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A REVIEW PAPER ON DESIGN AND ANALYSIS OF COMPLIANT MECHANISM USING TOPOLOGY

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ABSTRACT

The review systematically categorizes and examines diverse methodologies employed in the design of compliant mechanisms, with a focus on topology optimization approaches. It explores the influence of key parameters, such as material properties, loading conditions, and geometric constraints, on the performance of compliant systems. Furthermore, the paper discusses the integration of advanced materials and manufacturing processes in the optimization framework to enhance the functionality and efficiency of compliant mechanisms. In conclusion, this review provides valuable insights into the evolving landscape of compliant mechanism design through topology optimization. By synthesizing existing knowledge and identifying potential research directions, it serves as a valuable resource for researchers, engineers, and practitioners aiming to harness the full potential of compliant mechanisms in diverse engineering applications.

Keywords: Compliant mechanism, Topology, Design, Performance, parameters, and Optimization.

1. INTRODUCTION

Compliant mechanisms, distinguished by their inherent flexibility and absence of traditional joints, represent a paradigm shift in engineering design. These innovative structures leverage material deformations to achieve desired mechanical functions, offering a range of advantages such as reduced complexity, increased reliability, and improved precision. The evolution of compliant mechanisms has been further propelled by advancements in computational techniques, with topology optimization emerging as a powerful tool for their systematic design and analysis. This review paper aims to provide a comprehensive exploration of the current state-of- the-art in the design and analysis of compliant mechanisms using topology optimization. The integration of compliant elements in mechanical systems has become increasingly prevalent across diverse engineering disciplines, including aerospace, robotics, biomechanics, and micro-electromechanical systems (MEMS). The adaptability and efficiency of compliant mechanisms make them particularly suitable for applications where traditional rigid-link mechanisms face limitations. The introduction begins by establishing the foundational principles of compliant mechanisms, emphasizing their unique characteristics and the departure from conventional rigid-body designs. By embracing flexibility as a functional asset, compliant mechanisms offer solutions to challenges associated with precision, complexity, and maintenance in various engineering applications. The exploration of compliant mechanisms becomes even more intriguing when coupled with the capabilities of topology optimization, a computational approach that enables the systematic exploration of optimal material distribution within a given design space. As shown in figure 1.

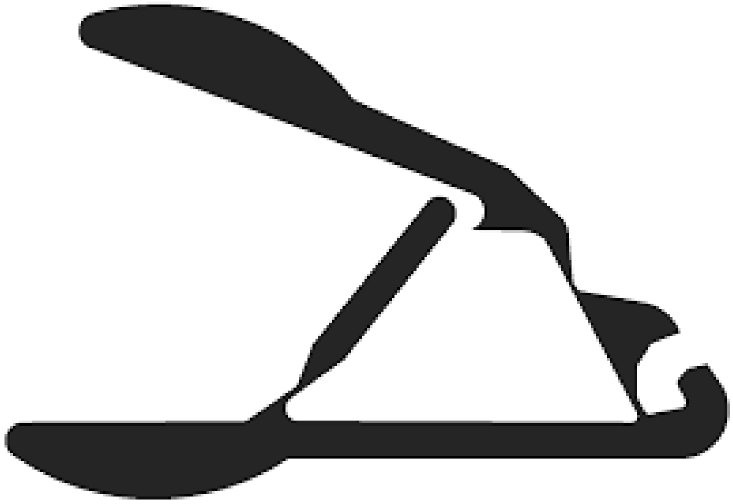

Figure 1 compliant Mechanism

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2. LITERATURE REVIEW

Literature reviews are integral components of academic research papers, theses, dissertations, and scholarly articles. They serve to situate the research within the existing body of knowledge, demonstrate the researcher's familiarity with prior work, and justify the need for new investigations.

Benliang Zhu et.al (2023) Compliant mechanisms have become an important branch of modern mechanisms. Unlike conventional rigid body mechanisms, compliant mechanisms transform the displacement and force at least partly through the deformation of their structural components, which can offer a great reduction in friction, lubrication and assemblage. Therefore, compliant mechanisms are particularly suitable for applications in microscale/nanoscale manipulation systems. The significant demand of practical applications has also promoted the development of systematic design methods for compliant mechanisms.[1]

Michael Yu Wang et. al. (2023) This paper focuses on design formulation of compliant mechanisms, posed as a topology optimization problem. With the use of linear elasticity theory, a single-input, single-output compliant mechanism, is represented by the stiffness matrix of its struc- ture with respect to the input-output ports. It is shown, that the stiffness model cap- tures the intrinsic stiffness properties of the mechanism. Furthermore, in order for the optimization problem to be properly defined, it is necessary that the stiffness matrix of the mechanism's structure must be guaranteed to be always positive definite.[2]

R Bharanidaran et. al. (2022) Advancement of precision industries, displacement amplifying device is essential to produce precise and long range of motion for micro-actuator. Compliant mechanism, based displacement amplifier (DA) is more appropriate to attain high precision motion. Compliant mechanism utilizes elastic nature of material to achieve required motion. In this research paper, compliant mechanism design is developed using topology optimization. The output of the topologically optimized design is impossible to fabricate as it is due to the presence of senseless regions.[3]

