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Analysis of JTEKT's Patent Layout for Steer-by-Wire and its Enlightenment to China's Automotive Industry

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Abstract

Against the backdrop of the rapid iteration of intelligent connected vehicles and autonomous driving technologies, Steer-by-Wire (SBW) has become the core technical direction for the upgrading of automotive steering systems. As a global leader in the electric power steering sector, as well as a pioneer and mass-production promoter of SBW technology, JTEKT has laid out a large number of core patents worldwide, forming significant technological barriers and intellectual property advantages. Based on global SBW patent data, this paper combs the technical architecture, analyzes the patent application trends, and dissects the competitive landscape of major applicants. It focuses on the patent application status, subdivided technical layout characteristics, and technological route evolution of JTEKT in the SBW field, summarizes its patent layout strategy and core technical advantages, and puts forward targeted suggestions for technological R&D and patent layout combined with the current situation of China's automotive industry, so as to provide a reference for domestic automakers and component enterprises to break through foreign technological blockades and achieve independent control of SBW technology.

Keywords

Steer-by-Wire; JTEKT; Patent Analysis; Technical Layout; Functional Safety; Autonomous Driving.

1. Introduction

With the accelerated transformation of the automotive industry toward electrification, intelligence, and connectivity, the limitations of traditional mechanical steering systems are increasingly prominent in spatial arrangement, control accuracy, function expansion, and adaptability to autonomous driving systems. Steer-by-Wire (SBW) replaces the traditional mechanical connection with electrical signals, realizing the physical separation between steering manipulation and steering execution. It not only greatly improves vehicle handling performance and riding experience but also provides a more flexible control interface for autonomous driving, making it the mainstream development direction of the next-generation steering system. Major global automotive component enterprises and vehicle manufacturers have increased R&D investment in SBW technology, and the number of relevant patent applications continues to grow. The industry competition has gradually shifted from technological R&D to a comprehensive contest in terms of intellectual property rights.

JTEKT is the world's largest manufacturer of electric power steering systems, with decades of experience in R&D and mass production of steering systems. It has laid out electric power steering technology since the 1980s and took the lead in mass-producing the non-mechanical

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connection SBW system, which has been applied to Toyota bZ4X, Lexus RZ and other mass-produced models. In core technical links such as functional safety, redundant design, and high-precision control, JTEKT has formed a complete technical solution and patent barrier. Its patent layout direction and technological evolution route largely represent the development trend of global SBW technology. A systematic analysis of JTEKT's SBW patents can clearly grasp the industry's technical hotspots, competitive landscape, and future directions, which is of great practical significance for China's SBW industry to break through technical bottlenecks and build an independent intellectual property system.

Taking December 25, 2025 as the patent retrieval benchmark date, this paper statistically merges the narrow patent families based on global patent databases such as AutoPat, IncoPat, Patsnap, and EPO. A total of 4,550 global SBW patent families are obtained, including 527 patent families of JTEKT. From the technical dimension, the architecture is decomposed into four branches: upper steering control, lower steering control, system control, and fusion control. The patent distribution characteristics and technological evolution path are comprehensively analyzed, and finally systematic research conclusions and industrial development suggestions are formed.

2. SBW Technical Architecture and Patent Data Description

2.1. SBW Technical Architecture System

Centered on steering control, SBW technology forms a complete technical chain covering upper-layer manipulation, lower-layer execution, system safety, and multi-domain fusion. According to functions and control levels, it can be divided into four secondary technical branches and twelve tertiary technical nodes, forming a complete technical architecture system as shown in Table 1.

