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Aspects regarding ESC System Influence in Stability of Vehicles Lateral Motion

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Abstract- The paper presents some theoretical and experimental aspects related to the influence of Electronic Stability Control system in stability of lateral motion. For the experimental research a Volkswagen Touareg equipped with ESC vehicle and the dedicated software were used. There will be presented some elements of control strategies and control algorithms used in practical experiments and in graphical mode. The influence of EASC system in maintaining the trajectory will also be presented.
Keywords- electronic stability control (ESC), vehicle stability, vehicle dynamics

I. INTRODUCTION

At present, vehicles are equipped with active systems for longitudinal and transversal stability control; for this purpose, rotational rolling and yaw motions control are assured separately by an integrated solution [4], [6], [7], [8], [9].

The main purpose of the present paper is to study ESC system influence in maintaining a specified trajectory of a vehicle. For that matter, there will be presented the main mathematical models of lateral dynamics, which are being used at ESC. Afterwards there will be shown the main elements specific to electronic control of stability, using control strategies and algorithms utilized and also using mathematical models for lateral dynamics.

Finally, the paper presents the main theoretical elements of fuzzy controller and uses experimental data obtained during tests to highlight ESC system influence in maintaining vehicle trajectory.

II. EXPERIMENTAL RESEARCH

During experimental research, a Volkswagen Touareg vehicle and the dedicated software for VAG group, Ross-Tech VCDS (which facilitate users professional communication with the vehicle`s command modules) has been utilized for data acquisition.

III.MATHEMATICAL SIMULATION OF LATERAL VEHICLE DYNAMICS

The most used mathematical model for lateral vehicle dynamics is with two degrees of freedom, the bicycle model.

The two degrees of freedom for this model can be lateral position y and yaw angle □, or lateral slip body angle □ and angular velocity $\square_z$ (figure 1).

Vehicle lateral position is measured according to lateral axis, from CG towards C. Yaw angle is defined by O_1X axis and vehicle`s longitudinal axis $Ox$. As shown in figure 1, there are taking in consideration global axis system $XO_1Y$ and $xOy$ axis system (attached to vehicle`s vehicle gravitation center) [8], [10].

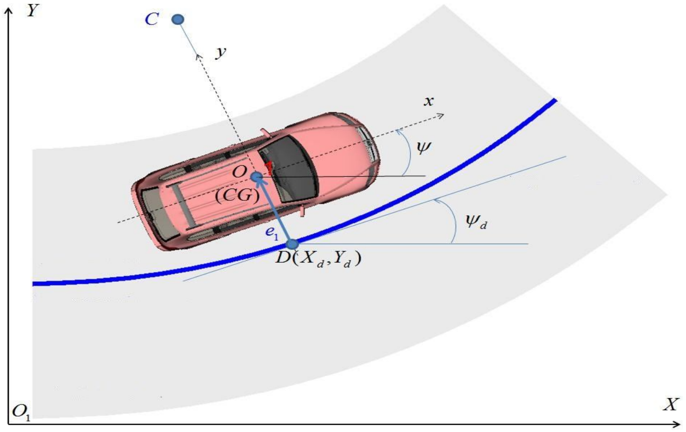

Fig. 1 Lateral vehicle dynamics

In figure 1 road line is considered imposed trajectory defined by $D(X_d,Y_d)$ points and yaw angle ψ_d .The distance between D point and gravity center CG is e_1 error.

The mathematical description of the model with lateral position y and yaw angle □□□as degrees of freedom is [2], [8]:

$$\begin{cases} m\left(y''+\psi' v_x\right)=F_y^f\cos\delta+F_y^s+F_x^f\sin\delta \\ J_z\psi''=aF_y^f\cos\delta-bF_y^s+aF_x^f\sin\delta \end{cases} \qquad (1)$$

with J_z as inertial yaw moment.

The mathematical description for model with body slip angle □ and yaw velocity □□as degrees of freedom is [2], [8]:

$$\begin{cases} mv_x\left(\beta'+\omega_z\right)=F_y^f\cos\delta+F_y^s+F_x^s\sin\delta \\ J_z\omega_z'=aF_y^f\cos\delta-bF_y^s+aF_x^f\sin\delta \end{cases} \qquad (2)$$

Within mathematical description (3) and (4), the two variables are lateral forces on axles F_y^f and F_y^s.

Mathematical model for lateral dynamics uses two parameters which indicate the imposed trajectory conformity:

- e_1 error: the distance between center of gravity (CG) and road center line (figure 1);
- e_2 error: longitudinal vehicle axis deviation from the trajectory.

