifies situation in hand, the microcontroller makes an correct calculation of brake force required and distributes it between the wheels as per the current scenario. This system is regarded as another important milestone to enhance driving safety. Also, the system offers features to reduce the driver's workload with additional features like Traffic Jam Assist, Soft Stop function, etc. SBC transforms the conventional hydraulic brake into a more powerful mechatronic system in which, a large number of mechanical components are only replaced by electronics which has simplified braking for driver and opened the new page for future and scope for brake-by-wire systems like never before. Despite being removed from practical use from most of the vehicles of Mercedes-Benz, the Sensotronic Braking System hasn't lost its significance.

IndexTerms - Proportional braking, SOFT-STOP, Traffic-assist, Critical wear region of brake pad

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I. INTRODUCTION

When it comes time to stop 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 analyze 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.
Mercedes-Benz first introduced the Sensotronic brake system on their SL-Class sports car.

Sensotronic Brake Control (SBC) is the name given to an innovative electronically controlled brake system which Mercedes – Benz first introduced on the R230 SL- class , which went on sale in Europe in October 2001. In May 2004, Mercedes recalled 680,000 vehicles equipped with the system; in March 2005 1.3 million additional vehicles were recalled. And eventually Mercedes decided to drop the feature altogether in higher volume models, such as the E-class. Lower volume models continued to use Sensotronic due to the high cost of redesigning a braking system.
SBC Incorporates these Functions:

- ABS (Anti lock Brakes 1984)
- ASR (Automatic Slip Regulation 1991)
- ETS (Electronic Traction System 1995)
- ESP (Electronic Stability Program 1996)
- BAS (Brake Assist System 1998)

Following on from the Mercedes innovations ABS, ASR, ESP and Brake Assist, this system is regarded as yet another important milestone to enhance driving safety.

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. As a result, SBC offers even greater active safety than conventional brake systems when braking in a corner or on a slippery surface. A high-pressure reservoir and electronically controllable valves ensure that maximum brake pressure is available much sooner. Moreover, the system offers innovative additional functions to reduce the driver's workload. These include Traffic Jam Assist and Soft Stop Assist .

II. NEED OF THE STUDY

The modern age automobiles have incorporated various systems to maximize safety and comfort of driver and passengers while also increasing the efficiency and performance of the vehicle itself. SBC by Mercedes was one such system that introduced brake-by-wire technology in the Benz cars. The system worked together with other safety and performance systems. This integration and working of all systems together is fascinating by a technological point of view. A lot can be learned about electro-hydraulic braking system by studying SBC.

III. CONTRIBUTION OF MECHATRONICS

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 brings together two disciplines which in many cases were thought to be irreconcilable, namely mechanics and electronics.

Hence automobile functions which hitherto worked purely mechanically and partly with hydraulic assistance will in future be controlled by high-performance microcomputers and electronically controllable actuators. These either replace the conventional mechanical components or else enhance their function. The mechatronic interplay therefore opens up hitherto inconceivable possibilities to further raise the safety and comfort levels of modern passenger cars. For example: it was only thanks to mechatronics that an electronically controlled suspension system which instantly adapts to prevailing conditions when driving off, braking or cornering -- thus providing a totally new driving experience -- became a reality. In 1999 Mercedes-Benz launched this system under the name Active Body Control (ABC) in the flagship CL coupé, thereby signalling the advent of a new era of suspension technology.

This electronically controlled suspension system has quickly been followed by the electronic brake system: Mercedes-Benz and Bosch have teamed up on this benchmark development project which will shortly enter 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.