Table 1. Classification of SBW Technical Architecture

Technical Branch 1	Technical Branch 2	Technical Branch 3
System Control	System Control	Hand Feeling Control
		Variable Transmission Ratio
	System Control	Rack Force Estimation
		Angle Servo Control
		Response Compensation
	System Control	Alignment and Decoupling
		Getting On/Off Assistance
		Endpoint Control
		Failure or Degradation
	Fusion Control	Locking
		DMF (Understeer/Oversteer Control)
		DSTC (Separator Control)

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Upper steering control is mainly for the driver's manipulation end, including two key technologies: hand feeling control and variable transmission ratio. Its core functions are to simulate real road feel, realize dynamic adjustment of steering ratio, and improve driving comfort and handling flexibility. Lower steering control focuses on the steering execution end, including rack force estimation, angle servo control, and response compensation. It mainly realizes the accurate calculation, fast response, and stable output of steering force and steering angle, which is the core link to ensure steering control accuracy[1]. Aiming at safety and practicability, system control covers alignment and decoupling, getting on/off assistance, endpoint control, and failure or degradation. It focuses on solving system decoupling control, user convenience, steering endpoint limit, and safety protection after system failure. Fusion control is for vehicle dynamic control and autonomous driving collaboration, including locking control, understeer/oversteer control (DMF), and separator control (DSTC). It realizes the collaborative control of the steering system with the vehicle body stability system and autonomous driving system, improving vehicle driving stability and intelligent driving safety. This technical architecture fully covers all technical links of SBW from the bottom execution to the upper-layer decision-making and from basic functions to advanced fusion, providing a clear framework for patent retrieval and technical analysis[2].

2.2. Patent Data Sources and Processing Methods

This study takes global patent data as the analysis object. The retrieval databases include AutoPat Global Automotive Patent Big Data Platform of China Automotive Technology and Research Center, IncoPat, Patentics, Patsnap, and European Patent Office (EPO) database. The retrieval scope covers invention patents and utility model patents. To ensure a unified statistical caliber and accurate and reliable results, this paper strictly merges patent families and adopts the definition of narrow patent families, that is, a group of patents with exactly the same priority is recorded as one family to avoid repeated statistics caused by multi-country applications[3]. The retrieval benchmark date is set as December 25, 2025 to ensure that the data covers the latest published patent information. After multiple rounds of retrieval, screening, deduplication, and merged family processing, a total of 4,550 global SBW patent families are finally determined, including 527 patent families of JTEKT, which are used as the basic data for subsequent analysis[4].

3. Global Development Trend and Competitive Landscape of SBW Patents

3.1. Global Patent Application Trend

The development of global SBW technology patents shows obvious phased characteristics. Before 2014, SBW technology was in the early exploration stage. The number of relevant patent applications remained at a low level for a long time, with annual applications fluctuating below 100. The technical direction was mainly conceptual verification and basic structure R&D[5]. The overall industry R&D investment was limited, and large-scale layout had not yet been formed. From 2014 to 2023, SBW technology entered a period of rapid development. With the rapid rise of autonomous driving technology, the strategic value of SBW became increasingly prominent. The number of patent applications continued to climb, rising rapidly from 75 in 2014 to 468 in 2023. Especially after 2017, the growth trend accelerated significantly, making it a R&D hotspot in the field of automotive intelligence. From 2024 to 2025, the number of patent applications dropped periodically to 441 and 236 respectively. This phenomenon is mainly affected by the lag of patent publication, and a large number of submitted applications have not yet entered the public stage. With the gradual disclosure of unpublished patents and the continuous increase of industry R&D investment, the number of global SBW patent applications is expected to return to an upward channel in the next few years, and technological competition will further intensify[6].

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3.2. Patent Competitive Landscape of Major Applicants

From the perspective of patent applicant distribution, global SBW patents present a competitive pattern of "one superpower, multiple strong powers, and obvious echelon differentiation", with traditional international automotive component giants occupying an absolutely dominant position, as shown in Figure 1.

