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# Review on The Stabilizer Bar Equipped with The Vehicle

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ABSTRACT

Today, the automobile can move at a very high speed. Therefore, the safety and stability issues of the vehicle are especially concerned. To limit the vehicle's lateral instability when steering at high speeds, the solution of using the stabilizer bar is proposed. There are 2 types of stabilizer bars commonly used, including the passive stabilizer bar (mechanical) and the active stabilizer bar (hydraulic, electronic). When the vehicle is equipped with the stabilizer bar, the vehicle's lateral instability problems have been significantly improved. With simple construction, compactness, and high performance, the stabilizer bar is equipped with most vehicles. This article focuses on the introduction and review of the effectiveness of the stabilizer bars used in the vehicle.

KEYWORDS

Stabilizer bar, Anti-roll bar, Instability Problem, Rollover

## INTRODUCTION

Automobiles were first created and introduced about 135 years ago [1]. Today, this vehicle is commonly used all over the world. According to the development of science and technology, the automotive industry also developed strongly. In the past, the vehicle was just a means of transporting people or goods at a very low speed. Currently, the actual speed of the vehicle can reach about 180 km/h (conventional vehicle) or more than 350 km/h (super vehicle). Therefore, the issues of safety and stability of the vehicle when moving are always concerned by manufacturers. Many accidents of the vehicle happen while moving at high speeds. In particular, if the steering angle and steering acceleration are large, the safety of the vehicle can be affected [2-4]. When the vehicle steers with a large steering angle at high speed, the vehicle may be sideslip or rollover. Especially, the phenomenon of rollover is very dangerous [5-8]. The accidents of rollover often have serious consequences for passengers and cargoes. To limit this problem, there are many solutions proposed such as using the electronic stability program (ESP), replacing the passive suspension system by the active suspension system (AS), using the electronic power system (EPS), etc… [9-14]. However, these systems are usually only available on high-end vehicles because they are so expensive.

Therefore, the method of using the stabilizer bar on the vehicle is proposed to improve the vehicle's stability when steering at high speeds. With compact construction and proper price, the stabilizer bar is equipped with on most vehicles today. The stabilizer bar (also known as the anti-roll bar, stability bar, or sway bar) [15] is capable of enhancing the vehicle's stability. The stabilizer bar is only effective when the vehicle steers, it will generate the force F that acts in contrast to the vehicle's external forces. Therefore, the roll angle of the vehicle and the difference of the vertical force at the wheel on each axle can be reduced if the vehicle is equipped with the stabilizer bar [16]. At this time, the phenomenon of rollover can be limited, the vehicle can move stably and safely [17]. There are two types of stabilizer bar commonly used, including the passive stabilizer bar (mechanical) and the active stabilizer bar (hydraulic or electronic) [18]. They have different advantages and disadvantages. Each of these types will be equipped with the models corresponding to their segment.  In order to be able to further clarify the characteristics of the stabilizer bar, this article focuses on the introduction and review of the two mentioned types of stabilizer bars. The object's method of analysis and information collection will be used in this article.

THE PASSIVE STABILIZER BAR

The passive stabilizer bar (mechanical stabilizer bar) is used in most popular vehicles. The advantage of the passive stabilizer bar is a cheap price, compact structure, easy to arrange. The structure of the passive stabilizer bar is shown in Figure 1. The passive stabilizer bar consists of three main parts (as Figure 1): 1- lever arm, 2- bearing, 3- back. The ends of the bar are attached to the un-sprung mass (wheel and hub). The back of the bar is mounted to the chassis through the bearing (2). The transition area between the lever arm (1) and back (3) is bent to avoid other components and to reduce concentrated stress.

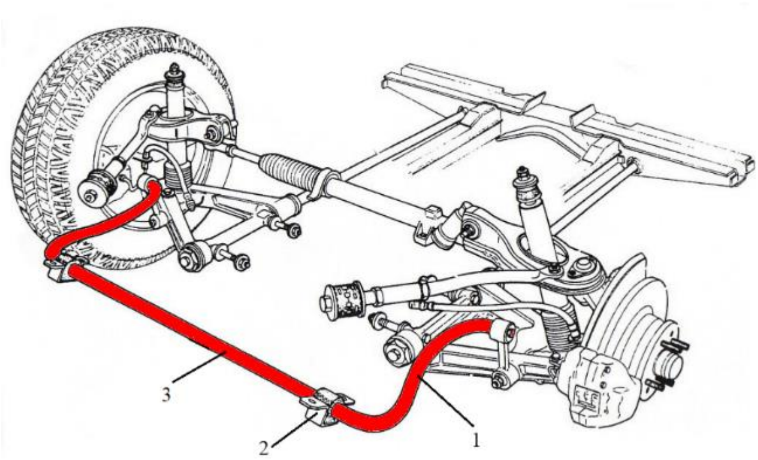


**Figure 1.** The passive stabilizer bar

When the vehicle steers, the centrifugal force will appear. Therefore, the body of the vehicle (sprung mass) will be tilted, the center of gravity of the sprung mass will displace from the original position. The load of the wheel inside the turning arc will be reduced, and the load of the wheel outside the turning arc will be increased. As a result, the inner wheel will tend to lift and the outer wheel will be pushed down. At this time, the ends of the stabilizer bar will move with the wheel. Because the stabilizer bar's displacement on both sides is the opposite, the back of the stabilizer bar will be twisted. The torque generated by the stabilizer bar is opposite and equal. Thus, the value of roll moment will be partly canceled.

