Electronic Stability Program(ESP)

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Aim of the Project

The aim of this project is to show how Electronic Stability Program(ESP) can contribute to safety of driver's, pedestrian's, passenger's and vehicles in today's use and showcase how it works and how it achieves this.

Overview of ESP system

The anti-lock brake system ABS is a part of all traction control systems(TCS). Both ESP and ABS contribute and work together to ensure overall safety of vehicle and passenger but the main difference between them is:

- **ABS** is a anti brake lock system; this means that it intervenes only when the brake pedal is pressed.
- **ESP** electronic-stabilization programme intervenes independently when it senses deviation between the driver's command and vehicle's actual behavior.
- The ESP system relies on the ABS system components to intervene in dynamic driving situations.

<u>These components include:</u>

1. **ABS/ESP control unit:** This unit is the brains of System it receives data from various components in this system and determines if any wheel is locking up and rectifies this.
2. **Hydraulic Unit:** This component is responsible for modulating brake pressure to individual wheels. It's controlled by the ABS/ESP control unit and adjusts brake pressure based on wheel speed sensor readings.
3. **Wheel speed sensors:** Both ESP and ABS systems utilize wheel speed sensors to monitor the rotational speed of each wheel. These sensors send real-time data straight to control unit.
4. **Steering angle sensor (SAS):** ESP utilizes the steering angle sensor to detect the direction the driver intends to steer, By monitoring the steering angle, the ESP system can detect if the vehicle is not following the intended path, indicating a potential loss of control or skidding.
5. **Yaw Rate Sensor:** This sensor measures the rotational movement (yaw) of the vehicle around its vertical axis. Yaw rate is an important parameter for determining the vehicle's stability.

Yaw Rate: Yaw rate refers to the rate of rotation of a vehicle around its vertical axis. In simpler terms, it measures how quickly a vehicle is turning left or right. (shown in figure 1)

By measuring the rate of rotation, The ESP system can detect potential skids, oversteer, or understeer situations and intervene to help the driver maintain control and stability.

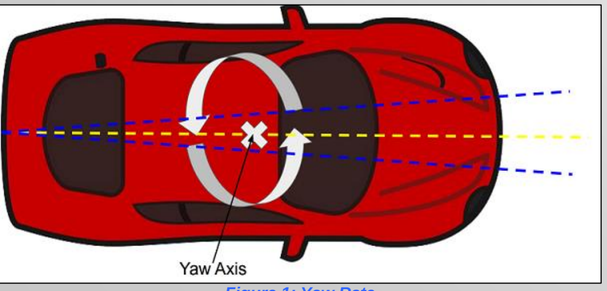

Figure 1: Yaw Rate

How does ESP work?

Electronic Stability Program (ESP) is designed to counteract both oversteer and understeer to enhance vehicle stability and control. Firstly, we will explain **oversteer and understeer** and then we will describe how ESP can counteract both.

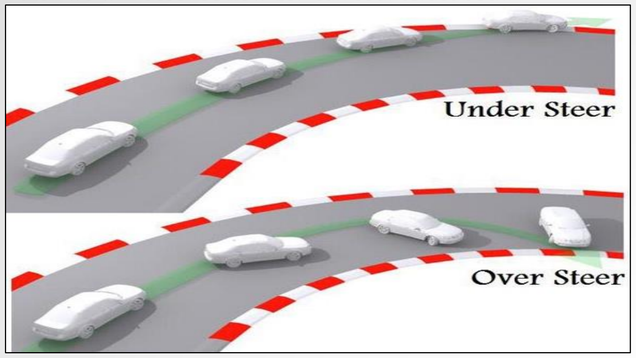

Figure 2: Understeer & Oversteer

Understeer as shown in figure 2, occurs when the front tires lose traction (grip with road), and the vehicle tends to plow straight ahead despite steering input of the driver. To counteract understeer, ESP can reduce engine power and selectively apply brakes to individual wheels to redirect the vehicle's path and regain control. This shows how ESP communicates with Steering angle sensor (SAS) to compare steering angle by driver and the actual path of the vehicle. ESP may reduce engine power to decrease speed and, if necessary, apply brakes to the inner rear wheel to create a yaw moment, helping to steer the vehicle more effectively through the corner.

Oversteer as shown in figure 2, occurs when the rear tires lose traction and the vehicle's rear end begins to slide outwards relative to the front tires. Oversteer is often considered more critical as you tend to lose the rear end and enter a sudden and unpredictable spin. To counteract oversteer, ESP can selectively apply brakes to individual wheels to help regain traction and stabilize the vehicle, Aswell as applying brakes to the outer front wheel which creates a yaw moment opposite to the direction of oversteer brining the vehicle back in line.

What situations is ESP particularly useful in?

- **ESP** is particularly useful in situations where there is a sudden risk of skidding or loss of control, such as during sudden manoeuvres, slippery road conditions, or emergency braking.
- The system continuously monitoring various vehicle parameters, such as wheel speed, steering angle, and lateral acceleration, ESP can detect when the vehicle is deviating from the intended path or experiencing loss of stability and will correct it.