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IV. COMPONENTS OF SBC

- Brake Operating Unit (BOU)
- Wheel speed sensors
- Traction System Hydraulic unit

4.1 BRAKE OPERATING UNIT (BOU)

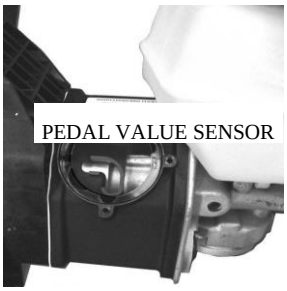
The Brake Operating Unit (BOU) consists of the following:

- Brake fluid reservior
- SBC pedal value sensor
- Tandem master cylinder
- Brake pressure simulator

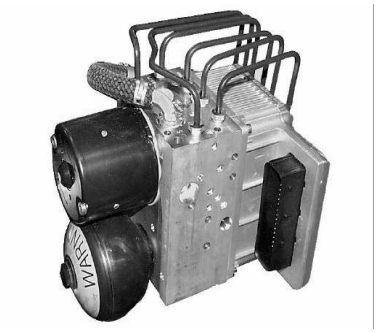
BOU

4.1.1 PEDAL VALUE SENSOR

It contains two hall effect sensors. Converts pedal travel distance into electrical signal.



4.2 TRACTION SYSTEM HYDRAULIC UNIT



TRACTION SYSTEM HYDRAULIC UNIT

It contains SBC control module , pressure reservoir and high pressure charge pump.

V. CHARACTERISTIC FEATURES AND ADVANTAGES OF SBC

5.1 ELECTRONIC BRAKE PEDAL

To turn to the technical side: when drivers hit the brake pedal today, their foot moves a piston rod which is linked to the brake booster and the master brake cylinder. Depending on the pedal force, the master brake cylinder builds up the appropriate amount of pressure in the brake lines which – in a tried and tested interaction of mechanics and hydraulics – then presses the brake pads against the brake discs via the wheel cylinder.

In the Mercedes-Benz Sensotronic Brake Control, by contrast, a large number of mechanical components are simply replaced by electronics. The brake booster will not be needed in future either. Instead sensors gauge the pressure inside the master brake cylinder as well as the speed with which the brake pedal is operated, and pass these data to the SBC computer in the form of electric impulses.

To provide the driver with the familiar brake feel engineers have developed a special simulator which is linked to the tandem master cylinder and which moves the pedal using spring force and hydraulics. In other words: during braking the actuation unit is completely disconnected from the rest of the system and serves the sole purpose of recording any given brake command. Only in the event of a major fault or power failure inside the 12V vehicle battery does SBC automatically use the services of the tandem master cylinder and instantly establishes a direct hydraulic link between the brake pedal and the front wheel brakes in order to decelerate the car safely.

5.2 PRESSURE MODULATORS FOR EACH WHEEL

The central control unit under the bonnet is the centrepiece of the electrohydraulic brake. This is where the interdisciplinary interaction of mechanics and electronics provides its greatest benefits – the microcomputer, software, sensors, valves and electric pump work together and allow totally novel, highly dynamic brake management:

In addition to the data relating to the brake pedal actuation, the SBC computer also receives the sensor signals from the other electronic assistance systems. For example, the anti-lock braking system (ABS) provides information about wheel speed, while ESP® makes available the data from its steering angle, turning rate and transverse acceleration sensors.

The transmission control unit finally uses the data highway to communicate the current driving range. The result of these highly complex calculations is rapid brake commands which ensure optimum deceleration and driving stability as appropriate to the particular driving scenario. What makes the system even more sophisticated is the fact that SBC calculates the brake force separately for each wheel.

The high-pressure reservoir contains the brake fluid which enters the system at a pressure of between 140 and 160 bar. The SBC computer regulates this pressure and also controls the electric pump which is connected to the reservoir. This ensures much shorter response times than on conventional brake systems.

5.3 FULL BRAKE POWER AVAILABLE EVEN WHEN THE ENGINE IS SWITCHED OFF

The hydraulic unit mainly comprises four so-called wheel pressure modulators.

They mete out the brake pressure as required and pass it onto the brakes. In this way it is possible to meet the microcomputer's stipulations while each wheel is slowed down separately in the interests of driving stability and optimum deceleration. These processes are monitored by pressure sensors inside the wheel pressure modulators.

5.4 EMERGENCY BRAKING : STOPPING DISTANCE REDUCED BY 3%

The main performance characteristics of Sensotronic Brake Control include the extremely high dynamics during pressure build-up and the exact monitoring of driver and vehicle behaviour using sophisticated sensors. Mercedes-Benz is thus moving into new dimensions of driving safety.

