

Research Progress and Application Review of Tesla Valve

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Abstract: This paper systematically reviews 30 articles on Tesla valves, comprehensively elucidating the current research status of Tesla valves. Starting from their principles and structural characteristics, it provides a detailed analysis of how different structural parameters affect performance. It summarizes the application scenarios in multiple fields such as energy, chemical engineering, and thermal management, discusses existing issues in current research, and looks forward to future research directions. The aim is to provide a reference for further research and application of Tesla valves.

Keywords: Tesla valve; structural parameters; performance research; application field; research prospect.

1. Introduction

The Tesla valve is a passive, component-free fluid control device with unique unidirectional flow characteristics: it has low resistance when flowing in one direction and high resistance when flowing in the opposite direction. This special performance makes it potentially valuable in various fields, attracting significant attention from researchers in recent years. With continuous technological advancements and increasing demand for fluid control technology across sectors, research and application of Tesla valves have seen rapid development. This article will review relevant literature to outline the progress and current status of Tesla valve research and applications.

2. The Principle and Structural Characteristics of Tesla Valve

The unidirectional flow characteristic of the Tesla valve stems from its unique geometric structure, typically composed of a series of curved channels and bifurcations. When the fluid flows in the forward direction, it can pass through the channels relatively smoothly; however, when flowing in reverse, intense turbulence and vortices form within the channels, significantly increasing flow resistance. Wiley S and Huang P H (2024) studied the impact of bifurcated geometry on the unidirectionality of the Tesla valve in *"The Effect of Bifurcated Geometry on the Diodicity of Tesla Valves"*, finding that different bifurcations can markedly alter the unidirectional flow performance of the Tesla valve. This distinctive structural feature allows the Tesla valve to effectively control the direction of fluid flow without external power or moving parts, offering advantages such as simple structure, high reliability, and low maintenance costs.

3. Performance Study of Tesla Valve

3.1. Flow characteristics study

Many studies have delved into the flow characteristics of Tesla valves. Zeidan M et al. (2024) revealed the transient flow dynamics inside Tesla valves through computational fluid dynamics simulations in *"Transient Flow Dynamics in*

Tesla Valve Configurations: Insights from Computational Fluid Dynamics Simulations", providing crucial insights into their flow mechanisms. Jiang B H et al. (2024) investigated the flow characteristics within rectangular Tesla valves with different width-to-length ratios in *"Flow characteristics inside rectangular Tesla valve with different width-to-narrow ratios"*, finding that variations in these ratios affect the velocity distribution and pressure loss of the fluid. These studies provide a theoretical foundation for optimizing the structural design of Tesla valves.

3.2. Flow characteristics study

References are cited in the text just by square brackets . (If square brackets are not available, sIn terms of heat transfer, many studies have shown that Tesla valves can significantly enhance heat transfer efficiency. Liu Z et al. (2025) investigated flow boiling phenomena in copper heat sinks composed of Tesla microchannels in *"Flow boiling in a relatively large copper heat sink comprised of Tesla microchannels"*, finding that the Tesla valve structure can effectively improve heat transfer efficiency. Han Q et al. (2024) discussed the role of Tesla valves in microchannel flow boiling in *"The role of Tesla valves in microchannel flow boiling"*, noting that Tesla valves can enhance heat transfer by increasing fluid turbulence. These research findings provide strong support for the application of Tesla valves in thermal management.

3.3. Study on voltage drop characteristics

Pressure drop is one of the key performance indicators for Tesla valves. Shi Jiabai et al. (2024) analyzed the pressure drop in reverse-flow Tesla valves using super/subcritical fluids, studying the pressure drop variation under different operating conditions. Jiang E et al. (2025) investigated the impact of Tesla valves on heat transfer performance and pressure drop oscillation suppression in liquid cooling loops in *Effect of the Tesla Valve on the heat transfer performance and the suppression of pressure drop oscillation in a liquid cooling loop*, finding that Tesla valves can suppress pressure drop oscillations to some extent.

4. Application fields of Tesla valve

4.1. Energy sector

In the energy sector, Tesla valves have broad application prospects. Wang Y et al. (2025) proposed a two-stage day-ahead and intra-day low-carbon dispatch method for enhancing peak regulation capabilities of combined heat and power units based on a new multi-stage Tesla valve thermal storage device in "Two-stage day-ahead and intraday low-carbon dispatch method based on enhancing the peak-load regulation capability of cogeneration units with a novel multi-stage Tesla valve thermal storage device." By leveraging the characteristics of Tesla valves, they improved the performance of the thermal storage device and enhanced the peak regulation capability of the combined heat and power unit. Hai T et al. (2024) studied the performance of Tesla valve channels in photovoltaic thermal systems through numerical simulations in "Investigating the performance of the Tesla valve channel in a photovoltaic thermal system through numerical simulation: Evaluation from the standpoint of thermodynamic laws," finding that Tesla valves can improve the thermodynamic performance of photovoltaic thermal systems.

