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An analysis of the application of mechatronics in the modern automotive field

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Abstract. Nowadays, mechatronics technology is more and more widely used in the automotive field, and the author starts from this point to analyze the development in this field of China. By enumerating concrete examples of the application of electromechanical integration technology in the automotive field, the paper analyzes and summarizes the direction of developing electromechanical integration technology in the current automotive field based on existing literature and data, so as to make a contrast with our country's low level of electromechanical integration technology, and puts forward several suggestions on the application of electromechanical integration technology in the automotive field. The results show that the application of mechatronics in the modern automobile field is mainly in automatic fuel filling system, car attitude control, ABS anti-lock system, electronic stability program, racing car design and so on, concluding that progress should be made in the fields of enterprise reform, innovation, and specialty setting.

Keywords: mechatronics, automotive, technology, application, design.

1. Introduction

The word "mechatronics" was first proposed by a senior engineer at Yaskawa Corporation in Japan in 1969. Mechatronics is the combination of mechanical engineering, electronic engineering, computer engineering, control engineering and system design engineering, which is the core technology of the automotive industry. With the development of mechatronics technology, its applications in the automotive field are becoming more and more extensive, such as the Automatic Fuel Filling System, Car attitude control, Antilock brake system (ABS), Electronic Stability Programmer (ESP), optimization of a car equipped with a semi-active suspension and so on. Considering the importance attached to the technology in various countries, Chinese universities began to introduce the major in the 1980s [1]. But due to the late start, there is still an obvious gap in technology between China and some developed countries. For example, many researchers in developed countries have launched many innovative researches such as Agile model-driven engineering that focus on the development and design of complex, software-driven electromechanical systems Develop software for complex electromechanical systems, which shows their mechatronics technology has entered the innovation stage while the technology in China is still in the infrastructure stage [2]. Therefore, this article will list some specific applications of mechatronics technology in the automotive field of developed countries and put forward the author's some opinions on the development of this field in China. The results of this paper are favorable for domestic researchers and practitioners in this field, and some

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useful insights will be made on the application of electromechanical integration technology in automobiles in China.

2. Background

Currently, the number of cars is increasing year by year, and the structure of automobiles is becoming more and more complicated. However, the traditional production mode is low in efficiency and quality, unable to effectively control many production components, and even the cooperation ability between various systems is insufficient [2]. Fortunately, the use of mechatronics technology can bring a comprehensive and thorough collection of vehicle driving and running data, a timely reasonable regulation of vehicles and an efficiently systematic control. Developed countries for the application of mechatronics technology in automobiles earlier, so it is worth learning from experience and researching methods. Therefore, this paper will introduce the application of mechatronics technology from developed countries in the automotive field. Examples are illustrated as follows.

3. Specific application

3.1. Automatic fuel filling system

Traditional refueling is achieved by manual operation, which requires a huge amount of manpower, i.e., high labor cost, and gas stations in some remote and poor areas are not open all day. Considering this situation, an automatic fuel filling system designed by mechatronics comes into being. In this system, vehicles follow color signals or markers to enter the refueling area in order to wait for refueling. Once stopped, sensors and cameras capture the details of the vehicle’s fuel tank and send them to controllers [3]. When the controller obtains the coordinates through some kind of algorithm, the robot can be driven by the controller to align the coordinates so that the robot arm is aligned with the fuel tank. In this project, users should make payments via ATM or mobile payments. After the payment is completed, the manipulator begins to enter the fuel cap to fill the fuel at the command of the controller. After the process is complete, it can be ready for the next car. This design reduces the waste of human resources and makes the operation safer.

3.2. Car attitude control

Obviously, high performance sports cars need very precise control of its motion, especially the chassis attitude motion. Therefore, a mechatronic suspension called Series Active Variable Geometry Suspension (SAVGS) is essential to the process of controlling chassis roll and pitch motion. Taking into account the factors above, a cascaded control scheme that drives the four actuators independently and respects all physical and design limitations is presented [4]. Then the control system is applied to the specific SAVGS configuration, and the nonlinear simulation test is carried out on the whole vehicle model of a general high performance sports car. A set of simulation results corresponding to standard open-loop maneuvers are obtained, coming up with an in-depth understanding of SAVGS performance, its requirements, operation, and impact on vehicle directional response. The simulation results show that SAVGS and the corresponding control system can keep rolling to zero at a normal acceleration level of 0.9g and maintain good performance at a higher acceleration level under a reasonably sized actuator. These results show that the SAVGS based mechatronic technology is very suitable for controlling the chassis attitude motion for vehicles, and the regenerative ability of the mechatronics suspension gives it a very low average power consumption [4].