Usually, the passive stabilizer bar is made of steel or alloy steel. This material has high stress and great elasticity [19, 20]. When calculating and designing the stabilizer bar, there are two very important influencing factors, including mass and displacement. To reduce mass, the stabilizer bar is usually made hollow [21]. However, the value of displacement will be very large if the bar's thickness is small. If the mass of the bar is too large, the vehicle's smoothness and comfort may be affected. If the bar's displacement is too large, the geometry dimensions of the bar will not be guaranteed. Therefore, the stabilizer bar needs to be optimized the above two parameters when calculating and designing [22, 23].

When the vehicle is equipped with the passive stabilizer bar, the roll angle $\varphi$ and the difference of the vertical force at the wheel of each axle $\Delta F_z$ have been improved. There are many methods to determine the impacting force of the passive stabilizer bar. In [24], Vu et al. calculated this value based on the roll angle of the sprung mass $\varphi$ and the roll angle of the un-sprung mass $\phi$. Besides, the authors used the displacement of the un-sprung mass to calculate this value. Overall, when the vehicle is equipped with the stabilizer bar, the stability and safety issues have been more ensured. However, the conventional passive stabilizer bar is not able to work in special dangerous situations (high speed, large steering angle). Therefore, the active stabilizer bar is used to replace the passive stabilizer bar in these cases.

THE ACTIVE STABILIZER BAR

The active stabilizer bar is used to aid the vehicle's safety and stability in dangerous situations. The active stabilizer bar includes 2 types: the hydraulic stabilizer bar and the electronic stabilizer bar. The structure of the active stabilizer bar is more complex than the conventional passive stabilizer bar. Therefore, the cost of the active stabilizer bar is also more expensive.

THE HYDRAULIC STABILIZER BAR

The structure of the hydraulic stabilizer bar is shown in Figure 2.

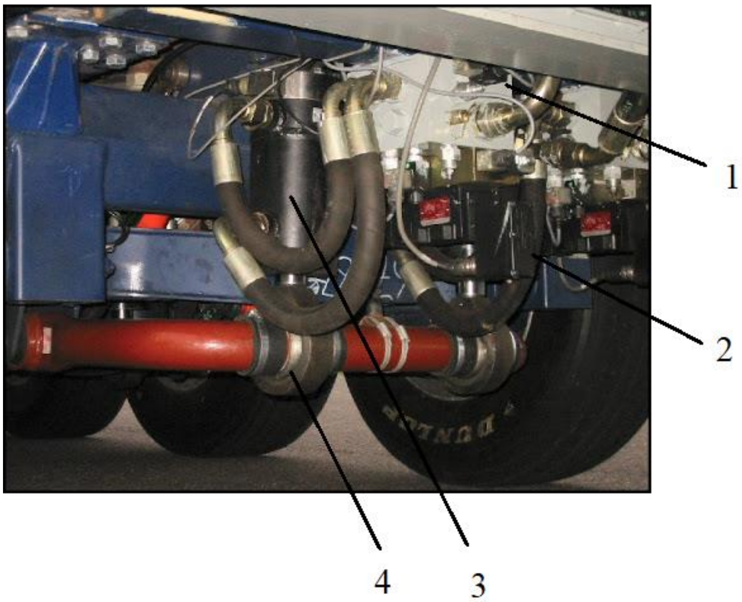


**Figure 2.** The hydraulic stabilizer bar

The hydraulic stabilizer bar includes: (1) the electrohydraulic servo valve, (2) the oil line, (3) the actuator, and (4) the bearing. When the vehicle steers, the changes of sprung mass's roll angle, wheel's displacement, etc... are collected by the sensors. These signals are then sent to the ECU for analysis and evaluation. Next, the ECU sends voltage signals to the electrohydraulic servo valve unit (1) to control the opening and closing of the valve doors. The hydraulic oil from the tank flows through the valve along the oil lines (2) to the actuator (3). On large trucks and tractors, actuators in the form of the pistons (as shown in Figure 3.1). For Sedan or SUV models, the actuator is in the form of a hydraulic motor. The high-pressure oil pushes the piston to lift the sides of the vehicle's body. Therefore, the roll angle of the vehicle's body $\varphi$ and the difference of the vertical force at the wheels of each axle $\Delta F_z$ will be reduced, the vehicle moves more stably and safely.

