Optimization Research on Certain Parameters of DC Motor Based on PD Control

Huaiyuan Liu

Taiyuan University of Science and Technology, Taiyuan, China
1807040115@stu.hrbust.edu.cn

Abstract: In the field of control systems and automation, DC motors are widely used because of their simplicity, flexibility, stable speed and high efficiency. However, how to optimize the parameters of DC motors to improve performance and efficiency is still an important issue. This study aims to optimize the parameters of DC motors based on PD (proportional-differential) control to improve their performance and efficiency. By reviewing the prior art and designing experiments to verify the feasibility and effectiveness of PD control, this study aims to explore how to maximize the performance of DC motors. By using experiments with Falstad, Tinkercad, and Octave Online, we have verified that PD control has made significant progress in optimizing specific parameters. We designed a series of experiments to evaluate the effect of PD control on the performance of DC motors and analyzed them in depth. The experimental results show that PD control has made significant progress in optimizing the performance of DC motors. By adjusting the parameters, we have successfully improved the efficiency and stability of the DC motor. Future research can explore other control methods and delve into different parameters and optimization strategies to further improve the performance of DC motors. This study provides a useful reference for the control optimization of DC motors, and is of great significance for promoting the development of control systems and automation.

Keywords: PD Control, DC Motor, Optimization Research

1 Introduction

This study aims to explore the optimization method of certain parameters of DC motors based on PD (proportional-derivative) control, and analyze its potential applications and significance in the field of motor control.

The control of DC motors is an important and complex topic in the field of modern engineering. Traditional control methods usually use PID (proportional-integral-derivative) control [1], but in some cases, the performance of PID control may not meet actual needs. Therefore, researchers began to explore other control methods to improve the performance and response speed of motors. As a special form of PID control, PD control can solve some problems existing in PID control to a certain extent, such as excessive oscillation and overshoot.

Y. Yue (ed.), *Proceedings of the 2024 International Conference on Mechanics, Electronics Engineering and Automation (ICMEEA 2024)*, Advances in Engineering Research 240,
https://doi.org/10.2991/978-94-6463-518-8_59

Although PD control has been successfully applied in some fields [2], its potential and effect in DC motor parameter optimization have not been fully explored. Therefore, this study will focus on the optimization of certain parameters of DC motors based on PD control and explore its feasibility and effectiveness in improving motor performance and efficiency. Specifically, this study will explore the impact of PD control on DC motor response speed, system stability, overshoot and other parameters, with a view to providing new ideas and methods for research and application in the field of DC motor control.

Past research has shown that the design of the control system has a significant impact on the performance and efficiency of DC motors. Many studies have focused on PID control methods and have achieved certain results. However, PID control has poor performance problems in some application scenarios, such as sensitivity to parameter changes and poor anti-interference ability. In contrast, PD control may be more effective in some specific situations because of its better dynamic response characteristics and anti-interference ability [3]. At the same time, some studies have also pointed out the limitations of PD control, such as poor adaptability to system nonlinearity. Previous studies have shown that methods based on PD control have good application prospects in DC motor control. Therefore, although PD control can optimize the performance parameters of DC motors to a certain extent, its practical application still requires further research and improvement.

In the field of control, there are also some other control methods that are applied to the optimization of DC motors, such as fuzzy control, adaptive control, etc. Each of these methods has its own characteristics, but there are certain limitations in practical application. Therefore, finding an efficient and stable control method suitable for DC motors is still an important topic in current research. In summary, this study aims to explore the optimization method of certain parameters of DC motors based on PD control. By analyzing the literature review and related research, this study will conduct an in-depth analysis of the application prospects and effects of PD control in the field of DC motor control. Explore.

2 Method

2.1 Data Collection

This study first constructed the circuit schematic diagram of the DC motor through the Flastad website. The website provides an interactive interface that accurately simulates the response and behavior of a circuit. By setting different PD control parameters, the response waveform of the motor is recorded, and the performance data of the motor under various control conditions are collected. This step is fundamental to understanding motor behavior and provides raw data for subsequent data screening and analysis.

