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Two Different Tires Types Affecting on Electronic Stability Program during Severe Conditions

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ABSTRACT:
Electronic Stability program is an active safety system which was introduced by Robert Bosch to improve the vehicle stability and prevent the vehicle from severe conditions such as skidding, under-steer, over-steer and rollover. This paper studies the effectiveness of ESP by using practical tasting methods. It also shows the effect of two different types of tires on the ESP. Car model Mercedes E 200 Kompressor was chosen and tested by using various tests in various conditions.

KEYWORDS:ESP, Yaw rate, steering angle and lateral acceleration.

I. INTRODUCTION

Electronic Stability Program (ESP) is a computerized safety technology presented in most modern cars which has been evolved from anti-lock braking system [ABS] and traction control [TC]. **[1]** It is designed to improve a vehicle's stability by detecting and reducing loss of traction, thus preventing the tires from skidding uncontrollably. When the ESP detects a loss of steering control, it automatically applies individual brakes to steer the vehicle where the driver intended it to go.

It is also known by Vehicle Dynamic Control (VDC), Vehicle Stability Assist (VSA) and Dynamic Stability Control (DSC) [2].

ESP Main Function

ESP is basically a term that refers to a collection of driving safety systems which all work towards keeping a car on the road in a controlled manner. These systems include traction control (TC) and anti-lock brakes (ABS).

When driving a car, the control inputs which includes use of the wheel and pedals is monitored by sensors which send data to a central computer. This computer compares what is doing with how the car is responding. [3]

For example, if a driver is steering right but the car is continuing to move straight ahead, the computer can instruct the safety systems to assist with this issue.

If a driver pressed hard on a brake pedal and there is a risk of locking up the wheels due to low grip on the road, the computer can instruct the anti-lock braking system to kick in. Figure 1 shows critical maneuver with / without ESP. [1 and 2]

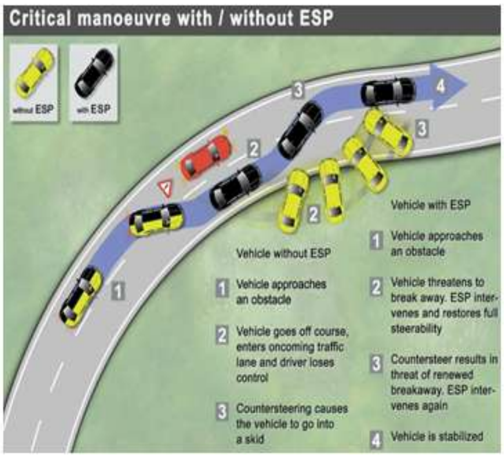

Fig.1 Critical maneuvers with / without ESP

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Another way it can help if a driver accelerates hard on a wet or icy road and the driven wheels begin to spin. ESP can instruct the traction control to control acceleration in a way that will keep the car moving without any spinning of the wheels. [4]

The whole process of the ESP is detecting trouble in a car and using other safety systems to assist with driving. That is all happening in just fractions of a second. Figure 2 shows ESP block diagram. [5]

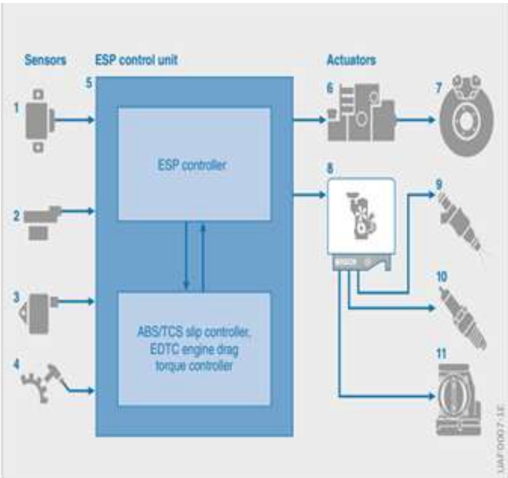

Fig. 2 ESP Block Diagram

<u>**Hence:**</u>

1. Yaw-rate sensor with lateral-acceleration sensor.
2. Steering-wheel angle sensor.
3. Brake-pressure sensor.
4. Wheel-speed sensors.
5. ESP control unit.
6. Hydraulic modulator.
7. Wheel brakes.
8. Engine-management system ECU.
9. Fuel injection only for gasoline engines.
10. Ignition-timing intervention.
11. Throttle-valve intervention (ETC).

