



## Article

# Structural Optimization Design of a Six-Degrees-of-Freedom Serial Robot with Integrated Topology and Dimensional Parameters

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**Abstract:** In the structural design of serial robots, topology and dimensional parameters design are independent, making it challenging to achieve synchronous optimization design between the two. To address this issue, a topology-and-dimension-parameter integrated optimization method (TPOM) is proposed by setting critical variables to connect topology layout and dimensional features. Firstly, the topology layout is extracted by the edge detection technique. Structural manufacturability reconstruction is conducted by measuring the dimensions of the layout through a program. Additionally, for the reconstructed structural layout, critical variables are set using three-dimensional software (SOLIDWORKS2021). The experiments primarily involve critical variables, quality, and deformation as variables. Then, the response surface methodology is selected to construct the stiffness–mass metamodel, and based on this, the structural deformation is analyzed. Lastly, the multi-objective genetic algorithm (MOGA) is employed to optimize the critical variables, and an optimized structure is established for validation. The results indicate that the proposed method (TPOM) reduces the mass of the structure by 15% while maintaining its stiffness. In addition, the deformation of the whole structure is less than 0.352 mm, which meets the requirements of industrial applications. Through quantitative analysis of the experimental results, the feasibility and superiority of the proposed method have been demonstrated.

**Keywords:** critical variables; integrated optimization method; stiffness–mass metamodel; MOGA

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## 1. Introduction

Robotics is a field that focuses on the development and study of robots, encompassing the modeling, design, and manufacturing of robotic systems [1]. Industrial robots are extensively employed in the automotive and electronics industries, as well as in other fields [2–4]. Serial robots [5–7] are essential components of robots. The complex parameter coupling and multi-objective design of serial robots have attracted the attention and research of scholars [8–11]. To address the structural requirements for serial robots in different environments, researchers evaluate and improve the performance of robots through simulations, providing accurate design and optimization solutions [12,13].

With the industry's continuous improvement and the demand for precision component machining, serial robots face higher performance requirements, especially in structural design. In the past, the design approach involved increasing the cross-sectional area of the stress concentration regions in the structure to enhance stiffness. However, this design method increases the serial robots' weight and causes more significant deformation under the influence of gravity. To address this issue, in recent years, new technologies such as topology optimization, evolutionary structural optimization (ESO), and solid isotropic material with penalization (SIMP) have been widely used in the structural design of serial

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## **Table of Contents Six And Six Structural Reading Program**

1. Understanding the eBook Six And Six Structural Reading Program
  - The Rise of Digital Reading Six And Six Structural Reading Program
  - Advantages of eBooks Over Traditional Books
2. Identifying Six And Six Structural Reading Program
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Six And Six Structural Reading Program
  - User-Friendly Interface
4. Exploring eBook Recommendations from Six And Six Structural Reading Program
  - Personalized Recommendations

- Six And Six Structural Reading Program User Reviews and Ratings
- Six And Six Structural Reading Program and Bestseller Lists
- 5. Accessing Six And Six Structural Reading Program Free and Paid eBooks
  - Six And Six Structural Reading Program Public Domain eBooks
  - Six And Six Structural Reading Program eBook Subscription Services
  - Six And Six Structural Reading Program Budget-Friendly Options
- 6. Navigating Six And Six Structural Reading Program eBook Formats
  - ePub, PDF, MOBI, and More
  - Six And Six Structural Reading Program Compatibility with Devices
  - Six And Six Structural Reading Program Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Six And Six Structural Reading Program
  - Highlighting and Note-Taking Six And Six Structural Reading Program
  - Interactive Elements Six And Six Structural Reading Program
- 8. Staying Engaged with Six And Six Structural Reading Program
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Six And Six Structural Reading Program
- 9. Balancing eBooks and Physical Books Six And Six Structural Reading Program
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Six And Six Structural Reading Program
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine Six And Six Structural Reading Program
  - Setting Reading Goals Six And Six Structural Reading Program
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Six And Six Structural Reading Program
  - Fact-Checking eBook Content of Six And Six Structural Reading Program

- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
- 14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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