For this matter, imposed angular yaw velocity is:

$$\psi_d'=\frac{v_x}{R}=\omega_{zd} \qquad (3)$$

where v_x is longitudinal velocity and R is road curve.

Results vehicle`s imposed lateral acceleration:

$$a_y=\frac{v_x^2}{R}=v_x\psi_d'=v_x\omega_{zd} \qquad (4)$$

Defining e_1'' and e_2 as:

$$e_1''=\left(y''+v_x\psi'\right)-\frac{v_x^2}{R}=y''+v_x\left(\psi'-\psi_d'\right)=y''+v_x\left(\omega_z-\omega_{zd}\right) \qquad (5)$$

$$e_2=\psi-\psi_d=-\frac{b}{R}+\frac{a}{2C_\alpha^s A}\frac{mv_x^2}{R} \qquad (6)$$

Results:

$$e_1'=y'+v_x\left(\psi-\psi_d\right)\Rightarrow e_1'=v_y+v_xe_2\Rightarrow e_1'=\frac{v_x^2}{R}+v_xe_2 \qquad (7)$$

IV. CONTROL OF LATERAL VEHICLE DYNAMICS

In practice, fuzzy logic and genetic algorithms based control is often used at present, in singular form or in combination with neural networks and genetic algorithms; all this forms are constituent part from intelligent control, called so because of its link with biological concepts and algorithms [11].

General scheme for a control fuzzy based system has error e as input parameter and u as output command.

Following, using Mathlab software, is presented an example for Wolkswagen Touareg lateral dynamics simulation with a fuzzy controller for yaw motion stability, using ESC to maintain stability to a predefined trajectory.

In figure 2 is presented vehicle motion on a circular road with radius, R=300m and longitudinal velocities of 50 km/h respective 70 km/h without ESC. As is shown, without ESC, car fails to respect the imposed trajectory; the deviation has higher values as the vehicle speed increases.

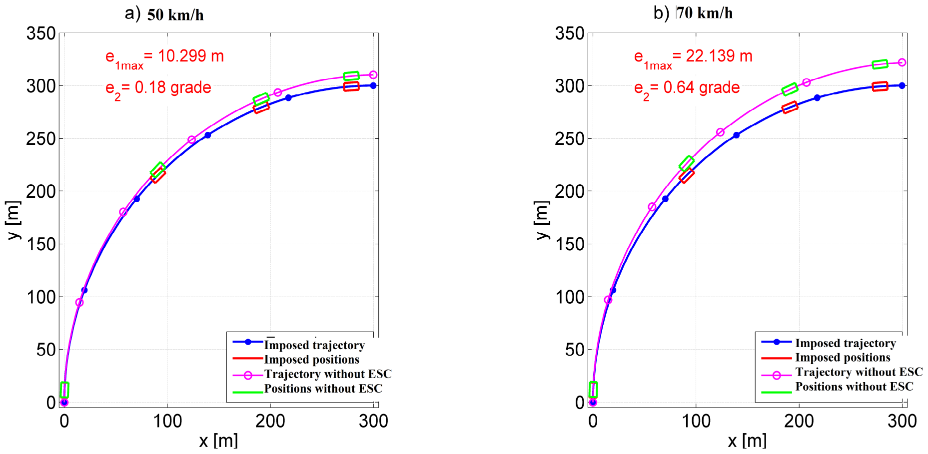

Figure 2 Volkswagen Touareg motion on a circular road with radius of *R*=300m at different longitudinal speeds, without ESC

Therefore, ESC system must to be present so that imposed trajectory to be respected.
In figure 3 it is presented Mathlab scheme for fuzzy controller with error and error derivative as input parameters.