II. EXPRIMENTATION

Mercedes E 200 Kompressor car model tests various methods to analyze the conditions leading to skidding, under-steer, over-steer,rollover and they can be classified into:

a. Rollover analyzing method

This method is used to evaluate the vehicle handling characteristics, where the vehicle is accelerate by an input speed and then the steering wheel is turned suddenly. This method is used to find the lateral acceleration, which is themain reason for a rollover situation. Figure 3 shows **Rollover test.**

Fig. 3 Rollover Test

b. Self-steering analyzing method

The vehicle is accelerated on a circular path of a knownradius(r) until the lateral acceleration (ay) is achieved. This test is done to understand over-steerand under-steer of the car.**Figure 4 shows Self-steering Test**

Fig. 4 Self-steering Test

c. ESP effect analyzing method

This test is done to find the braking effect on the road with different coefficients on the road's right and left sides. The vehicle accelerates to an input speed and suddenly decelerated by fullpressing of brake pedal until the vehicle completely stop. It is one of the best methods for a testingvehicle with and without ESP system.**Figure 5 shows ESP Effect Test**

Fig. 5 ESP Effect Test

d. Yaw rate analyzing test

The vehicle passes on a road with series cones placed at constant distances. The vehicle is accelerated continuously and it is follow a spiral / sinusoidal path. This test shows the vehicle path, vehicle speed, yaw angle and yaw rate. Figure 6 shows Yaw Rate Test

Fig.6 Yaw Rate Test

III. RESULTS

i. Experimental Results

All tests were done on off-road conditions.
Launch device was used to read the results.

First tire type:

a. Rollover analyzing method

Table 1: Steering rate for first tire type

	80 km/hr	90 km/hr	100 km/hr	120 km/hr
Steering rate [deg/s]	-388 : 192	-388 : 192	-388 : 192	-388 : 192

b. Self-steering analyzing method

Table 2: Lateral acceleration for first tire type

	40 km/hr	50 km /hr	60 k m/ hr	70 km/hr
The radius of the driving circle [m]	2.7	2.7	2. 7	2.7
Maximum lateral acceleration [m/s^2]	2.1	2.3	2. 8	3
Time to reach maximum acceleration [s]	30	30	30	30

c. ESP effect analyzing method

Table 3: Braking stopping distance for first tire type

	0 km/hr	90 km/hr	100 km/hr	120 km/hr
friction coefficient rate	.8 : 1	0.8 : 1	0.8 : 1	0.8 : 1
Stopping distance [m]	5.5	6.5	9.9	13

d. Yaw rate analyzing test

Table 4: Distance between cones for first tire type

	80 km/hr	90 km/hr	100 km/hr	120 km/hr
Distance between cones (ds) [m]	5	5	5	5
Number of cones	3	3	3	3

Second tire type:

a. Rollover analyzing method

Table 5: Steering rate for second tire type

	80 km/hr	90 km/hr	100 km/hr	120 km/hr
Steering rate [deg/s]	-388 : 192	-388 : 192	-388 : 192	-388 : 192

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b. Self-steering analyzing method