3.3. ABS braking systems

ABS is a system that automatically controls the braking force of the brake when the car brakes, so that the wheel is not locked in the state of roller sliding (slip rate is about 20%), so as to ensure the adhesion of the wheel and the ground in the maximum value. In fact, ABS braking system has been widely used in the automotive field. They have gone from being an optional feature in high-end vehicles to becoming an essential part of most vehicles. Since the system has been developed for generations, many also believe that there is little that can be done to improve it. However, the introduction of electromechanical integration technology to all the principles of ABD — components, sensors, actuators, and so on — has had a significant impact but also caused people to reflect [5].

However, the current regulation braking system works by reducing and increasing the circulation pressure in braking, which has low efficiency and high energy consumption. Therefore, the intelligent braking systems (IBS) is introduced to solve these problems and optimize performance, which is obviously better than traditional ABS. It is worth mentioning that the system is widely open and can work with a variety of brakes, sensors and actuators, as well as various types of control algorithms [5].

3.4. Electronic stability programmer

The common cause of vehicle accidents is skidding due to understeering or oversteering. Understeer means the car didn't turn as sharply as expected and appears to "plow" straight forward while oversteer means the car turned more steeply than expected and the rear of the vehicle swings outward.

For this situation, ESP compares the driver's expected direction in steering and braking inputs to the vehicle's response through lateral acceleration, rotation (yaw), and individual wheel speeds [6]. The ESP then brakes the individual front or rear wheels as needed, and/or reduces excess engine power to help correct understeer (plowing) or oversteer (towing). What's more, the ESP also incorporates full speed traction control, which senses slippage of the drive wheels under acceleration and individually brakes sliding wheels or wheels, and/or reduces excess engine power until control is regained. Besides, the ESP cannot exceed the physical limits of the car and cannot prevent a crash if the driver pushes the chassis of the car and the possibility of the ESP too far which is a tool that helps drivers maintain control. In conclusion, the ESP combines anti-lock brakes, traction control and yaw control. In addition, numerous international studies have demonstrated the effectiveness of ESP in helping drivers maintain control of their vehicles, helping to save lives and reduce the severity of accidents [6].

3.5. Applications in the field of racing car design

In the robot racing design competition "CARbot", participants through AVR (Alf and Vegard's RISC) microcontroller learning to control PWM hardware, to control the motor speed, where is the application of mechatronics technology [7]. AVR microcontroller can design the control program of a racing car through vehicle control, navigation control, image control (through the CCD optical sensor), steering control, motor speed control, and other aspects of the program. To improve the understanding ability of mechatronics technology and design ability, this is a great help.

What's more, there are specific cases such as the Silesian green power electromechanical vehicle design [8]. To make the motor control operate at high speed while keeping the motor safe, the project designed a PWM controller, which is characterized by the presence of a "turbocharged" mode, switching the reference voltage to the full range of the transducer, and controlling the controller to work at 1kHz. This design is very helpful for the design of the new structure of the car, because all the advanced analysis carried out during the design process indicates the direction in which the vehicle structure should be specifically modified.

4. Discussion

As can be seen from the above cases, the proportion of electromechanical integration in the software is gradually increasing, as is the focus of the development of electromechanical integration in the future. Therefore, "intelligence" will be the next feature of mechatronics. Moreover, due to the increasing complexity of tasks and situations, mechatronics will also involve the use of fuzzy control, neural network terminals, expert systems and other areas of unconventional tools [9].

But how to judge whether the application of mechatronics technology in the automotive field is good or bad? This question has also been effectively answered by relevant scholars. According to some scholars, the selection of criteria for evaluating electromechanical systems is based on the collective knowledge proposed by the Multi-year Roadmap of European Robotics (MAR) [10]. These

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definitions of robotic capabilities can also be applied to mechatronics technology in the automotive field for good or ill. In all, it has nine abilities: suitability, cognitive ability, configurability, decision autonomy, reliability, interaction ability, control ability, motor ability and perception ability. Therefore, the designer can use the proposed electromechanical indicators to evaluate the design scheme and select the best design scheme through combination.

Taking into account the current development status of electromechanical integration technology in the automotive field, a conclusion can be drawn that this area in our country still has no initiative for many sensitive technologies of electromechanical integration applied in the automotive field, such as ABS and ESP. It has reasons as follows: (1) Although the Chinese automobile industry competition is fierce, the mechanical and electrical integration technology equipment is relatively backward, and most enterprises cannot afford the high cost of the equipment. (2) The Chinese automobile design fields independent innovation research and development projects are few, and innovation has not become the market driven mainstream. (3) The electromechanical integration technology major was set up late in our country, and the lack of professionals with outstanding theoretical and practical abilities has also led to a shortage of human resources in related enterprises in this respect, which leads to slow development [11].