Sushant Gangadhar Bapat (2022) The pseudo-rigid-body model (PRBM) concept, developed for the analysis and design of large-deflection flexible members, has proved over time to be a simple, efficient and accurate tool for the synthesis, analysis and design of compliant mechanisms. This dissertation investigates a variety of compliant mechanism analysis and design problems using the PRBM concept and assists in further advancement of the implementation of the PRBMs. The dissertation begins with the development of a PRBM for a fixed-guided compliant beam with one inflection point in the deformed state.[4]

Roshan S. Kulkarni & Kshitij Dwivedi (2022) The project revolves around how the compliant mechanisms are redefining the design of our products which we us in our day-to-day life. All these years we have been building our products by combining or joining separately manufactured components to make a single component that satisfies our purpose. In this type of manufacturing, we often compromise on efficiency and performance due to incapability, cost of manufacturing. The rise in the industry of additive manufacturing due to 3D printing has a major contribution in helping the manufacturing of compliant mechanism.[5]

S. Premanand et.al (2022) The topology optimization design invariably shall be used in various applications such as four bar mechanisms, robotics designs, aircraft engineering designs, and many other mechanical innovative systems for improving the efficiency in the system. This research paper emphasizes more on general topology optimization design for a rectangular domain in which numerically analysed with defined boundary conditions. Furthermore, the same setting geometry has been taken for sensitivity analysis to find the objective stress and nonstress zones. Then, the geometry is topology optimized to analyse stress, safety factor, output deflection, and mass reduction.[6]

Jincheng and Huaping Tang (2021) This paper presents a stiffness-oriented structure topology optimization (TO) method for the design of a continuous, hinge-free compliant mechanism (CM). A synthesis formulation is developed to maximize the mechanism's mutual potential energy (MPE) to achieve required structure flexibility while maximizing the desired stiffness to withstand the loads. Different from the general approach of maximizing the overall stiffness of the structure, the proposed approach can contribute to guiding the optimization process focus on the desired stiffness in a specified direction by weighting the related eigen-frequency of the corresponding eigenmode.[7]

Nadim Diab and Farah Jouni (2021) This work addresses the design of miniature compliant displacement amplifers. The optimum design of the compliant mechanism is generated through topology optimization of two-node frame elements with linearly varying cross sections using the Ant Colony Optimization technique. First, stifness matrices that account for the change in the cross-section dimensions are formulated. Then, each element is assigned 5 independent ants that represent its design variables defned as the width and thickness of each of the two peripheral cross-sections in addition to the material density. Three case studies with customized cost functions are furnished; the

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frst maximizes the amplifcation ratio, the second maximizes the output displacement, while the third maximizes both amplifcation ratio and output displacement simultaneously.[8]

Ole Sigmund (2020) This paper presents a method for optimal design of compliant mechanism topologies. The method is based on continuum-type topology optimization techniques and finds theoptimal compliant mechanism topology within a given design domain and a given position and direction of input and output forces. By constraining the allowed displacement at the input port, it is possible to control the maximum stress level in the compliant mechanism.[9]

Patrick V. Hull and Stephen Canfieid (2019) The field of distributed-compliance mechanisms has seen significant work in developing suitable topology optimization tools for their design. These optimal design tools have grown out of the techniques of structural optimization. This paper will build on the previous work in topology optimization and compliant mechanism design by proposing an alternative design space parameterization through control points and adding another step to the process, that of subdivision. The control points allow a specific design to be represented as a solid model during the optimization process.[10]

Lin Cao (2018) Compliant mechanisms (CMs) take advantage of the deformation of their flexible members to transfer motion, force, or energy, offering attractive advantages in terms of manufacturing and performance over traditional rigid-body mechanisms (RBMs). This dissertation aims to advance the topology optimization (TO) technique (1) to design CMs that are more effective in performing their functions while being sufficiently strong to resist yield or fatigue failure; and (2) to design CMs from the perspective of mechanisms rather than that of structures, particularly with the insight into the concepts of joints, actuations, and functions of mechanisms.[11]

3. RESEARCH GAP

Identifying and addressing research gaps is essential for advancing knowledge, contributing to academic discourse, and guiding future research endeavours. Researchers often conduct a thorough literature review to pinpoint these gaps, allowing them to define the objectives and significance of their own studies. Addressing a research gap not only contributes to the academic community but also has practical implications for informing policies, practices, or applications in various fields.

4. OBJECTIVES OF WORK

The following objectives we are finding.

- Examine compliant mechanism.
- Investigate topology optimization techniques.
- Evaluate material properties.

5. METHODOLOGY

The methodology section of a review paper typically outlines the systematic approach taken to gather, select, and analyse the relevant literature. Since a review paper on the design and analysis of compliant mechanisms using topology focuses on synthesizing existing knowledge, the methodology involves specific steps related to literature review and analysis.

Formulation of search: Develop comprehensive search queries that combine keywords related to compliant mechanisms, topology optimization, and associated terms. Optimize search queries for each selected database to ensure a thorough and targeted literature retrieval.

6. CONCLUSION

In conclusion, this comprehensive review has endeavoured to illuminate the evolving landscape of the design and analysis of compliant mechanisms utilizing topology optimization. Through an extensive examination of the existing literature, we have gained valuable insights into the fundamental principles, methodologies, challenges, and opportunities inherent in this interdisciplinary field at the intersection of mechanical engineering, materials science, and computational optimization. While acknowledging the progress made, it is evident that challenges persist, including issues related to computational efficiency, multi-objective optimization, and the robustness of designs in real-world applications. The evolving landscape of compliant mechanism design demands a concerted effort to overcome these challenges and bridge existing gaps in knowledge.

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