Table 6: Lateral acceleration for second tire type

	40 km/hr	50 km/hr	60 km/hr	70 km/hr
The radius of the driving circle [m]	2.7	2.7	2.7	2.7
Maximum lateral acceleration [m/s^2]	3.1	3.3	3.8	4
Time to reach maximum acceleration [s]	30	30	30	30

c. ESP effect analyzing method

Table 7: Braking stopping distance for second tire type

	0 km/hr	90 km/hr	100 km/hr	120 km/hr
friction coefficient rate	.8 : 1	0.8 : 1	0.8 : 1	0.8 : 1
Stopping distance [m]	8	10.5	13.8	17

d. Yaw rate analyzing test

Table 8: Distance between cones for second tire type

	80 km/hr	90 km/hr	100 km/hr	120 km/hr
Distance between cones (ds) [m]	5	5	5	5
Number of cones	3	3	3	3

ii. Theoretical Results

Theoretical equations are applied to obtain Yaw rate, Lateral acceleration and Stopping distance graphs. By adding the values which be experimented to these equations in MATLAB program to show required graphs. **[1,3]**

Equations

Difference of YAW rate

$\Delta\Psi = \Psi - \Psi t$ **(1)**

Hence**:** Ψ: actual yaw rate.
Ψt: theoretical yaw rate.
When:
$\Delta\Psi < 0$ the car under-steer (car rotates not enough).
$\Delta\Psi > 0$ over-steer (the car rotates too much).

Ψt = 2Vx tan β1 2L + b tan β1 **(2)**

Hence:
Vx: Vehicle longitudinal speed (Input measure value) (m/s).
β1: Steering angle of the inner wheel (Input measure value) (degree).
L: wheelbase of the vehicle (Input from vehicle specifications) (m).
b: wheelbase (Input from vehicle specifications) (m).
L: Distance between the two axis.
B: Distance between the two rear wheels or the two front wheels.
Difference of lateral acceleration:

$\Delta ay = ay - ayt$ **(3)**

Hence:
ay: actual lateral acceleration.
ayt: theoretical lateral acceleration,
$ayt = V^2/Rc$
$Rc = L/\delta$ – radius of rotation from the center of mass.
$\delta = \beta 1 + \beta 2/2$ – average wheel turn angle.

MT = MR + MF **(4)**

a = L MR MT **(5)**

Hence:
MT: total load of car.
MR: load on rear axis.
MF: load o front axis.
L: Distance between the two axis

c = L (1 − MF α / MT) **(6)**

d = (c – a) / tan α **(7)**

Hence:
MF α – load on front axis inclined at an angle.

First tire type analysis [used for six months]

Figure 7 shows that Yaw rate is presented in a regular reading with steering angle (from -6 to 8 deg / s) during different velocities (80, 90, 100 and 120 km / hr). Figure 8 shows that difference in reading the lateral acceleration (from -1 to 3 m / s^2) during different velocities (40, 50, 60 and 70 km / hr). Although braking stopping distance during different velocities (80, 90, 100 and 120 km / hr) is presented in Figure 9.

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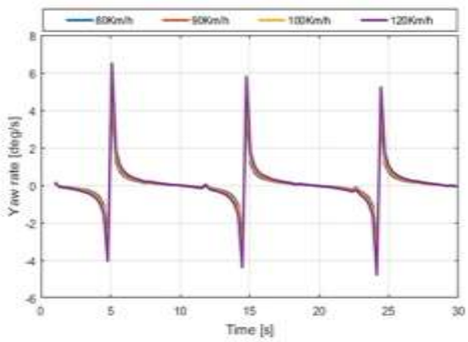

Fig.7 Yaw Rate analysis during different velocities

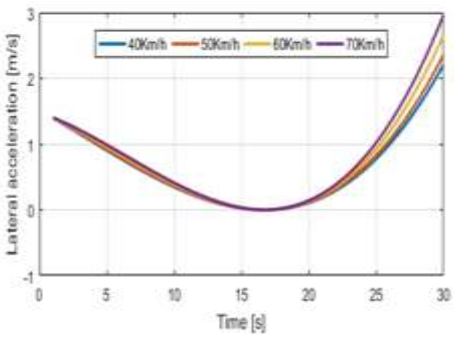

Fig.8 Lateral acceleration during different velocities

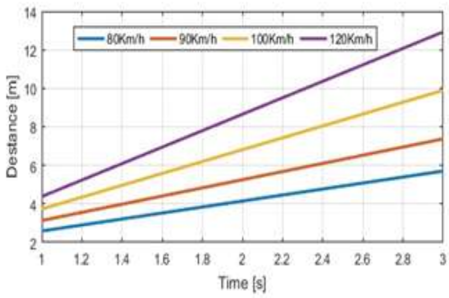

Fig. 9 Distances during different velocities

Second tire type analysis [used for eighteen months]