4.2. Chemical industry

In the chemical engineering field, Tesla valves can be used in processes such as mixing and separation. In "Design, Simulation, and Experimental Study of a Micro Mixer Based on Tesla Valve Structure," Weng Xiangyu et al. designed a micro mixer based on the structure of a Tesla valve and studied its mixing performance through simulation and experiments. The results showed that this micro mixer has excellent mixing effects. Wang Tao et al. (2020) conducted a numerical study on the hydraulic cavitation phenomenon of Tesla valves in "Numerical Study of Hydraulic Cavitation in Tesla Valves," providing theoretical support for their application in chemical reactions.

4.3. Thermal management

Tesla valves also have significant applications in thermal management. Liu W et al. (2024) compared the performance of different types of Tesla valves in "Comparative analysis of performance of different types of Tesla valves", exploring their potential applications in thermal management systems. Ran L et al. (2024) optimized the performance of microchannel heat sinks based on Tesla valve profiles using multi-objective optimization and artificial neural network models in "Multi-objective optimization and artificial neural network models for enhancing the overall performance of a microchannel heat sink with fins inspired Tesla valve profile", enhancing the efficiency of thermal management systems.

4.4. Other areas

In addition to the aforementioned fields, Tesla valves have also found applications in other areas. For example, Sun Tong et al. (2024) studied the vibration damping performance of viscous dampers based on Tesla valves in their paper "Research on the Vibration Damping Performance of Viscous Dampers Based on Tesla Valves," providing new insights for structural vibration reduction. Li Wei et al. (2024) conducted a numerical simulation study on the hydraulic characteristics of Tesla valve fishways and vertical slot fishways in their paper "Numerical Simulation and Feasibility Analysis of Hydraulic Characteristics of Tesla Valve Fishways,"

exploring the feasibility of its application in water conservancy projects.

5. Existing Problems and Challenges

5.1. Structural optimization still needs to be further developed

Despite the current research on the structural parameters of Tesla valves, further in-depth studies are needed to achieve optimal design that meets the requirements of different application scenarios. Different application fields have varying performance demands for Tesla valves, and finding a balance among multiple performance metrics is a significant challenge at present.

5.2. Insufficient research on multiphysics coupling problems

In practical applications, Tesla valve often involves the coupling of many physical fields, such as flow, heat transfer and mass transfer. At present, the research on multi-physical field coupling is not deep enough to fully and accurately describe the working process and performance of Tesla valve.

5.3. Difficulties in application promotion

Although Tesla valves have demonstrated potential application value in multiple fields, they still face some challenges during practical promotion. For example, certain application scenarios require high performance from Tesla valves, which current technology cannot fully meet; furthermore, the manufacturing costs and process complexities of Tesla valves also limit their large-scale application.

6. Future Research Directions

6.1. Carry out in-depth research on structural optimization

In combination with advanced optimization algorithm and numerical simulation technology, the structural optimization of Tesla valve is deeply studied. For different application scenarios, a multi-objective optimization model is established to comprehensively consider various performance indexes such as unidirectional flow performance, heat transfer performance and pressure drop, so as to realize the optimal structural design of Tesla valve.

6.2. Strengthen multi-physical field coupling research

The research of multiphysics coupling problems is carried out to establish a more perfect mathematical model and deeply understand the physical process inside the Tesla valve. By combining experimental and numerical simulation methods, the influence law of multiphysics coupling on the performance of the Tesla valve is revealed, and theoretical support is provided for its application in complex conditions.

6.3. Promote application technology innovation

Strengthen the application technology innovation of Tesla valve, reduce the manufacturing cost, simplify the manufacturing process, and improve its performance stability and reliability. At the same time, actively explore the application potential of Tesla valve in new fields and expand its application scope.

7. Summary

In summary, the Tesla valve, as a fluid control element with unique performance characteristics, has shown broad application prospects in various fields. In recent years, research on the Tesla valve has made certain progress, with deeper understanding gained in terms of principles, structure, performance, and applications. However, current research still faces some issues and challenges that require further in-depth study. In the future, with the continuous development and innovation of related technologies, the Tesla valve is expected to be widely applied in more areas, providing new ideas and methods for solving practical engineering problems.

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