

Original Research Article

Demand Analysis of Hybrid Shunting Locomotive Application at Railway Technical Stations Based on the “Double Carbon” Goal*Geng Fang¹, Li Kunhao^{2*}**1 Department of Railway Transportation, Hebei Vocational College of Rail Transportation Shijiazhuang 052165, Hebei, China;**2 China Railway Beijing Group Co., Ltd. Shijiazhuang Railway Station Shijiazhuang 050051, Hebei, China*

Abstract: The application of oil-electric hybrid shunting locomotives in railway technical stations is analyzed in depth. Firstly, the technical characteristics of this kind of locomotive and its advantages in the application of railroad technical station are analyzed; then the main problems existing in the current application are analyzed, including short range, insufficient energy recycling, intelligent control level needs to be upgraded and so on; finally, the measures and suggestions for systematic optimization are put forward from the levels of technological innovation, construction of ancillary facilities, policy support and so on, with a view to providing references to promote the application of hybrid shunting locomotive in the railway technical station. In order to promote the application of oil-electric hybrid shunting locomotives in the railroad technology station to provide reference.

Keywords: Hybrid Shunting Locomotives; Railway Technology Stations; Technological Innovation; Transportation Equipment; Carbon Neutrality

1. Introduction

In recent years, to deal with climate change and environmental pollution has become a global consensus, China has also put forward a major strategic plan to achieve the goal of “carbon peak, carbon neutral” (referred to as “double carbon”)^[1]. As the lifeblood of the national economy, the railroad transportation industry also shoulders the important responsibility of realizing green and low-carbon transformation.

As the key equipment of railroad transportation system, the energy-saving and emission reduction performance of railroad locomotives directly affects the energy consumption and emission level of the whole railroad industry chain. Under the leadership of the “double carbon” goal, the railroad industry is accelerating the promotion and application of new energy-saving and environmentally friendly railroad locomotive technology, of which the green locomotive represented by hybrid technology is one of the key development directions^[2].

Railroad technical station is an important part of the railroad transportation system, shunting operation is larger, and at present, China’s railroad technical station mainly adopts diesel as the energy source of internal combustion locomotives as the main model of shunting locomotives^[3]. Unlike most intermediate stations, the operating environment of technical stations puts forward higher requirements on the performance, economy and environmental protection of shunting locomotives. Therefore, it is of great significance to analyze the application demand for hybrid shunting locomotives in railroad technical stations based on the goal of “double-carbon”, in order to promote the application of green low-carbon technology in the railroad industry.

To sum up, it is necessary to comprehensively analyze the application demand for hybrid electric shunting locomotives in railroad technical stations from the perspectives of the operational characteristics of railroad technical stations and the technical advantages of hybrid electric shunting locomotives, so as to provide decision-

making references for upgrading the level of green development of railroad transportation.

1.1. Characteristics and Technical Advantages of Hybrid Shunting Locomotives

Hybrid oil-electric shunting locomotive is a new type of green locomotive technology promoted by the railroad industry in recent years. Compared with the traditional diesel combustion locomotive, its main features and technical advantages are as follows.

1.2. Flexible structure of hybrid power system

Oil-electric hybrid shunting locomotive adopts the hybrid power system design of diesel generator set and electric motor, which can flexibly switch the driving mode according to the operational requirements. In low-speed shunting operation, it can be driven by pure electricity to reduce emissions; in high-speed driving, it can be switched to diesel generator set drive to improve range. This structural design significantly improves the comprehensive energy utilization efficiency of the locomotive.

1.3. Significant energy saving and environmental protection performance

Compared with traditional diesel locomotives, hybrid shunting locomotives can realize zero emission during low-speed shunting operations, and the overall energy consumption and carbon emission levels are also greatly reduced. Taking the practical application of the first batch of FXN3B hybrid shunting locomotives of Fuxing as an example, its fuel economy can be improved by more than 30%, and carbon dioxide emissions can be reduced by about 40%^[4]. These excellent energy-saving and environmental protection performance can help the railroad technical station to realize the goal of “double carbon”.

1.4. Stronger operational adaptability

Hybrid shunting locomotives have stronger climbing ability and faster acceleration performance, which are very suitable for the complex and changing shunting operation environment in railroad technical stations. At the same time, its noise level is significantly lower than that of traditional diesel locomotives, which is conducive to improving the environmental quality of the operating site.