Figure 10 shows that Yaw rate is presented in a non-regular reading with steering angle (from -2 to 4 deg / s) during different velocities (80, 90, 100 and 120 km / hr). Figure 11 shows that difference in reading the lateral acceleration (from 0 to 4 m / s^2) during different velocities (40, 50, 60 and 70 km / hr). Although braking stopping distance during different velocities (80, 90, 100 and 120 km / hr) is presented in Figure 12.

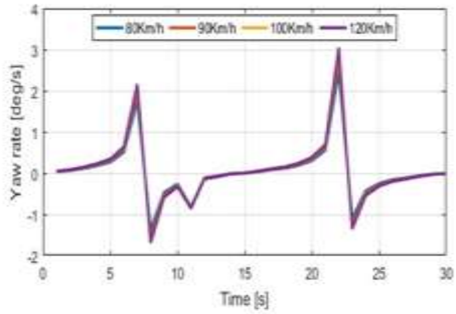

Fig. 10 Yaw Rate analysis during different velocities

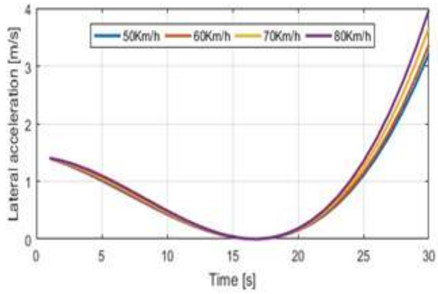

Fig. 11 Lateral acceleration during different velocities

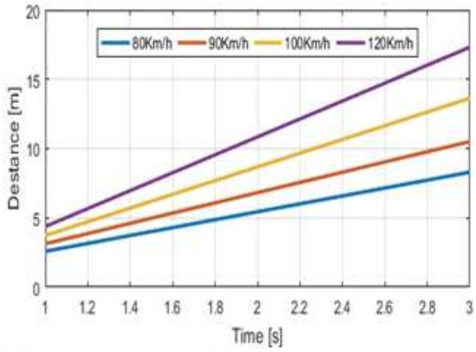

Fig. 12 Distances during different velocities

IV. CONCLUSION

Car model Mercedes E 200 kompressor was tested during various severe road conditions. It also tested by two different types of tires which have different lifetime. The first tire type has 75% of lifetime and the second tire type has 40% of lifetime. The comparison between them showed that the difference in ESP resulting readings is almost small. So, this proves that ESP is safer than any other system. ESP prevents vehicle and passengers from rollover or accidents. Even with using an old tire type, the vehicle performance is almost great compared with another one has an old tire without ESP. The difference in range of Yaw rate between the two types of tires is small during different velocities (80, 90, 100 and 120 km / hr). The first type has a steering angle rate (from -6 to 8 deg / s). Although the second type has a steering angle rate (from -2 to 4 deg / s). The difference in lateral acceleration between the two types of tires is small during different velocities (40, 50, 60 and 70 km / hr). The first type has a lateral acceleration (from -1 to 3 m / s^2). Although the second type has a lateral acceleration rate (from 0 to 4 m / s^2). The difference in braking stopping distance between the two types of tires is small during different velocities (80, 90, 100 and 120 km / hr). The first type of tire has a braking stopping distance 5.5 m, 6.5m, 9.9m and 13m respectively. Although the second type has braking stopping distance 8 m, 10.5 m, 13.8 m and 17 m respectively.

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