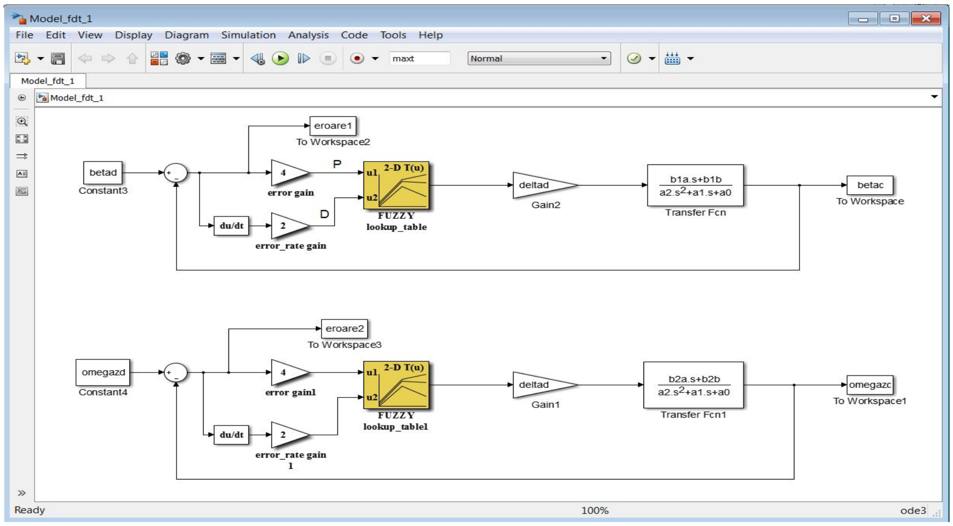

Figure 3 Mathlab scheme with fuzzy controller

The result is presented in figure 4, where can be seen a good concordance between imposed trajectory and actual trajectory with ESC; additionally, form figure 4a can be notice reduced deviations between the two trajectories.

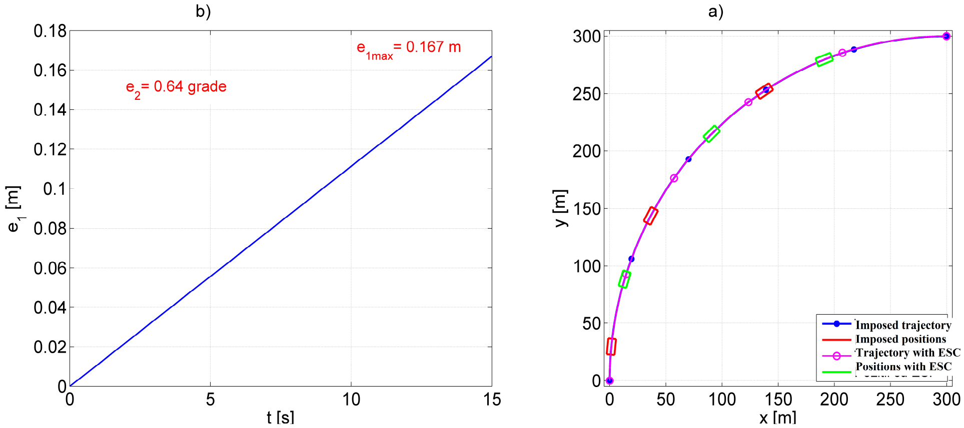

Figure 4 Volkswagen Touareg motion on a circular road with radius of *R*=300m at 70 km/h with ESC (fuzzy controller)

The reduced deviations between the two trajectories (imposed one and with ESC) is confirmed in figure 5 (detail A). It can be seen that e_1 deviation is 0.16 m.

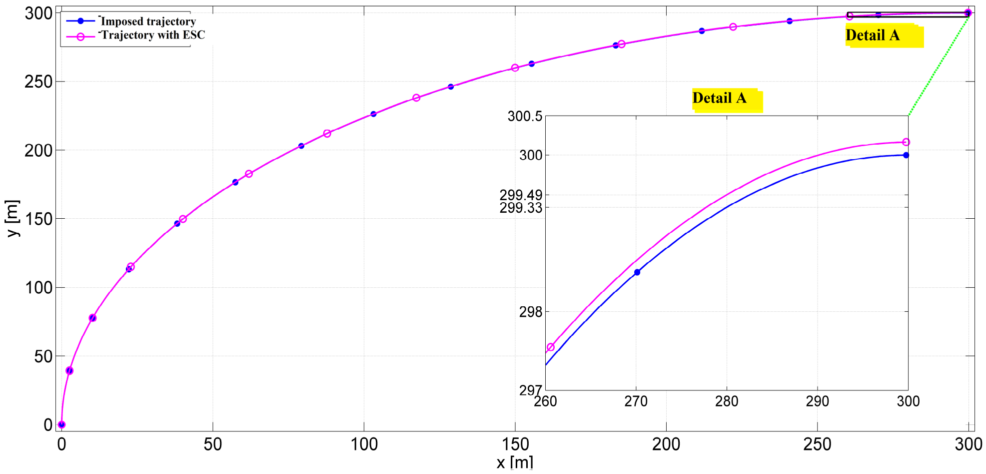

Figura 5 Differences between imposed trajectory and with ESC (fuzzy controller), Volkswagen Touareg

V. CONCLUSIONS

At present, vehicles equipped with sensors, actuators and electronic command units in manufacturing process, allows complex research with complete access to all high speed dynamical processes privacy, characteristics to motions electronic stability control.