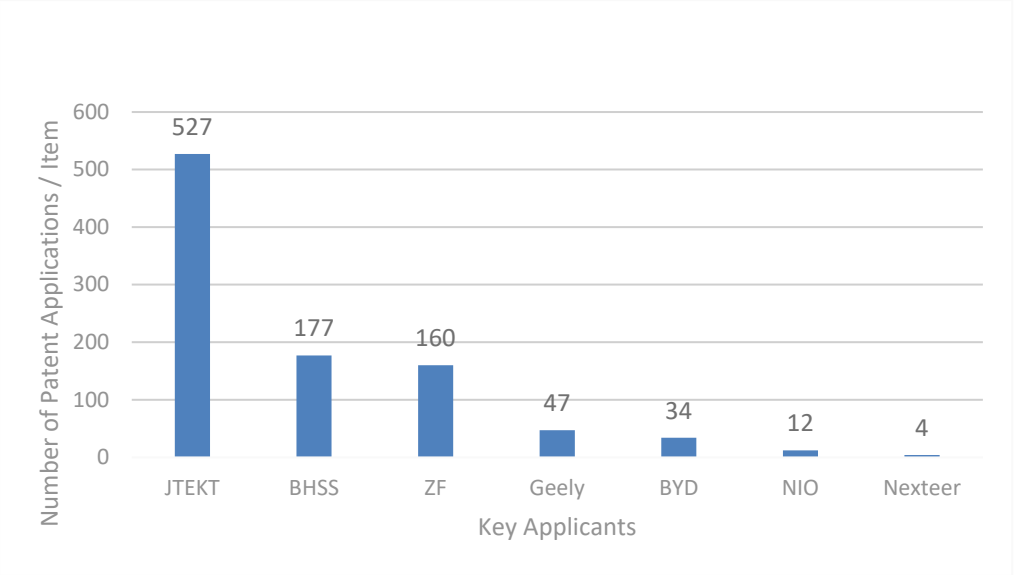

Fig 1. Patent Statistics of Key SBW Applicants

JTEKT ranks first globally with 527 patent families, far exceeding other competitors, demonstrating a long-term, continuous, and systematic R&D investment and patent layout strategy, making it an absolute leader in the SBW field. Bosch Huayu Steering Systems (BHSS) and ZF Friedrichshafen AG (ZF) form the second echelon with 177 and 160 patent families respectively. Relying on their comprehensive technical accumulation in automotive steering and chassis control, the two enterprises closely follow the industry leaders and form strong competitiveness. Chinese independent brand vehicle manufacturers represented by Geely and BYD constitute the third echelon, with 47 and 34 patent applications respectively[7]. Although the speed of patent layout has accelerated significantly in recent years, showing a strong technological catching-up trend, there is still a significant gap compared with international leading component enterprises. NIO and Nexteer have relatively few patent applications, 12 and 4 respectively, with relatively conservative R&D investment and layout strategies in this field. On the whole, the core intellectual property rights in the SBW field are highly concentrated in a few international component giants. Domestic enterprises are still in a catching-up position in terms of patent quantity, technical depth, and layout integrity, and need to accelerate the breakthrough of core technologies and intellectual property layout.

4. Analysis of JTEKT's Patent Layout Characteristics for SBW

4.1. Patent Application Trend

In the past two decades, JTEKT's patent applications in the SBW field have shown a steady upward trend as a whole, reflecting the enterprise's continuous attention and high-intensity R&D investment in this technology, as shown in Figures 2 and 3.

From the perspective of annual application volume, JTEKT's SBW patent applications peaked at 48 in 2021, and then fluctuated and declined in the following years, mainly affected by factors such as the patent publication cycle and the adjustment of the enterprise's R&D focus. Judging from the overall trend, JTEKT's SBW patent layout is highly continuous and stable. It is not a

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phased or short-term investment, but a long-term core strategic business. Consistent with the overall industry trend, JTEKT's patent applications have accelerated significantly since 2017, which is highly synchronized with the global industrialization process of autonomous driving, reflecting that its technical route closely follows market demand and industrial trends, with strong forward-looking and mass-production orientation. Long-term and continuous patent layout has enabled JTEKT to form profound technical accumulation and insurmountable intellectual property barriers in the SBW field [8].

