

MODERN TYPES OF STEERING DRIVES AND THEIR STRUCTURAL FEATURES**Yuldashev Abdusamat Khalimovich**

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ABSTRACT

Steering drive systems form the main mechanical and electromechanical interface between the driver and the road wheels of a vehicle. Their structural design directly affects controllability, manoeuvrability, energy consumption and road safety. Objective: The purpose of this article is to analyse the modern types of steering drives and to compare their structural features, advantages and limitations. Methods: A comparative technical review was conducted on mechanical steering, hydraulic power steering (HPS), electric power steering (EPS), Steer-by-Wire (SbW), and hybrid steering solutions on the basis of automotive design literature and functional classification. Results: Mechanical steering systems are simple, reliable and inexpensive but require greater driver effort. HPS systems improve steering comfort by using hydraulic pressure, although they increase fuel consumption and require fluid maintenance. EPS systems reduce energy losses and allow electronic control of steering assistance according to vehicle speed and driving conditions. SbW and hybrid systems represent the most advanced direction because they reduce mechanical components and integrate well with automated driving functions. Conclusion: The development trend of modern steering systems is moving from purely mechanical and hydraulic solutions toward electronically controlled EPS, SbW and hybrid systems that provide higher efficiency, better safety and wider integration with intelligent vehicle control technologies.

Keywords: steering drive; mechanical steering system; hydraulic power steering; electric power steering; Steer-by-Wire; hybrid steering; vehicle control; structural features.

1. INTRODUCTION

The vehicle steering system plays an essential role in controlling the movement and direction of a transport vehicle. At the centre of this system is the steering drive mechanism, which transmits the driver's hand movement from the steering wheel to the road wheels and changes their angular position. Since the appearance of early mechanical steering systems in the seventeenth century, steering technology has undergone significant technical improvement and has become one of the most important units of vehicle safety and controllability.

In modern vehicles, steering drives are no longer limited to a simple mechanical linkage. They are expected not only to make steering easier but also to improve vehicle stability, reduce energy consumption, adapt to different road conditions and support electronic driver assistance systems. Therefore, the selection and design of a steering drive must be evaluated from the viewpoints of structural complexity, reliability, energy efficiency, maintenance requirements and safety performance.

The main types of steering drive systems used in vehicles can be classified as mechanical steering systems, hydraulic power steering systems, electric power steering systems, Steer-by-Wire systems and hybrid steering solutions. Each type has its own structural features, operational advantages and technical limitations. The present article provides a systematic analysis of these

Journal: <https://ifsmrc.org/index.php/aijrm>

systems and explains how their construction affects driving comfort, fuel economy and vehicle safety [1-4].

2. MATERIALS AND METHODS

The study was carried out as a descriptive and comparative technical analysis of steering drive systems. The source material consisted of automotive design textbooks, maintenance manuals and theoretical descriptions of vehicle control mechanisms. The classification was based on the type of force transmission between the steering wheel and the road wheels.

Five steering drive configurations were considered: mechanical steering, hydraulic power steering (HPS), electric power steering (EPS), Steer-by-Wire (SbW), and hybrid steering. The systems were compared according to the following criteria: structural composition, operating principle, driver effort, energy consumption, maintenance complexity, safety potential, and compatibility with automated control functions.

The comparison was qualitative because the article is focused on constructive features rather than experimental measurement. Nevertheless, the selected criteria make it possible to identify the engineering advantages and disadvantages of each steering type and to determine the general direction of development in modern automotive steering technology.

3. RESULTS

3.1 Mechanical Steering Drive

A mechanical steering system is the simplest type of steering drive, in which there is a direct mechanical connection between the steering elements and the road wheels without any power assist. The driver's torque is transmitted through the steering column to a rack-and-pinion or screw-type steering mechanism, which changes the wheel angle.

The main structural advantage of this system is its simplicity. It contains fewer components, has low mass, is highly reliable and can be serviced or repaired without complex diagnostic equipment. Due to its simple design, mechanical steering is cost-effective and suitable for small vehicles or older vehicle models. However, the absence of assistance means that the driver must apply greater force, especially during low-speed manoeuvring and parking. This can increase fatigue during long journeys or in urban driving conditions.

3.2 Hydraulic Power Steering

Hydraulic power steering combines mechanical steering components with a hydraulic pump, hydraulic cylinder, fluid lines and control valves. The hydraulic pump is driven by the engine and generates pressure in the fluid circuit. When the driver turns the steering wheel, the hydraulic pressure assists the steering motion and reduces the effort required at the steering wheel.

The main advantage of HPS is the significant reduction of steering effort. This is especially noticeable in city driving and at low vehicle speeds. In addition, hydraulic systems are appreciated for their stable and familiar steering feel. However, the pump is continuously driven by the engine, which increases fuel consumption and causes energy losses even when steering assistance is not required. The system also requires periodic inspection of hydraulic fluid, hoses, seals and pump condition. Changes in fluid temperature or leakage can affect the performance and reliability of the steering system.

