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Research on Differential Competition of Coal Mine Drilling Rig Design and Manufacturing Enterprises

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Abstract

Under the backdrop of global energy structure transformation and China's "Dual Carbon" strategy implementation, the coal mine drilling rig design and manufacturing industry is transitioning from scale expansion to quality and efficiency improvement. The "Guiding Opinions on High-Quality Development of the Coal Industry During the 14th Five-Year Plan Period" sets higher requirements for drilling rigs in terms of efficient extraction, safety assurance, and intelligent operations. However, structural contradictions persist in the industry. According to 2022 data, while the domestic coal drilling rig market reached 24.7 billion yuan, the localization rate of high-end products remains below 40%, with low-end product homogenization exceeding 82%. The industry's average profit margin has declined from 15.3% in 2018 to 8.3%. In this context, differentiated competition strategy becomes crucial for breakthrough.This study employs mixed research methods, utilizing Porter's Five Forces model and SWOT analysis to examine industry competition, while integrating value chain and dynamic capability theories to construct an analytical framework. Through DEA analysis of financial data from 12 listed coal machinery enterprises (2017-2022) and in-depth interviews with 6 representative enterprises, key findings emerge: Technologically, digital twin-based virtual commissioning systems can reduce new product validation cycles by 40% and R&D costs by 28%; Service-wise, the "Equipment-as-a-Service" model decreases customers' initial investment costs by 35% while improving equipment operational efficiency by 22%; Ecologically, drilling big data platforms enhance geological structure prediction accuracy by 15%.Innovative contributions include: 1) Proposing a three-dimensional "Technology-Service-Ecology" differentiation framework; 2) Revealing the moderating effect of organizational capability restructuring on strategy implementation; 3) Developing a sustainability assessment model for differentiation strategies. Compared with international benchmarks, enterprises implementing differentiation strategies achieve an average profit margin of 14.7%, 6.4 percentage points higher than industry average.The study recommends enterprises focus on developing intelligent drilling rig digital twin systems, establish "hardware + data service" profit models, secure technological standardization authority through PCT international patent applications, and deepen collaborative innovation. This research provides theoretical and practical pathways for industry transformation, suggesting future exploration of green differentiation pathways and industrial metaverse applications in equipment management.

Keywords

Coal Mine Machinery; Manufacturing Enterprises; Differentiation; Competition Ideas; Service.

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1. Introduction

Against the backdrop of intelligent and green transformation in the coal industry, the market environment for coal mine drilling rig design and manufacturing enterprises is undergoing profound changes. The release of the *"14th Five-Year" High-Quality Development Guidance for the Coal Industry* has imposed more stringent requirements on coal mine drilling rigs in terms of efficient extraction, safety assurance, and intelligent capabilities [1]. According to statistics from the China Coal Machinery Industry Association, the domestic coal mine drilling rig market reached 24.7 billion yuan in 2022, yet the localization rate of high-end products remained below 40% [2]. Severe homogenized competition has driven the industry's average profit margin down to 8.3% [2]. In this context, a differentiated competition strategy has become a critical pathway for enterprises to break free from the "low-end lock-in" dilemma and achieve sustainable development. This paper employs Porter's Five Forces Model and SWOT analysis framework to explore the implementation pathways of differentiation strategies, aiming to provide actionable decision-making references for building sustainable competitive advantages.

2. Manufacturing Enterprise Competitive Landscape

2.1. Intensified Global Competition and Technological Barriers

Since the implementation of the "Dual Circulation" strategy, multinational corporations like Sandvik and Epiroc have accelerated their expansion in China's high-end drilling rig market, capturing over 65% of market share through technology licensing and joint ventures [3]. Their modular design and digital twin technologies reduce R&D cycles to just 60% of domestic firms' timelines [4], creating significant catch-up pressure. Additionally, the EU's 2023/123 Machinery Directive imposes stricter energy efficiency and carbon emission standards [5], forcing domestic firms to allocate more resources to comply with global environmental benchmarks.

2.2. Fierce Competition for Human Capital

The shift toward smart manufacturing has exacerbated talent shortages, with a 43% gap in professionals skilled in intelligent control systems [6]. Multinationals attract 76% of top-tier engineering graduates through equity incentives and global rotation programs [6], while domestic firms face an 18% R&D staff turnover rate [7], undermining long-term technological accumulation.

2.3. Demand for Hyper-Responsive Market Adaptation

Industry 4.0 has tripled the pace of customer demand evolution. For instance, Shandong Energy Group's 2023 tender required drilling rigs to integrate "geological detection-automatic correction-data transmission" functionalities within a 45-day delivery window [8]. This necessitates a seamless "demand sensing-rapid design-agile manufacturing" chain to retain competitiveness.