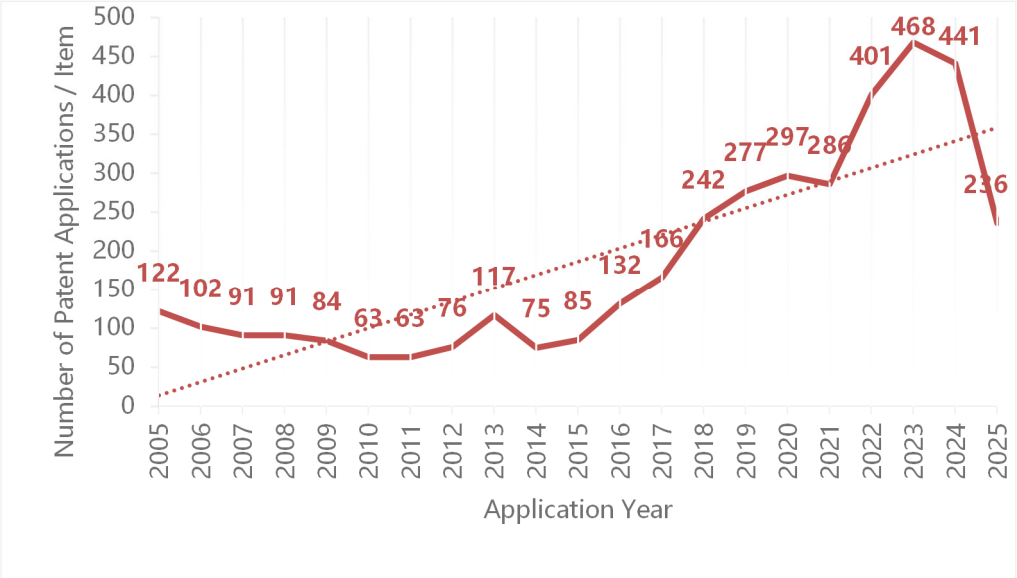

Fig 2. Global SBW Patent Application Trend

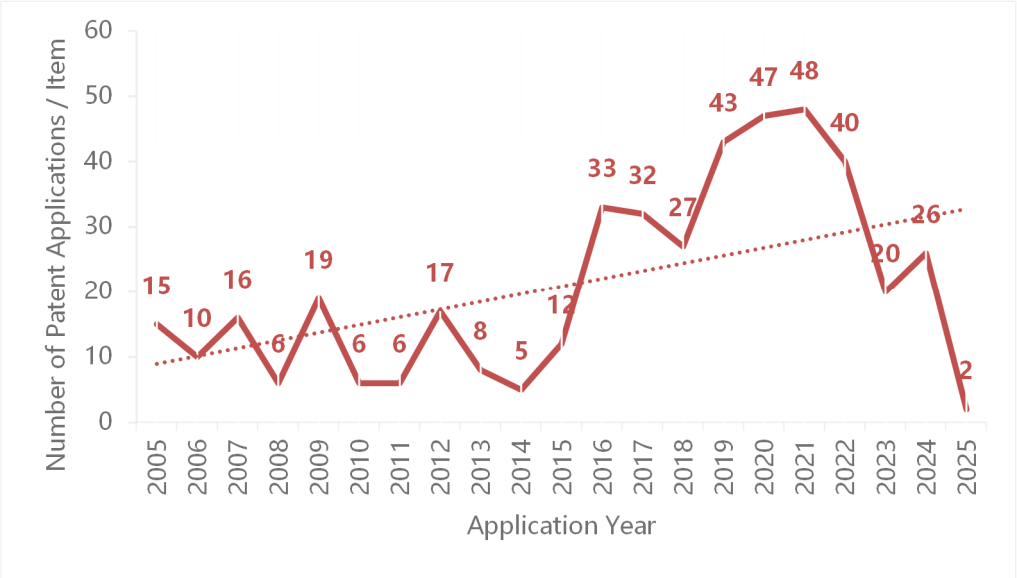

Fig 3. Global Patent Application Trend of JTEKT in the SBW Technology Field

4.2. Patent Distribution in Subdivided Technical Fields

JTEKT's 527 SBW patent families cover all twelve tertiary technical nodes, and the layout structure presents a distinct characteristic of "safety first, control core, experience supplement", with technical directions highly focused on the core needs of mass production. Among all technical branches, failure or degradation technology takes an absolutely dominant position with 277 patent applications, making it the core field with the most intensive layout and the