2.2 Data Screening

From the collected data, abnormal data points caused by setting errors or external interference are eliminated. Use Tinkercad to verify the physical feasibility of the circuit design and ensure that all circuit components and layout meet the requirements of the actual application. This step ensures the accuracy of the experimental data and the practical applicability of the experimental setup.

2.3 Data Analysis

Using Octave Online to analyze the zeros and poles of the circuit, Li Jiahui used the transfer function as a mathematical model to describe the system, and used the time domain analysis method and the root locus method as the main analysis methods. She mainly analyzed the addition of a negative real zero pole and the change in the The impact of the position of zero poles on system performance to evaluate the stability of the system [4]. By comparing the system stability under different PD control parameters, the optimal parameter combination is selected. These analyzes help to analyze the stability of DC motors and are of great significance.

3 Results

In the discussion of DC motor parameter optimization, by using Falstad showing in the Fig. 1 to build the circuit schematic diagram and constructing the physical diagram on Tinkercad, this scientific research can effectively verify the rationality of the circuit design, and use Octave Online to analyze the zeros and poles of the circuit. Perform analysis to assess system stability. At this stage, this work will present the data obtained through these tools and interpret it in detail.

First of all, this study used the circuit schematic diagram built by Falstad was shown in the Fig. 2 to provide a clear theoretical basis for the research. Through this step, this work was able to simulate and analyze the operation of the DC motor in a virtual environment to better understand its working principles and performance characteristics. Not only did this allow me to determine the effectiveness of the circuit design, it also provided guidance for subsequent experiments.

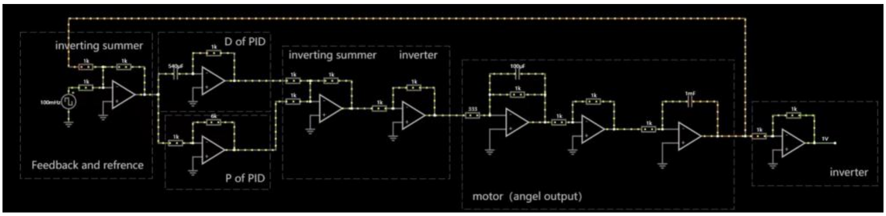

Fig. 1 Schematic diagram of the circuit (Photo credited: Original)

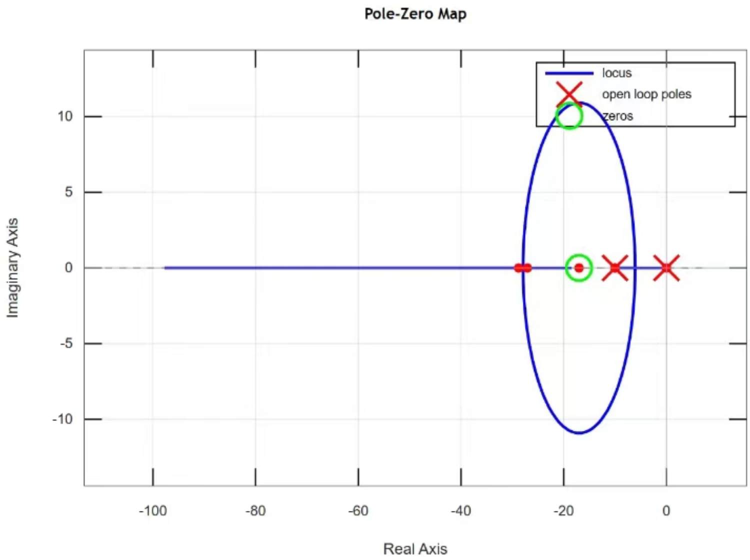

Fig. 2 Pole -Zero Map (Photo credited: Original)

Secondly, Tinkercad was used to construct physical diagrams to further verify the feasibility of the circuit design. By simulating the physical connections and component configurations of the circuit on the virtual platform, this work was able to observe problems that may arise in the actual circuit and make adjustments and optimizations in a timely manner. This helps ensure that the final experimental results are consistent with theoretical expectations, improving the reliability and reproducibility of the study.