Lateral vehicles dynamic stability control require access to control strategies and algorithms which can meet the expectations not only in dynamics and economics performances, but also in systemic performances.

Analyzing research results, concludes the importance of ESC system functionality in driver assist for that the vehicle to respect the imposed trajectory.

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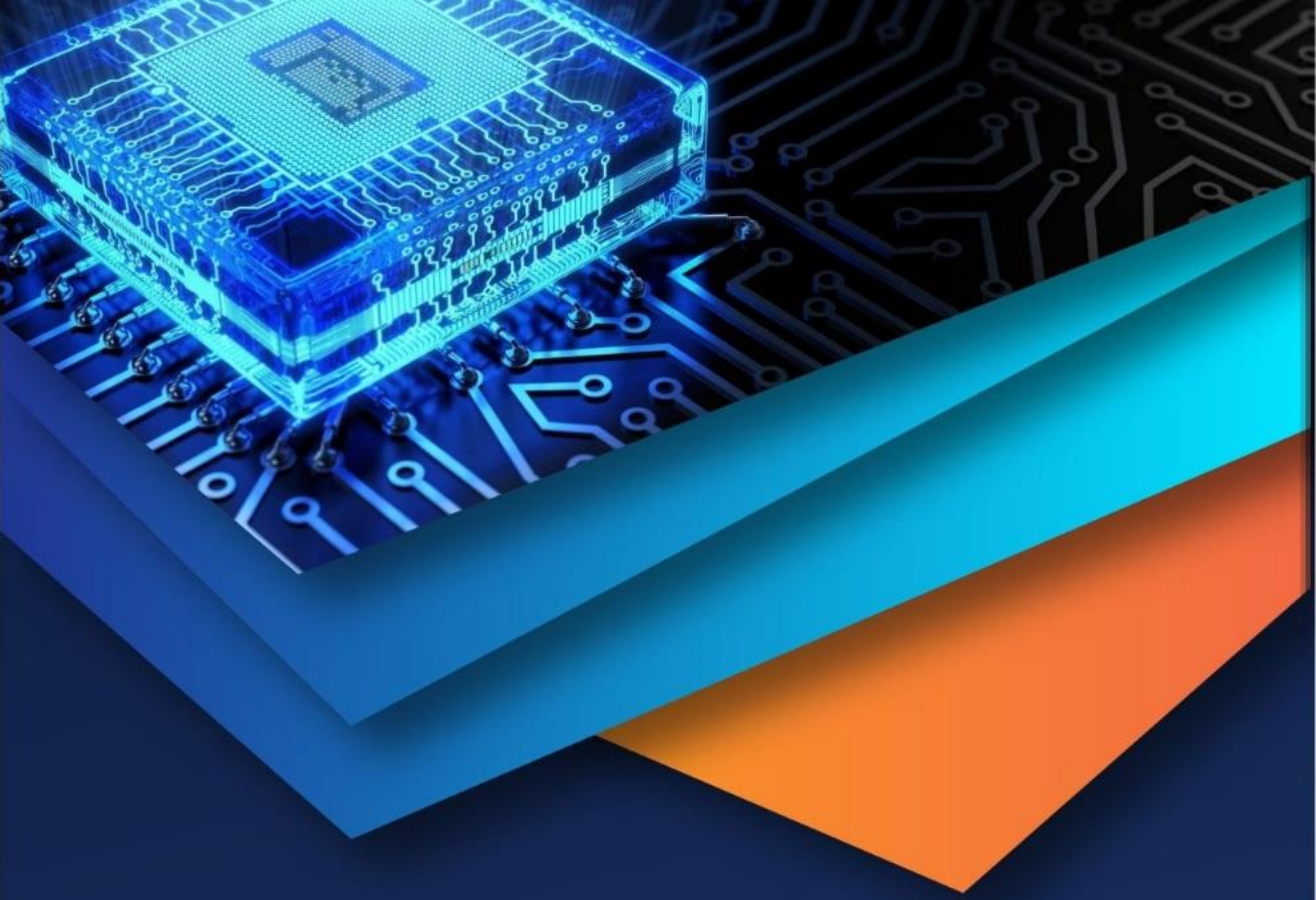

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