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highest technical barrier for JTEKT. Relevant patents mainly focus on fault diagnosis, multi-dimensional redundant architecture, and system degradation control strategies to ensure that the SBW system can maintain basic steering functions in the event of a single-point failure, which is the safety bottom line for the mass production of SBW. Endpoint control follows with 187 patents, focusing on technologies such as angle limit, torque control, and shock mitigation at the steering execution end, which directly affect vehicle handling stability and driving smoothness, reflecting JTEKT's high attention to steering execution accuracy and dynamic performance. Angle servo control and alignment & decoupling have reached 121 and 90 patents respectively. The former is the basis for accurate steering execution, and the latter solves the coupling interference between upper and lower steering control, both belonging to the core control technologies of the system. In contrast, hand feeling control, variable transmission ratio, DMF, locking and other technologies have relatively few patent layouts, mainly focusing on driving experience optimization and multi-system fusion control, with significantly lower layout intensity than safety and core control technologies[9]. On the whole, JTEKT has a clear patent layout logic: prioritizing overcoming functional safety, the key bottleneck of mass production, then deepening technologies around control accuracy and dynamic response, and prospectively laying out user experience and fusion control technologies, forming a patent system with distinct levels, prominent priorities, and complete coverage.

4.3. Evolution of Core Technical Routes

By sorting out the priority dates and technical contents of JTEKT's patents in various subdivided fields, the evolution law of its technical routes can be clearly restored. Hand feeling control technology has been laid out since 2013. In the early stage, mechanical structures were used to transmit road feel, and gradually shifted to software algorithms to match steering reaction force, stiffness, and sensory characteristics to improve the consistency of steering feel at different vehicle speeds. However, patent layout has been interrupted in recent years, and the technology tends to be mature and stable. The layout of variable transmission ratio technology can be traced back to 2005. The technical route has evolved from early static transmission ratio adjustment to dynamic transmission ratio correction based on vehicle status and steering angle, better adapting to the requirements of high-speed driving stability and low-speed handling flexibility. Failure or degradation technology is the earliest and longest-lasting technical direction for JTEKT. Relevant R&D was launched in 1999. It has been upgraded from early mechanical structure redundancy and torque limitation to a comprehensive safety scheme such as sensor redundancy, communication redundancy, control circuit redundancy, and multi-channel signal verification, covering all-scenario safety protection such as driving, starting, parking, and ramps. The technical maturity and reliability have reached the mass production level. Endpoint control technology has evolved from early mechanical limit and angle threshold limit to virtual operation range control and intelligent endpoint limit, effectively reducing steering impact and improving handling smoothness. Fusion control technologies have shifted from mechanical locking and mechanical separation structures to digital command control and autonomous driving collaborative control, realizing in-depth integration with high-level intelligent driving systems. On the whole, JTEKT's technical route has steadily evolved around three directions: safety and reliability, precise execution, and intelligent fusion. All technological R&D is aimed at mass production, with strong engineering and practical characteristics.

5. Enlightenment of JTEKT's Patent Layout to China's SBW Industry

Combined with the global SBW competitive landscape and JTEKT's patent layout characteristics, domestic automakers and component enterprises should fully learn from the experience of leading enterprises, base on their own development stage, clarify the direction of technological

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R&D, optimize the patent layout strategy, and accelerate the realization of independent control of SBW technology.

First, comprehensively strengthen the patent layout in all fields of SBW and improve the comprehensive strength of intellectual property rights. At present, SBW technology has entered a critical period of mass production and landing, and patent competition has become the core of market competition. Domestic enterprises should change the local and scattered layout mode, carry out systematic layout around four branches: upper steering control, lower steering control, system control, and fusion control, and gradually build a full-stack patent system of "functional safety + core control + user experience + intelligent fusion". While increasing the number of patents, more attention should be paid to patent quality, focusing on high-value invention patents such as control algorithms, functional safety solutions, redundant architectures, and software-defined steering. At the same time, global patent layout should be actively carried out, covering major automotive markets such as China, Europe, the United States, and Japan, to build an international intellectual property barrier and lay a foundation for product export and market competition[10].