With flexible power system design, excellent energy-saving and environmental protection performance, and excellent adaptability, hybrid shunting locomotives have obvious advantages in meeting the needs of railroad technical stations, and are worth further popularizing and applying in the railroad industry.

2. Operational characteristics of railroad technical stations and demand for railroad locomotives

Railroad technical station is an important part of railroad transportation system, which is mainly responsible for providing locomotive dispatching, train dismantling and grouping and other operations for neighboring railroad sections, while neighboring locomotive sections are responsible for key operations such as locomotive and vehicle repair and maintenance. Compared with ordinary intermediate stations, the operation characteristics of technical stations and the demand for locomotive performance have the following aspects.

2.1. Large amount of shunting operation

Technical station is an important hub in the railroad transportation system, undertaking a large number of train grouping and shunting operations. Take a large technical station as an example, every day need to complete thousands of carloads of shunting tasks. This high-intensity shunting operations on the locomotive power

performance, maneuverability and reliability put forward higher requirements.

2.2. Complex and changeable operating environment

The operating environment of the technical station is often more complex than ordinary lines, requiring frequent low-speed shunting, rapid acceleration and deceleration and other actions. At the same time, it is also necessary to flexibly dispatch locomotives in narrow station yards, which puts forward stricter standards for locomotive mobility and environmental performance.

2.3. Higher demand for economy and environmental protection

As an important part of the railroad transportation system, the energy consumption and emission level of technical stations directly affect the green development goal of the whole railroad industry. Therefore, technical stations put forward higher demands on the economy and environmental performance of locomotives, hoping to significantly reduce energy consumption and carbon emissions.

To summarize, the high-intensity shunting operation, complex and changing operating environment, and the higher demand for economy and environmental protection in railroad technical stations have all posed new challenges to the technical development of railroad locomotives. Under the guidance of the goal of “double-carbon”, hybrid shunting locomotives, with their excellent performance characteristics, will surely become the green locomotive of choice for future key applications in technical stations.

3. Analysis of the application requirements of hybrid shunting locomotives in railroad technical stations

Based on the aforementioned analysis of the operating characteristics of railroad technical stations and the technical advantages of hybrid shunting locomotives, we further discuss the specific application requirements of hybrid shunting locomotives in railroad technical stations.

3.1. Meet the needs of high-intensity shunting operations

Traditional diesel combustion locomotives in frequent low-speed shunting operations, the power output is often not flexible enough, prone to pulley slippage, startup difficulties and other problems, affecting the operational efficiency. Hybrid shunting locomotives can well meet this demand.

The hybrid locomotive adopts the hybrid power system design of diesel generator set and electric motor, which can flexibly switch the driving mode according to the operation demand. In low-speed shunting operation, it can be driven by pure electric power to improve mobility and maneuverability; in high-speed driving, it can be switched to diesel genset drive to improve range. This structural design not only meets the frequent low-speed shunting needs of the technical station, but also ensures that the locomotive maintains good power performance at high speeds, which significantly improves operational efficiency.

At the same time, hybrid shunting locomotives also have stronger climbing ability and faster acceleration performance, these features are also very suitable for the complex and changing operating environment of the railroad technical station. In general, the power performance and maneuverability of these locomotives can well meet the needs of high-intensity shunting operations in technical stations.

3.2. Improve the operating environment and reduce emissions

Compared with traditional diesel locomotives, hybrid shunting locomotives can realize zero emission during

low-speed shunting operation, which significantly reduces the environmental pollution of the technical station operation site. At the same time, its noise level is significantly lower, which helps to improve the quality of the operating environment and enhance the working experience of employees.

Taking the practical application of the first batch of FXN3B hybrid shunting locomotives of Fuxing as an example, its fuel economy can be improved by more than 30%, and carbon dioxide emissions can be reduced by about 40%. These outstanding energy-saving and environmental protection performance not only help the technical station to realize the goal of “double-carbon”, but also create a cleaner working environment for the station operators, and help the environmental protection work in the service area.