3.3 Electric Power Steering

Electric power steering is one of the most widely used modern steering technologies. In this system, steering torque and wheel position are measured by sensors, and an electric motor supplies the required assisting torque to the steering column or rack-and-pinion mechanism. Unlike HPS, the EPS system does not use hydraulic fluid, which reduces maintenance requirements and improves energy efficiency.

The main advantage of EPS is that it consumes energy only when steering assistance is needed. This reduces engine load and contributes to lower fuel consumption. The assistance level can be changed according to vehicle speed and driver behaviour: at low speed the steering can be made lighter, while at high speed the system can provide greater stability and more precise control. Modern EPS systems can also be integrated with automatic parking, stability control, lane-keeping assistance and other advanced driver assistance systems. These functions increase the overall safety level of the vehicle.

3.4 Steer-by-Wire and Hybrid Steering Systems

One of the most advanced steering drive technologies is the Steer-by-Wire system. In SbW there is no permanent mechanical transmission between the steering wheel and the road wheels. The driver's steering input is converted into electronic signals and transmitted to an electronic control unit. The control unit then operates actuators that change the wheel angle.

Although the SbW system is structurally and electronically more complex, it provides very high steering sensitivity and can be integrated with automated driving systems. It also makes it possible to simplify vehicle layout and reduce mechanical components. For safety reasons, such systems require reliable sensors, redundant electronic circuits, fail-safe algorithms and high-quality actuators.

In recent years, some manufacturers have also introduced hybrid steering systems that combine the stable feel of hydraulic assistance with the responsiveness and control flexibility of electronic assistance. Such systems aim to provide accurate steering, improved energy management and stable operation under different driving conditions.

3.5 Comparative Assessment of Steering Drive Types

The comparative characteristics of the main steering drive types are summarised in Table 1.

Table 1. Comparative characteristics of modern steering drive systems

Steering type	Main components	Advantages	Limitations	Typical application
Mechanical steering	Steering wheel, column, rack-and-pinion or screw mechanism	Simple design, low cost, high reliability, easy repair	High driver effort, less comfortable at low speed	Older and small vehicles
Hydraulic power steering (HPS)	Hydraulic pump, fluid lines, cylinder, valves, mechanical linkage	Low steering effort, stable steering feel, proven construction	Higher energy loss, fluid maintenance, possible leakage	Passenger cars, trucks and service vehicles
Electric power steering (EPS)	Electric motor, torque sensors, ECU, steering rack or column	Energy efficient, adjustable assistance, compatible with	Requires electronic diagnostics and reliable software	Modern passenger cars, hybrid and electric vehicles

	mechanism	ADAS	control	
Steer-by-Wire (SbW)	Sensors, ECU, actuators, electronic signal transmission	High integration potential, reduced mechanical parts, flexible control	Complex design, high safety and redundancy requirements	Advanced and automated vehicles
Hybrid steering	Combined hydraulic and electronic assistance units	Balances stability with electronic control flexibility	More complex than single-system designs	Vehicles requiring both steering feel and advanced assistance

4. DISCUSSION

The comparison shows that the development of steering drive systems is closely connected with the general trend of vehicle electrification and automation. Mechanical steering systems remain important from the historical and structural point of view because they demonstrate the basic force-transfer principle. However, their limited comfort and the high driver effort required during manoeuvres restrict their use in modern passenger vehicles.

Hydraulic power steering has been widely adopted because it provides reliable steering assistance and preserves a traditional road feel. Nevertheless, continuous engine-driven pump operation is a serious disadvantage in modern vehicle design, where energy efficiency and emission reduction are major requirements. The need for hydraulic fluid maintenance also increases service costs and creates potential reliability issues related to leakage, wear and temperature sensitivity.

EPS technology has become the preferred solution for many modern vehicles because it combines compact construction, lower energy consumption and electronic controllability. Its ability to change steering assistance according to speed and driving conditions improves both comfort and safety. In addition, EPS is suitable for integration with automated parking, stability control and lane-keeping systems. This explains why manufacturers are gradually replacing hydraulic systems with electric alternatives.

Steer-by-Wire and hybrid systems represent the next stage of steering system development. SbW offers great potential for future intelligent vehicles, but its implementation requires strict safety measures and redundant control architecture. Hybrid systems, in turn, can serve as a transitional solution by combining the benefits of hydraulic stability and electronic control. Thus, the choice of steering drive type depends on vehicle category, cost requirements, safety level, maintenance infrastructure and integration with electronic control systems.

5. CONCLUSION

This article analysed the modern types of steering drives and their constructive features. Based on the comparison, the following conclusions can be drawn:

1. Mechanical steering systems have the simplest structure and high reliability, but they require greater physical effort from the driver and are less suitable for modern comfort requirements.
2. Hydraulic power steering reduces steering effort and provides stable road feel; however, it consumes additional engine power and requires regular maintenance of hydraulic components.

3. Electric power steering is the most common modern solution because it improves energy efficiency, reduces maintenance needs and can be controlled by electronic algorithms.

4. Steer-by-Wire systems provide the highest potential for integration with automated driving technologies, although their design requires high reliability, redundancy and strict safety control.

5. The general development trend of steering drive technology is the transition from mechanical and hydraulic systems toward electronically controlled EPS, SbW and hybrid systems that increase driving comfort, safety and energy efficiency.

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