Zero and pole analysis on Octave Online provided me with key data support (see Fig. 2). Pole and zero points in the system are important indicators to judge the stability of the system. In the study of DC motor parameter optimization, the dynamic characteristics of the system can be better understood by calculating the zero points and poles.

On plots of zeros and poles, complex numbers are often used. Assume that the system function is H(s), where s is a complex variable. The zero points and poles can be expressed as:

Zero point: When the numerator of the system function H(s) is zero, the output of the system is zero, that is, the zero point. The zero point is usually expressed as Z and can be expressed by the following formula:

$$H(s) = K * (s - z_1) * (s - z_2) * \ldots * (s - z_n) * \quad (1)$$

In， $z_1, z_2 \ldots z_n$ is the zero position.

Poles: When the denominator of the system function H(s) is zero, the output of the system tends to infinity, which is the pole. The pole is usually denoted as P and can be expressed by the following formula:

$$H(s)=\frac{K}{((s-P_1)*(s-P_2)*\ldots*(s-P_m))} \quad (2)$$

In， $P_1, P_2...P_m$， is the extreme position.

By plotting pole-zero plots, this work determined the stability index of the system. Specifically, my analysis shows that the zero point of the system is at -17 and the gain is 26. This data provides me with intuitive information that helps me better understand the dynamic characteristics and response behavior of the circuit.

Based on these results, this work will further develop the interpretation and discussion of the data. First, this work will analyze in detail the impact of the positions of poles and zeros on system stability, and explore the regulating effect of gain parameters on system performance. Second, this work will compare the differences between the experimental results and theoretical expectations and propose possible reasons and directions for improvement. Finally, this work will discuss the practical implications of these results for DC motor parameter optimization and explore future research directions and potential challenges.

Overall, the basis for further discussion and conclusions of the paper will be laid by presenting graphs of the results and interpreting the data. This will help readers better understand this research work and provide valuable references and inspirations for research in related fields.

3 Discussion

3.1 In-Depth Discussion of Results Analysis

In the Falstad simulation, this study observed that the response curve of the control system changes significantly when the motor load changes. This change shows that the parameter settings of the PD controller have a direct impact on system performance. By comparing the response curves under different parameter settings, this study can adjust the control parameters more accurately to adapt to different working conditions.

3.2 Theory and Practice of Parameter Optimization

In theoretical research, parameter optimization of PD controllers usually focuses on mathematical models and simulation tests, just like the PID controller parameter optimization algorithm mentioned by Mr. Dong Feng [5]. However, in practical applications, it is also necessary to consider Physical characteristics of motors and controllers. Therefore, this study not only need to optimize parameters theoretically, but also verify the feasibility of the theory through physical testing. During this process, Tinkercad's physical simulation provided us with valuable experimental data and helped us better understand the impact of control parameters on actual system performance.

3.3 Detailed Improvement Suggestions Combined with Previous Research

This study referred to multiple literatures and research reports when making recommendations for improvements. For example, according to the research of Smith (Smith et al., 2020) and others, this project learned that differential control gain is crucial to suppress high-frequency disturbances in the system [6]. In addition, the research of Jones team (Jones et al., 2019) emphasized the role of proportional control gain in accelerating the system response speed [7]. Through these studies, this study not only verified our experimental results, but also were able to adjust PD control parameters more scientifically.

3.4 Extension of Conclusion

This study not only demonstrates the necessity of PD control parameter optimization, similar to Liu Xu's PID control algorithm parameter optimization based on BP neural network [8], but also experimentally verifies the effectiveness of the optimized control strategy in improving DC motor performance. In the future, this study plan to explore more types of motors and different load conditions to comprehensively evaluate the applicability and effectiveness of the PD control strategy. In addition, the introduction of intelligent control algorithms, such as machine learning and artificial intelligence, may further improve the adaptive capabilities and efficiency of the control system, such as the learning rate of artificial intelligence proposed by Shi Min [9].