In addition, the low-noise characteristics of hybrid shunting locomotives are also very suitable for the operational needs of technical stations. Technical stations are usually located near cities or residential areas, where the control of noise pollution is more stringent. Compared with traditional diesel locomotives, oil-electric hybrid locomotives are almost noiseless when shunting at low speeds, which greatly improves the environmental quality of the operation site and creates a more livable living environment for residents along the railroad.

3.3. Improve economy and energy utilization efficiency

As an important part of the railroad transportation system, the operating cost of the technical station directly affects the economic efficiency of the entire railroad industry. Therefore, technical stations put forward higher requirements for the economic performance of locomotives, hoping to significantly reduce energy consumption and operating costs.

With its flexible power system design, the hybrid shunting locomotive is able to intelligently deploy the drive modes of diesel generator sets and electric motors according to the operational requirements, which significantly improves the overall energy utilization efficiency. This not only reduces the fuel consumption of technical stations, but also helps to reduce operating costs.

Taking FXN3B oil-electric hybrid shunting locomotive as an example, its fuel economy can be improved by more than 30%, and the average daily reduction of diesel engine working time is more than 75%, which significantly reduces energy consumption compared with traditional diesel locomotives. At the same time, due to the reduced use of diesel fuel, the maintenance cost of locomotives has also been reduced. These excellent economic performances not only bring direct cost savings for the technical stations, but also help to improve the economic efficiency of the entire railroad industry.

In addition, the energy utilization efficiency of hybrid shunting locomotives indirectly brings other economic benefits. Due to the significant reduction of energy consumption and carbon emissions, more policy support and subsidies can be obtained under the “dual-carbon” goal, which further improves the economic benefits of the technical stations^[5].

In summary, the hybrid shunting locomotive, with its excellent power performance, excellent environmental performance and good economy, can well meet the needs of railroad technical stations for shunting locomotives, and is an important support for the green transformation of technical stations in the future. Under the guidance of “double carbon” target, this kind of green locomotives will surely become the new type of shunting equipments to be applied in technical stations.

4. Optimization Measures and Suggestions

With the increasing demand for the application of oil-electric hybrid shunting locomotives in railroad

technical stations, how to further optimize the performance and application effect of this type of green locomotives is the next urgent problem to be solved in the railroad industry. Based on the aforementioned analysis, the following optimization measures and suggestions are put forward.

4.1. Strengthen technological innovation, improve overall performance

At present, the technical level of oil-electric hybrid shunting locomotives is still to be further improved, especially in the power system integration, energy recycling and other aspects there is still some optimization space. Therefore, railroad rolling stock manufacturing enterprises should increase technical innovation and continue to promote the optimization of the performance of such locomotives.

Further optimize the integration design of hybrid power system. Through the synergistic optimization of diesel generator sets, electric motors, batteries and other core components, the overall power output performance and energy conversion efficiency can be improved. At the same time, the application of new high energy density battery technology can also be explored to expand the range in pure electric drive mode, further improving the environmental performance of locomotives.

Strengthen the research and development of energy recycling technology. In the braking process, a large amount of kinetic energy is converted into heat and dissipated, resulting in a serious waste of energy. By integrating an efficient energy recovery device in the braking system, this part of kinetic energy is converted into electric energy and fed back to the battery system, which not only improves the overall energy utilization efficiency, but also reduces the heat load of the braking system and prolongs its service life.

Optimize the intelligent control strategy of the locomotive for different operating scenarios. Intelligent optimization of driving mode and energy management is carried out through AI algorithms to further enhance the adaptability and operational efficiency of oil-electric hybrid shunting locomotives in the complex operating environment of technical stations.

4.2. Improve supporting facilities, improve application effect

A single locomotive technology innovation does not give full play to the advantages of hybrid oil-electric shunting locomotives, but also need supporting infrastructure to support. Therefore, railroad enterprises should combine the actual needs of the technical station, comprehensive planning and construction of relevant supporting facilities.

Strengthen the construction of charging/filling facilities in technical stations. Aiming at the characteristics of oil-electric hybrid shunting locomotives, fast charging piles and diesel fuel filling stations are deployed inside technical stations to ensure that the locomotives can quickly replenish energy in the course of operation and improve operational efficiency. At the same time, it can also explore the construction of a centralized energy replenishment center to realize the unified management and dispatching of multiple locomotives and further enhance the efficiency of energy utilization.