Take the example of the emergency brake: SBC already recognises the driver's rapid movement from the accelerator onto the brake pedal as a clue to an imminent emergency stop and responds automatically: with the aid of the high- pressure reservoir, the system increases the pressure inside the brake lines and instantly presses the pads onto the brake discs so that they can get a tight grip the moment the driver steps onto the brake pedal.

As a result of this so-called prefilling of the brake system, the stopping distance of an SBC-equipped sports car from a speed of 120 km/h is cut by around three per cent compared to a car featuring conventional braking technology.

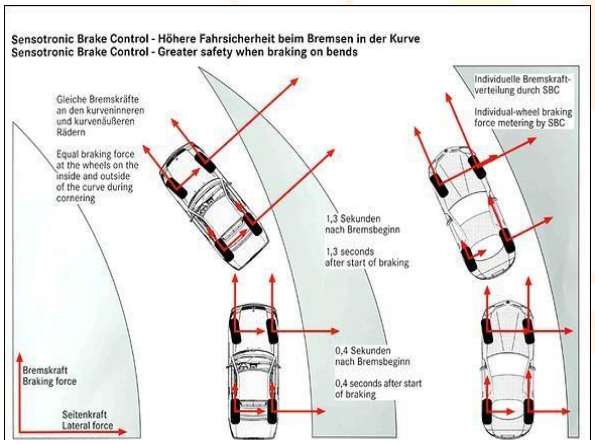
Thanks to electrohydraulic back-up, the performance of Brake Assist is also improved further. If this system issues the command for an automatic emergency stop, the quick pressure build-up and the automatic prefilling of the wheel brakes leads to a shorter braking distance.

5.5 DRIVING STABILITY : PRECISE BRAKING IMPULSES FOR PERFECT ESP PERFORMANCE

It is not just in emergency braking that Sensotronic Brake Control proves its worth, but also in other critical situations – for example, when there is a risk of swerving. Under such conditions, the system interacts with the Electronic Stability Program (ESP®) which keeps the vehicle safely on course through precise braking impulses at all wheels and/or by reducing engine speed.
SBC once again offers the benefits of greater dynamics and precision: thanks to the even faster and more accurate braking impulses from the SBC high-pressure reservoir, ESP® is able to stabilise early and comfortably a vehicle which is about to break away.
This is evident, for example, from the results of the VDA lane-change test which suspension engineers use to simulate a quick obstacle-avoidance maneuver and to demonstrate the high capabilities of the Electronic Stability Program. In conjunction with SBC, ESP® works even more effectively and significantly reduces vehicle swerving through quick and precise braking impulses.
At the same time the driver's steering effort is reduced. Thanks to SBC and ESP® he or she will have even less difficulty keeping the car on course.

5.6 BRAKING AT CORNERS : GREATER SAFETY THANKS TO VARIABLE BRAKE PRESSURE

Even when braking in corners, SBC also offers more safety than a conventional brake system. This is where the variable and targeted brake force distribution is of particular advantage to actively influence the car's compliance steer.
while conventional brake systems always mete out the brake pressure equally to the inner and outer wheels, SBC offers the possibility of assigning brake forces in a way appropriate to the situation. Hence the system will automatically increase the brake pressure at the outer wheels because the higher vertical forces also allow them to transfer greater brake forces. At the same time the brake forces at the inner wheels are reduced to provide the higher cornering forces needed to stay on course. The result is a more stable braking behaviour along with optimum deceleration values. With the innovative Sensotronic Brake Control Mercedes engineers still stick to the proven principle of a variable brake force control for the front and rear axles. They program the system in such a way that, when slowing down from a high speed, the larger part of the brake force continues to act on the front axle. This prevents a potentially hazardous overbraking of the rear axle. Again SBC is capable of adapting to the prevailing situation. At low speeds or during partial braking, the system automatically increases the brake force share at the rear axle to improve brake system response and achieve even wear and tear of the brake pads.