There are many methods to control hydraulic stabilizers. In [25], Zulkarnain used an LQG controller to control the operation of the hydraulic stabilizer based on the specified input signals. Recently, Nguyen has proposed the control method for the hydraulic stabilizer bar based on the linear controller [26]. Besides, the hydraulic stabilizer bar is also controlled by Fuzzy & PID Controller [27-29]. In general, these methods show the optimum when using. Compared with the passive stabilizer bar, the hydraulic stabilizer bar can produce a much greater anti-roll torque. This moment is generated based on the pressure change in the fluid flow inside the system. Therefore, the stability and safety of the vehicle can be significantly improved. However, the size of the hydraulic stabilizer bar is quite large. Besides, the delay of the hydraulic stabilizer bar when operating is also an unresolved issue. Therefore, the electronic stabilizer bar is used to replace the hydraulic stabilizer bar on high-end vehicle models.

The electronic stabilizer bar

Today, the electronic stabilizer bar is equipped with high-end vehicles such as Audi SQ7-TDI, Volkswagen Touareg 2019, Porsche Cayenne 2020, etc... Compared to the hydraulic stabilizer bar, the electronic stabilizer bar has a compact size, easy to arrange. Besides, the sensitivity of this bar is very high, its ability to respond well to dangerous conditions [30]. The structure of the electronic stabilizer bar is shown in Figure 3.

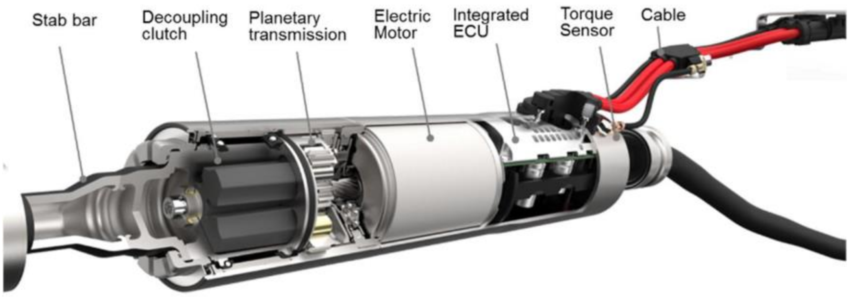


**Figure 3.** The electronic stabilizer bar

The structure of the electronic stabilizer bar includes cable line (48 V), integrated ECU, electric motor, planetary reduction gears set, and decoupling clutch. The torque sensor is mounted on the back of the stabilizer bar. Similar to the hydraulic stabilizer bar, the electronic stabilizer bar also works based on the difference in the vehicle's status parameters. The current supplied to the electric motor is 48 V (2 to 4 times more than the hydraulic stabilizer bar). Overall, the anti-roll torque generated by the electronic stabilizer bar is also very large, ensuring stable and safe operation of the vehicle in dangerous situations [31]. Because the electronic stabilizer bar is very complicated, the amount of research on its control problem is still very little and limited.

## CONCLUSIONS

The problem of lateral stability of the vehicle when moving has a great impact on the safety and comfort of passengers and cargoes. To improve this problem, the solution of using the stabilizer bar is proposed. The passive stabilizer bar (mechanical stabilizer bar) has a simple structure, low cost, and is commonly used on current vehicle models. When the vehicle is equipped with the passive stabilizer bar, the values of the roll angle of the sprung mass $\varphi$, the roll angle of the un-sprung mass $\phi$, and the difference of the vertical force at the wheel of each axle $\Delta F_z$ will decrease. Therefore, the vehicle moves more stable and safer. In some special cases (high speed, large steering angle), the passive stabilizer cannot guarantee the stability and safety of the vehicle. To improve this problem, the passive stabilizer bar is replaced by the active stabilizer bar. The active stabilizer bar (hydraulic stabilizer bar or electronic stabilizer bar) has a more complex structure. They are controlled automatically based on the vehicle's oscillation state that is detected by the sensors.

Therefore, the active stabilizer bar is expensive and is only used on high-end vehicles or tractors, and large trucks. The anti-roll torque produced by the active stabilizer bar is much larger than the conventional passive stabilizer bar. Hence, the stability and safety effect of the active stabilizer bar is much greater than the passive stabilizer bar. The hydraulic stabilizer bar that uses the actuator is the piston is commonly found on larger vehicles. In contrast, the hydraulic stabilizer bar that uses a hydraulic motor is only used on SUV, Sedans, ... Its torque generated is greater than that of the electronic stabilizer bar. However, its sensitivity is quite low. The electronic stabilizer bar uses an electric motor with the planetary transmission. It is highly effective when it is equipped with modern vehicles today. However, its price is very expensive. Besides, its control problems are also extremely complex. This article only focuses on the introduction, classification, and performance review of the stabilizer bar is equipped with vehicles. In the future, the problems of structural optimization and control of the stabilizer bar will continue to be studied more.

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