Strengthen the construction of information management system. Through real-time data interaction between on-board equipment and ground dispatching center, intelligent monitoring and optimization management of the whole process of locomotive operation status, energy consumption and maintenance can be realized. At the same time, big data analysis technology can also be utilized to deeply mine the historical operation data and provide decision-making support for the production plan and energy management of technical stations.

Strengthen the construction of locomotive repair and maintenance system. Aiming at the characteristics of

oil-electric hybrid locomotives, cultivate a professional team of maintenance personnel, equip special testing and diagnostic equipment, and establish a perfect spare parts supply system to ensure that the locomotives are always in good technical condition and maximize their performance advantages.

4.3. Improve policy support and create a favorable environment

In addition to technological innovation and infrastructure construction, policy support is also a key factor to promote the application of oil-electric hybrid shunting locomotives in technical stations. Therefore, the State Railway Administration and other relevant departments should introduce more perfect policy measures to create a favorable environment for the promotion and application of such green locomotives.

Increase financial and tax policy support. By providing purchase subsidies and tax reductions, railroad enterprises can reduce the cost pressure of introducing oil-electric hybrid shunting locomotives and improve their economy. At the same time, differentiated tax policies can also be implemented for energy consumption and carbon emissions in the use of locomotives to further incentivize enterprises to accelerate green transformation.

Improve the construction of the standard system. Formulate unified technical standards and specifications to standardize the design, manufacturing, testing and other life cycle management of oil-electric hybrid shunting locomotives to ensure product quality and safety. At the same time, the performance evaluation system of green locomotives can also be established to provide a basis for railroad enterprises to select models and promote technological innovation and application promotion.

Strengthen government guidance and demonstration application. Demonstration application of oil-electric hybrid shunting locomotives can be carried out in key regions or key enterprises, and its performance advantages can be verified through actual operation, which will lead to the cognition and acceptance of more national railways or local railroad enterprises. At the same time, the government can also introduce relevant incentive policies to guide the railroad enterprises to actively participate in the promotion and application of green locomotives.

In conclusion, to promote the application of oil-electric hybrid shunting locomotives in railroad technical stations, it is necessary to carry out systematic optimization and improvement from technological innovation, infrastructure construction, policy support and other levels. Only through a full range of optimization measures can we maximize the advantages of this type of green locomotive and contribute to the green transformation of the railroad industry.

5. Conclusion

As a kind of green railroad locomotive technology, the oil-electric hybrid shunting locomotive shows significant advantages in the application of railroad technology station. Through a comprehensive discussion on its technical characteristics, demand analysis and optimization measures, the key conclusions are as follows.

Oil-electric hybrid shunting locomotives have the advantages of energy saving and environmental protection, flexible operation, convenient maintenance, etc., which can effectively meet the demand for green locomotives in railroad technical stations. The technical level of such locomotives in terms of power system integration and energy recycling is constantly improving, which lays a solid foundation for their application in railroad technical stations.

At present, the application of oil-electric hybrid shunting locomotives in railroad technical stations still has certain limitations. It is mainly reflected in the short range, insufficient energy recovery and utilization, and the

level of intelligent control needs to be improved, which restricts its applicability and operational efficiency in the complex operating environment.

To further promote the application of hybrid shunting locomotives in railroad technical stations, it is necessary to carry out systematic optimization and improvement at multiple levels, such as technological innovation, construction of supporting facilities and policy support. This includes optimizing the power system integration, improving the efficiency of energy recovery and utilization, strengthening the research and development of intelligent control strategies, as well as constructing charging/filling facilities, information management systems, and improving the repair and maintenance system.

The government and relevant departments should introduce more perfect financial, tax, standards and other support policies to create a favorable environment for the promotion and application of such green locomotives, and guide railroad enterprises to take the initiative to participate in green transformation.

To sum up, hybrid shunting locomotives are undoubtedly one of the important grasps for the railroad industry to realize green development. In the future, with the continuous progress of related technologies and further improvement of supporting conditions, this kind of locomotives will certainly play a more important role in railroad station operations and mainline transportation tasks, contributing to the green transformation of the railroad industry.

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