Difference between conventional braking and SBC

5.7 COMFORT: NO PEDAL VIBRATION DURING ABS OPERATION

Both the separation of the SBC pedal from the rest of the brake system and the proportional pressure control using mechatronics serve to increase brake comfort – particularly during sharp deceleration or when the anti-lock braking system is operational.
The usual vibration of the brake pedal when ABS sets in does not occur, which, Mercedes engineers have found, is not only a comfort feature of the new system but also offers measurable safety benefits. Their research in DaimlerChrysler's Berlin driving simulator has revealed that almost two thirds of all drivers are startled when ABS pulsation sets in: they do not increase the brake force further and are even prone to taking their foot off the brake pedal for a short while, thereby lengthening the stopping distance of their vehicle – in the driving simulator by an average of 2.10 metres during ABS braking from 60 km/h on a snow-covered road surface.

5.8 SBC ADD-ON FUNCTIONS: SUPPORT SYSTEM TO REDUCE DRIVER STRAIN

Sensotronic Brake Control offers additional advantages in everyday driving situations – when slowing down ahead of traffic lights, in the wet, in traffic jams or hill starts:
The so-called **Soft-Stop function** of the SBC software ensures particularly gentle and smooth stopping which provides significant comfort benefits particularly around town when you need to slow down frequently for traffic lights. All this is made possible by the higher-precision pressure control thanks to mechatronics.
On a wet road surface the system metes out short brake impulses at regular intervals to ensure that the water film on the brake discs dries off and that SBC can always operate with optimum effectiveness. This automatic **dry-braking function** is activated at regular intervals when the car's windscreen wipers are running. The driver does not even notice these ultra-precise brake impulses.
The Sensotronic Brake Control also incorporates a so-called **Traffic Jam Assist** function, which is activated using the cruise control stalk while the car is stationary. The benefit is that during stop-and-go traffic drivers only need to use the accelerator

pedal; once they take their foot off the accelerator, SBC slows down the car to standstill at a steady rate of deceleration. The Traffic Jam Assist facility can remain operational up to 60 km/h and switches off automatically at higher speeds.

5.9 THE FUTURE: SBC PAVING THE WAY FOR FUTURE GUIDANCE SYSTEMS

The advent of electronics in brake technology opens up new and promising opportunities to Mercedes engineers – and not only in the disciplines of safety and comfort. Thanks to SBC they have also moved a considerable way closer to the realisation of their long-term objective, namely to be able to automatically guide the cars of the future along the roads with the aid of video cameras, proximity radar and advanced telematics.

VI. MAJOR DISADVANTAGE OF SBC: SOFTWARE FAILURE

The technology eliminates the mechanical link between the driver's brake pedal and the brakes, substituting an electrical link that actuates the brake calipers.
Customer complaints were linked to the failure of software for the brake system. When the system failed, the hydraulic system took over. But that resulted in a longer stopping distance and additional brake pedal effort by the driver.
"Statistically, (the Sensotronic Brake Control is) as good as our other braking systems and sometimes better," the insider said. "But we cannot get the doubts out of customers' heads."
Mercedes' SL roadster and the low-volume SLR McLaren and Maybach supercars will retain the brake system until the end of their life cycles.
It would be too costly to re-engineer those low-volume cars to accommodate a conventional system, a source said.
Sensotronic Brake Control was supposed to highlight Mercedes' technology leadership. Instead, it created a double blow to the brand's image.
In May 2004, Mercedes recalled 680,000 vehicles to fix the complex brake-by- wire system. Then, in March 2005, 1.3 million cars were recalled, partly because of further unspecified problems with the Sensotronic Brake Control system.
Mercedes dropped the Sensotronic Brake Control system from the E-Class in June 2006 when it introduced the car's midterm face-lift. At about the same time, the E Class-derived CLS also lost the system. Both cars now have a conventional hydraulic braking system. "**We can now offer all the comforts of SBC in a conventional system,**" said a Mercedes insider. "**SBC was a very expensive system."**
But the source also acknowledged that customers had lost confidence in the system.

VII. CARS WITH SBC

- Mercedes SL roadster (R230)
- Mercedes E-Class sedan (W211) and Estate (S211) until mid 2006
- Mercedes E-Class 4matic sedan (W211) and 4matic Estate (S211) until mid 2006
- Mercedes SLR (C199)
- Maybach 57 and 62 (W240)
- Mercedes CLS coupe (C219) until mid 2006

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