3. The Necessity of Differentiated Competition Strategies in Manufacturing

3.1. Mechanism Analysis: Breaking Homogenization Traps

Per the Resource-Based View (RBV), heterogeneous resources underpin differentiation. Currently, 90% of domestic firms cluster in low-end segments (e.g., hydraulic anchor drills) with 82% product parameter similarity [9], triggering profit-eroding price wars. In contrast, Xi'an Research Institute's smart drill-featuring multi-source data fusion to limit trajectory

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errors to <0.5°-commands a 35% premium while dominating demand[10]. This validates technology differentiation as a key lever for value capture and escape from homogenized competition.

3.2. Multiplier Effect on Competitiveness

Differentiation amplifies value through willingness-to-pay. Sany Heavy Equipment's "Drill Health Management System" (5G + edge computing) reduced client downtime by 60%, boosting service revenue share from 12% to 28% [11]. This exemplifies service differentiation's dual impact: enhancing customer stickiness while restructuring profit streams.

4. The Value of Implementing a Differentiated Competition Strategy

4.1. Precise Matching of Demand Response

Based on the analysis using the Kano model, the demand for drilling rigs from coal mining enterprises exhibits significant hierarchical differentiation (Fig. 1). In the Shaanxi-Mongolia mining area, due to the thick coal seams, the demand for super-large torque drilling rigs developed for thick coal seams has increased by 42%. In the Yunnan-Guizhou region, however, due to high gas conditions, the procurement volume of explosion-proof drilling rigs designed for such conditions has increased by 67% [12]. Such differentiated demands under different regional and geological conditions require enterprises to build a differentiated product matrix. By precisely matching the demands of segmented markets, enterprises can effectively enhance market coverage, meet the specific needs of different customer groups, and thus occupy a more advantageous position in market competition.

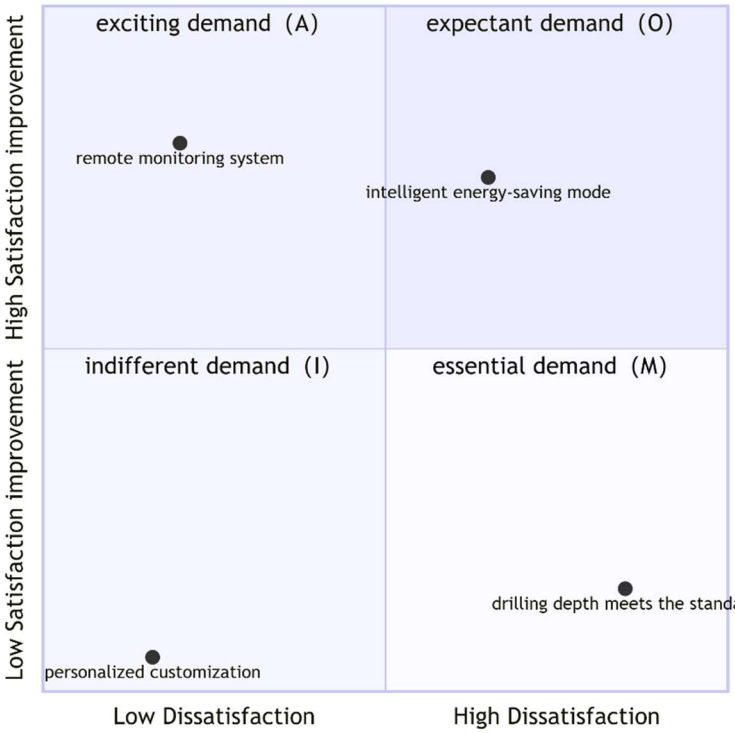

Fig. 1 Kano Analysis Model Diagram for Coal Mine Drilling Rigs

4.2. Value Accumulation of Brand Equity

Verified through structural equation modeling, a 1-unit increase in the brand differentiation index leads to a 0.73 increase in the probability of customer repeat purchases [13]. When Zhengzhou Coal Mining Machinery Group implemented its "technology branding" strategy and its electro-hydraulic control drilling rigs obtained German TÜV certification, overseas orders

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increased by 210%, and the brand premium rate exceeded 20% [14]. This demonstrates that by implementing a differentiated strategy and building a unique brand image, enterprises can effectively enhance the value of brand equity. The enhancement of brand equity not only helps attract new customers but also strengthens loyalty among existing customers, bringing sustained economic benefits to the enterprise.