Second, accurately avoid core patent risk points and reduce hidden dangers of intellectual property infringement. JTEKT has a highly intensive patent layout in failure or degradation, endpoint control, split-road control and other fields, forming a tight protection network, which is a risk area that domestic enterprises must focus on avoiding in the process of R&D and productization. Enterprises should establish a sound patent risk investigation mechanism, conduct in-depth analysis of the claims and protection scope of core patents, and avoid directly adopting the same technical solutions. Core barriers can be bypassed through technical avoidance design, peripheral patent innovation, patent cross-licensing and other means. Especially in key technical points such as redundant architecture, fault diagnosis, endpoint limit, and separation control, adhere to a differentiated R&D route to form technical solutions with independent intellectual property rights.

Third, focus on key breakthroughs in patent blank areas and seize new tracks for technological competition. The analysis results show that JTEKT has a relatively weak patent layout in DMF understeer/oversteer control, locking control, hand feeling optimization, split-road control and other fields, with the number of patents less than 30 families, showing obvious layout blanks and technical depressions. Domestic enterprises should take these fields as key directions for corner overtaking, increase R&D investment, focus on developing steering fusion control algorithms for high-level autonomous driving, low-cost and high-reliability redundant solutions, personalized road feel simulation technology, intelligent variable transmission ratio technology, etc., to form differentiated technical advantages. At the same time, combined with the advantages of China's new energy vehicles and autonomous driving industry, promote the in-depth integration of SBW with domain controllers, intelligent chassis, vehicle-cloud collaboration and other technologies, and open up new technical routes and patent directions.

Fourth, promote industry-university-research collaborative innovation and accelerate the mass production transformation of patented technologies. SBW technology highly relies on interdisciplinary support such as algorithms, control, functional safety, and reliability verification. Domestic enterprises should strengthen cooperation with universities and research institutes, carry out joint research on key links such as basic algorithms, standards and specifications, and test verification to improve core technological innovation capabilities. At the same time, adhere to the simultaneous promotion of R&D and mass production, quickly transform patented technologies into mass-produced products, verify technical performance through actual vehicle loading, and reversely optimize technical solutions and patent layout to form a virtuous circle of "R&D-patent-mass production-iteration". In addition, the industry can be promoted to set up patent pools to realize patent resource sharing and risk sharing, reduce

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R&D costs and infringement risks of small and medium-sized enterprises, and enhance the overall competitiveness of China's SBW industry.

6. Conclusion

SBW is the core underlying technology of intelligent connected vehicles and autonomous driving, and global patent competition is becoming increasingly fierce. With decades of technical accumulation and continuous R&D investment, JTEKT has formed a complete patent layout system in the SBW field with functional safety as the core, high-precision control as the support, and user experience and intelligent fusion as supplements. It has built extremely high technical barriers in key fields such as failure or degradation and endpoint control. Its patent layout strategy, technical evolution route, and mass-production-oriented R&D model have important demonstration significance for the development of the global SBW industry.

Although China's SBW technology started late, it has developed rapidly in recent years and made certain progress in patent applications and technological R&D. Faced with the patent barriers of international giants, domestic enterprises should adhere to independent innovation, clarify R&D priorities, optimize layout strategies, comprehensively strengthen patent layout in all fields, accurately avoid core patent risks, focus on breakthroughs in blank areas, and promote industry-university-research collaboration and mass production transformation, so as to accelerate the construction of an independently controllable technical system and intellectual property barriers. In the future, with the continuous improvement of autonomous driving levels and the increasing popularity of chassis-by-wire technology, SBW will accelerate toward domain control integration, software definition, full-stack redundancy, and vehicle-cloud collaboration. Patent competition will further focus on algorithm, functional safety, and multi-domain fusion innovation. Only by continuously increasing R&D investment and supporting technological innovation with intellectual property rights can domestic enterprises take the initiative in the global SBW industry competition and realize the transformation from technological catching-up to technological leadership.

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