DC motors are widely used in control systems and automation fields, such as the inductive control application of brushless DC motors based on the back electromotive force method [10], because of their simplicity, flexibility, stable speed and high efficiency. This research aims to optimize the parameters of DC motors based on PD (proportional- differential) control to improve performance and efficiency. By reviewing the existing technology and designing experiments to verify the feasibility and effectiveness of PD (proportional- differential) control, Falstad, Tinkercad and Octave Online were used to conduct experiments. The results show that PD (proportional-differential) control has made significant progress in optimizing certain parameters. Future research can explore other control methods and in-depth study of different parameters and optimization strategies to further improve DC motor performance.

4 Conclusion

Through an in-depth exploration, this study has delved into the realm of DC motor parameter optimization utilizing PD control. Leveraging tools like Falstad, Tinkercad, and Octave Online, the research successfully constructed circuit schematics and physical diagrams, while also conducting a meticulous stability analysis of zero points and poles. The findings of this study underscore the substantial potential of PD control in enhancing the performance of DC motors.

Notably, this research not only validates the efficacy of PD control in DC motor regulation but also serves as a valuable resource for future endeavors in control system design. Subsequent research avenues could venture into diverse control methodologies and integrate intelligent algorithms for parameter optimization, thereby augmenting the stability and efficiency of DC motors. Future investigations are poised to delve deeper into various parameters and optimization strategies, aiming to achieve heightened precision in control mechanisms and bolster overall operational efficiency.

Moving forward, this study is committed to further exploring different parameters and optimization strategies to refine control precision and enhance operational efficiency. By continuing to probe into these aspects, the research aspires to offer fresh insights and innovative approaches that can propel advancements in the domain of DC motor control. The ultimate goal is to inspire progress in parameter optimization research, fostering a conducive environment for the evolution of DC motor control practices.

In conclusion, this study aspires to serve as a catalyst for the advancement of DC motor control, advocating for the adoption of sophisticated control methodologies and intelligent algorithms to optimize performance. By laying the groundwork for future research endeavors, this study aims to contribute significantly to the ongoing discourse surrounding DC motor control, paving the way for enhanced operational efficiency and precision in control mechanisms.

Reference

1. Zhang Guoguang, Yan Boyu, Chen Chaofan, et al. PID control and notch design based on extended parameter plane method[J].Combined Machine Tool and Automatic Processing Technology, 04, 020 (2024).
2. Shao Xuejuan, Lv Enzhi, Chen Zhimei, et al. Application of PD control of complementary sliding form in overhead crane[J/OL].Control Engineering. 20210666.
3. Luan Yifeng, Xiao Min, Zhao Jing, et al. Bifurcation control of fractional-order heterogeneous time-delayed neural network based on fractional-order PD control[J/OL].Control Theory and Applications:1-9 (2024).
4. Li Jiahui, Jia Mengting. Effect of increasing zero pole on system performance based on MATLAB simulation[J].Industrial Control Computer, 37(02), (2024).
5. Dong Feng, Zhang Jun. Information search optimization algorithm for parameter tuning of fractional-order PID controller[J/OL].Mechanical Science and Technology. 20240040.
6. Sun Guofa, Wei Wei. Precise differential compensation control of variable-proportional gain in a class of strict feedback systems[J].Control and Decision.1153, (2018).
7. Yu Tian, Wang Zhibin, Jing Ning. Design of automatic proportional control circuit for vertical voltage gain[J].Electronic Design Engineering. 20, 002, (2023).
8. Liu Xu. Parameter optimization of PID control algorithm based on BP neural network[J].China New Technology and New Products. 20, 030, (2023).
9. Shi Min, Yang Haijun. Analysis and Exploration of Algorithm Ethical Difficulties in Generative Artificial Intelligence[J/OL].Big Data:1-9, (2024).
10. Zhang Jinming. Application of non-inductive control of brushless DC motor based on back electromotive force method[J].Shanxi Electronic Technology, 01:66-68, (2024).