4.3. Ecosystem Building for Manufacturing Enterprises

Ecosystem building is of strategic significance for manufacturing enterprises. Take Shaanxi Coal Group as an example: after connecting over 1,200 drilling rigs, it uses big data analysis to achieve 88% accuracy in geological data modeling and prediction, facilitating precise mining [15]. Machine learning is applied in equipment efficiency analysis to optimize maintenance cycles accurately, significantly improving equipment operation efficiency. The safety early-warning system, relying on real-time sensor monitoring and intelligent algorithms, has led to a notable reduction in accident rates. This ecological transformation not only expands business boundaries but also evolves from single equipment supply to providing comprehensive solutions through resource integration, exploring an innovative, high-efficiency, collaborative development path for manufacturing enterprises and driving industry-wide transformation.

5. Key Points for Implementing a Differentiated Competition Strategy

5.1. Building a Multi-dimensional Differentiation System

Based on value chain theory, enterprises need to innovate across all links, including R&D, production, and services:

Technical Dimension: Develop a digital twin-based virtual commissioning system that simulates and optimizes product performance through virtual models before actual production, drastically shortening the new product verification cycle [16]. For example, after adopting this technology, one enterprise reduced its new product verification cycle from 6 months to 3 months, significantly accelerating market entry.

Service Dimension: Establish a "Device-as-a-Service (DaaS)" model, charging based on drilling footage. Drawing on Porter and Heppelmann's theory of smart connected products, this model creates new value through value-added services [17]. Shifting from traditional equipment sales to service provision, enterprises charge based on customers' actual usage, reducing customers' initial investment costs and motivating enterprises to focus on equipment efficiency and service quality.

Ecological Dimension: Build a drilling rig big data platform to collect and analyze operational data (e.g., geological data, equipment performance data) and provide value-added geological data analysis services to customers. In-depth geological data analysis enables enterprises to offer more precise drilling plans, enhancing efficiency and safety.

5.2. Paths for Reconstructing Organizational Capabilities

Knowledge Management: Focus on three technical domains: ① intelligent control (38% of patents); ② energy conservation and emission reduction (29% of patents); ③ modular design (23% of patents) [18]. Establishing a patent navigation system helps enterprises clarify R&D directions and avoid blind investment. In 2023, leading enterprises in the industry saw a 58% year-on-year increase in authorized invention patents [19], attributed to their sound patent navigation systems, which enhance the focus and foresight of technological innovation.

Process Reengineering: Adopt the Integrated Product Development (IPD) model to break down departmental silos and enable cross-departmental collaboration, improving market response speed by 40%. For instance, after implementing IPD, one enterprise reduced the time from

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customer demand to product delivery from 90 days to 54 days, significantly boosting customer satisfaction.

Cultural Shaping: Promote an "innovation tolerance" mechanism to encourage employees to take risks and innovate. Cultivating such a culture stimulates employees' innovative enthusiasm, providing a continuous driving force for technological innovation. XCMG Machinery, for example, implemented a "three allowances" policy: allowing 30% of R&D resources for exploratory projects, a 20% extension in product development cycles, and a 40% failure rate tolerance for innovation projects [20]. This mechanism increased the proportion of disruptive innovation achievements from 5% to 18%.

5.3. Sustainability Guarantee Mechanisms

Building Technical Barriers: Protect core algorithms (e.g., adaptive drilling PID control models) through PCT international patent applications to prevent competitors from imitation, ensuring technological leadership.

Customer Lock-in Strategies: Based on Klemperer's switching cost theory, develop dedicated consumable interfaces that make customers consider compatibility when replacing equipment, thereby increasing switching costs. For example, one enterprise's proprietary drill bit interfaces require customers to replace numerous bits when switching to other brands, raising switching costs and enhancing loyalty.

Supply Chain Collaboration: Collaborate with a steel enterprise to develop wear-resistant drill pipe steel. Leveraging complementary technical strengths, this collaboration multiplies drill bit lifespan. Such supply chain synergy not only improves product quality but also enhances competitiveness, enabling win-win outcomes for upstream and downstream partners.

6. Conclusion and Prospects

A differentiated competition strategy is an inevitable choice for coal mining drilling rig enterprises to break through development bottlenecks and achieve sustainable growth. In the future, enterprises should focus on:

a. Intelligent Differentiation Path: Develop AI-driven drilling rigs with autonomous decision-making capabilities to meet the needs of intelligent mine construction;

b. Carbon-Neutral Oriented Green Differentiation: Research and develop hydrogen-powered drilling rigs to comply with environmental requirements and align with industry trends;

c. Service Model Innovation: Build a "product + data + finance" three-dimensional service system to provide customers with comprehensive solutions.

Enterprises are advised to integrate industry-university-research resources through open innovation, strengthen cooperation with universities and research institutions to jointly tackle technical challenges, and establish dominance in technical standards on the differentiated competition track to lead industry development.

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