In view of the above problems, a number of preferable suggestions can be summed up: (1) Realize the electronic design of the automobile: the use of electromechanical integration technology in the design of automobile engine, voltage regulator, can greatly improve the overall safety of the automobile and the stability of the configuration of electrical appliances. (2) Using microcontrol system: mechatronics technology is applied to the design of the microcomputer control system of the engine, which can reduce the energy loss of an automobile. The design core of microcomputer control system is the use of general microprocessor or large-scale integrated circuit specially designed for automobile engine. (3) Intelligent and flexible design: Based on the many advantages of mechatronic integration technology, in the future of automobile design, the development towards intelligent is the mainstream application direction. Specifically, it can realize the hologram of automobile control, and increase the combination of fuzzy technology and information technology, especially in the development of automobile operation software and chip implantation technology, which will have great innovation, in order to meet the multi-functional needs of modern people for automobiles. (4) Improve the professional level of designers: The design talent in electromechanical integration technology is relatively small in our country; therefore, designers should have a higher level of competence, and vigorously promote the relevant aspects of education system construction to realize the high quality development of our automobile industry. (5) Simulation biological design application: In the future, mechatronics technology and related devices depend more on simulation biology, especially on the basis of information technology and neural network composed of the system, simulation biology can further change the nature of the current car driving and operation, through simulation biotechnology to optimize the use of mechatronics in automotive design, to control system as the center, Thus, it can control the various operation modes of the automobile and keep consistent with the decision-making thoughts of human beings, which can further improve the safety of the automobile and also facilitate the miniaturization development of the product [12][13].

5. Conclusion

Through the previous case analysis and comparison, it was shown that the application of electromechanical integration technology in automobile design has become the mainstream of the automobile industry. According to the above, it is widely used in automatic refueling systems, vehicle attitude control systems, ABS brake systems, electronic stability programs (ESP), racing car designs, and so on. But because the research and application of electromechanical integration technology started late, the early development is limited by technology and equipment, leading to a weak foundation. To solve these problems, this article proposes solutions such as: realizing the electronic design of automobiles using microcontrol systems, improving the professional level of designers, simulating biological design applications, and so on. Therefore, the government and enterprises should pay more attention to this technology and focus on personnel training to promote the development of our automobile industry. The current paper is based on existing literature and data, future research will incorporate primary data for a more in-depth analysis.

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References

[1] Liu, Tao. (2022). “Application of Mechatronics technology in automobile design.” Automobile and New Powertrain. (6), 67-69.
[2] Eliasson, Ulf, et al. 2014. “Agile model-driven engineering in mechatronic systems-an industrial case study.” Model-Driven Engineering Languages and Systems: 17th International Conference, MODELS 2014, Valencia, Spain, September 28–October 3, 2014. Proceedings 17. Springer International Publishing.
[3] Sheth, Saurin, Kavit H. Patel, and Harsh Patel. 2016. Design of automatic fuel filling system using a mechatronics approach. In CAD/CAM, Robotics and Factories of the Future: Proceedings of the 28th International Conference on CARs & FoF(pp. 785-795). Springer India.
[4] Arana, Carlos, Simos A. Evangelou, and Daniele Dini. 2014. “Car attitude control by series mechatronic suspension.” IFAC Proceedings Volumes 47.3: 10688-10693.
[5] Gissinger, G. L., Christian Menard, and Alain Constans. 2003. “A mechatronic conception of a new intelligent braking system.” Control Engineering Practice 11.2: 163-170.
[6] Chavan, D. K., G. S. Tasgaonkar, and V. R. Deulgaonkar. 2011. “Mechatronics-A boon for technological development.” Int. J. Mech. and Production Eng. Research and Develop 1.2: 66-75.
[7] Layanto, Jeffrey, Sam Cubero, and Matthew Goode. 2003. “Autonomous racing car competition for mechatronics engineering education.” Proceedings of the 10th Annual Conference Mechatronics and Machine Vision 2003: Future Trends. Research Studies Press.
[8] Baier, Andrzej, et al. 2013. “Computer aided Process of designing the mechatronic Silesian Greenpower electric car.” Selected Engineering Problems.
[9] Schafer, W., & Wehrheim, H. (2007, May). The challenges of building advanced mechatronic systems. In Future of Software Engineering (FOSE'07) (pp. 72-84). IEEE.
[10] Pannaga, N., N. Ganesh, and Ravish Gupta. 2013. “Mechatronics—an introduction to mechatronics.” Int. J. Eng 2: 128-134.
[11] Dai, Qin. 2023. “Application research of Mechatronics technology in automobile intelligent manufacturing.” Auto Time. (3), 3.
[12] Moulianitis, V. C., G-AD Zachiotis, and N. A. Aspragathos. 2018. “A new index based on mechatronics abilities for the conceptual design evaluation." Mechatronics 49: 67-76.
[13] Wu, Quanhui, et al. 2019. “An mechatronics coupling design approach for aerostatic bearing spindles.” International Journal of Precision Engineering and Manufacturing 20: 1185-1196.