<u>ESP is useful in many situations as shown below:</u>

Situation 1 without ESP. An obstacle suddenly appears on the road, at first the driver steers very quickly to the left then immediately to the right. The vehicle swerves due to the driver's steering movements and the rear end breaks away. This results in driver no longer able to control the vehicle resulting in rotation about the vertical axis.

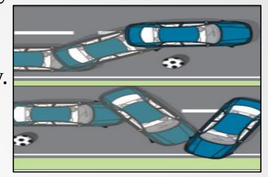

Figure 3: Obstacle no ESP

Situation 1 with ESP vehicle attempts to avoid the obstacle. From the data provided by the sensors, ESP recognizes that the vehicle is losing stability. The system calculates its counteractive measures. ESP brakes, the left-hand rear wheel. This promotes the turning motion of the vehicle.
As the vehicle swerves to the left, the driver steers to the right. To help the driver steer into the over-steer, the front right wheel is braked.
The preceding lane change can cause the vehicle to roll about its vertical axis. To prevent the rear end from breaking away, the front left wheel is braked.

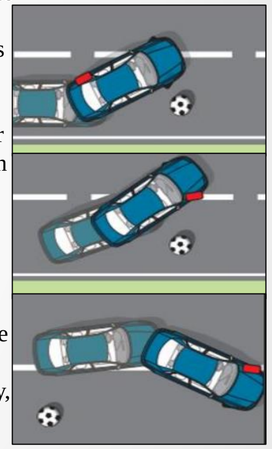

Figure 4: Obstacle with ESP

Situation 2 Traction control systems (ESP,ABS) provide increased vehicle stability and directional steerability when accelerating and this is particularly beneficial under heavy acceleration.
The TCS maintains the optimum level of slip at the wheels to allow the engine to transfer the maximum tractive effort without compromising safety under the given road conditions. slippery surfaces such as ice and snow.

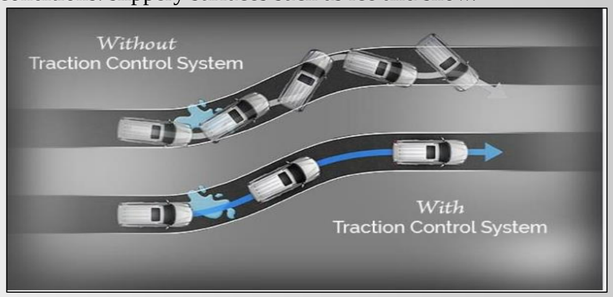

Figure 6: Slippery Surfaces

Conclusion

- In conclusion ESP is a critical system in vehicle stability and by using inputs from various sensors it helps to avoid potentially hazardous driving situations.
- ESP is a crucial safety feature that is implemented in all modern cars, it's been shown that ESP significantly reduces the risk of accidents involved in adverse conditions or emergency situations.
- ESP Provides an added layer of stability and control, helping drivers maintain confidence and control behind the wheel.

References

Figure 1: Innova.com/Yaw Rate
Figure 2: thereviewstories.com/Oversteer & Understeer
Figure 3,4,5,6,7: Figures were gathered on class notes in Moodle.

Forces that act on a vehicle

Now that we understand what the ESP system consists of and how it works, we will talk about what forces that act on a vehicle and the traction between the Road and surface of tires.

<u>Forces which act on a vehicle:</u>

1)**Tractive force** - Acceleration
2)**Brake pressure** - Counteracts Tractive force
3)**Lateral forces** - Preserves vehicle steerability
4)**Adhesion forces –** Friction, Gravity

The vehicle is also subject to Yaw moments as we mentioned earlier.

Figure 5: Forces acting on vehicle wheel

Interaction between some of these forces can be described using of the **Kamm friction circle**. The radius of the circle is defined by the adhesion force (4) between the road surface and the tires, in other words the lower the adhesion force (4) , the smaller the radius, the higher the adhesion force, the larger the radius. **If the total force lies within the circle, the vehicle is in a stable state, if it exceeds, vehicle is no longer controllable.**

In the Kamm circle, you can be either turning left, turning right, accelerating, braking, or a combination of this. The important thing the traction circle illustrates is that you can combine turning and speeding up or slowing down, <u>but the less of one you do, the more grip for other you have</u>.

This concept simplifies the idea that only so much traction is available at any moment for a tire, and this must be split between cornering and braking/acceleration

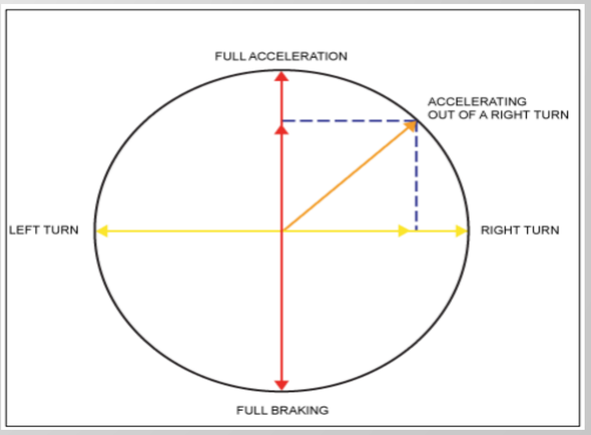

Figure 7: Kamm Friction circle