# Advancements and Applications of Steel Coil Transportation Equipment Technology in Modern Steel Strip Plants

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***Abstract***：*With the increasing demand for green and intelligent development in the steel industry, technological innovation in steel coil transportation systems has become particularly crucial. This paper reviews the technological advancements in steel coil transportation equipment in recent years, particularly their applications in hot rolling and cold rolling production plants. These include tray transportation systems, contact-less power supply transport vehicle systems, supercapacitor-powered transport vehicle systems, sliding contact line transport vehicle systems, automated guided vehicles (AGVs), and minimal turning radius steel coil transport vehicle systems. The significant advantages of supercapacitor-powered steel coil transportation technology are elaborated in detail. Practical production data demonstrates that compared with traditional tray transportation methods, this system reduces energy consumption by 72%, achieves remarkable annual energy savings and $CO_2$ emission reductions, and for the first time realizes plane-crossing transportation of steel coils with roadways and unmanned warehouse management. The new generation of steel coil transportation equipment demonstrates distinct advantages in enhancing production efficiency, reducing energy consumption, and enabling intelligent management, providing crucial technical support for process re-engineering in the green and intelligent transformation of the steel industry.*

**KEY WORDS**: STEEL COIL TRANSPORTATION； METALLURGICAL INTERFACE TECHNOLOGY； INTELLIGENCE; SUPER CAPACITOR POWER SUPPLY; TECHNICAL INNOVATION

## 1 Overview

The steel coil transportation technology in metallurgical enterprises belongs to the interface technology of metallurgical process science.The Interface technology refers to the connection, matching and coordination technology between various manufacturing units (such as blast furnace, converter, rolling mill, etc.) in the metallurgical production process. In the construction of intelligent plants in metallurgical industry, the intellectualization of the internal interface technology is one of the difficulties [1].

To meet this requirement, in the past 20 years the internal steel coil transportation of metallurgical enterprises (especially the steel coil transportation of the newly built hot rolling plant) has changed from the traditional methods (walking beam, chain conveyor, etc.) to the new pallet type transportation. In 2007, the world's first double-layer pallet transport system was put into use. In 2008, the world's first double-row pallet transport system was put into use. In 2011, the world's first ultra-long distance heavy-duty transport car with non-contact power supply technology appeared [2, 3, 4, 5]. Around 2017, the sliding contact wire type coil transport car and the supercapacitor-powered coil transport car began to be batch applied in industry [5, 6]. The overall change trends of the coil transportation technology are from mechanical handling to rail transportation, from traditional industrial control to full use of big data and other AI technologies.

## 2 Steel coil transportation methods and comparisons in modern steel plants

**2.1 The common methods of steel coil transportation include:** [3, 4, 5, 6]

(1) Walking beam (Figure 1). This technology has existed long time. The characteristic is that each walking step distance is a fixed distance, which requires a large hydraulic station. The useless energy consumption is large, maintenance is large, and the rhythm is slow. The structure is complex, and the outer ring of the steel coil is easy to get injured. It is difficult to realize its own intelligence.

(2) Chain conveyor (Figure 2). This technology has existed for a long time and has been used worldwide. Vertical or horizontal steel coils transport on the heavy transport chain, which can be used for long-distance transportation. But the transportation distance of a single chain is limited, and the walking beam must be used between two chains or at the turning point, with a slow rhythm and a large amount of maintenance. Frequent brake-start activation results in large energy consumption. Vertical transportation damage the inner circle of the steel coil.

**Fig.1 Walking beam**

**Fig.2 Chain conveyor**

(3) Pallet type. The feature is that the steel coil is placed on the pallet and the pallet moves on the roller table. It is divided into double-layer type and double-row type. Double-layer type was pioneered by SMS, and was first implemented in the 2250mm hot rolling mill plant of Maanshan Steel company in 2007. The double-row type was first implemented in Shougang Jingtang 2250mm hot rolling mill plant in 2008. The double-row type has more advantages. As shown in Figure 3 and Figure 4.

(4) Truck transportation. It is flexibility, but requires special vehicles, load cranes, special roads, and drivers. The daily maintenance and costs are expensive, which cannot meet the rhythm requirements of the rolling line.

**Fig.3 double-layer type**

**Fig.4 double row type**

(5) Non-contact power supply steel coil transport car (Figure 5). The patented product of Shougang is characterized using non-contact power supply technology, which can meet the needs of over-span and over-workshop transportation in the case of ultra-long distance and heavy load. However, due to the high invest cost and limited transportation capacity, the special requirements for cable laying and the environment, it cannot meet the requirements of continuous transportation in the hot rolling plant.

(6) Sliding contact wire type steel coil transport car. This technology was first developed by SMS and had been used in Baogang in 1980s. In recent years, Primetals and China First Heavy Industries group have also some projects used this type. The feature is that the coil car travels on the rail, and the power supply adopts the sliding contact wire power supply technology. See Fig. 6 and 7.

**Fig.5 Steel coil transport car with non-contact power supply**

**Fig.6 SMS's type** **Fig.7 Primetals's type**

Figure 6 shows the sliding contact wire type steel coil car developed by SMS in the 1980s, which uses a side contact sliding contact wire power supply and is applied to Baosteel's 2050mm hot rolling plant. Figure 7 shows the sliding contact wire type steel coil car developed by Primetals in recent years, which adopts a vertical contact sliding contact wire power supply method and has been applied in a few plants.

The practice of Baosteel has proofed that due to the physical contact and wear of slide contact, the reliability was reduced during long-distance transportation, and the maintenance workload is large. Special treatment is required for outdoor transportation or road crossing.

### 2.2 Comparison of common steel coil transportation technologies

At present, modern hot rolling lines mainly use four types of steel coil transportation methods: walking beam, chain conveyor, sliding contact wire steel coil car, and pallet type transportation. The comparison of them is shown in table 1:

**Table 1 Comparison of four types**

| Item | Walking beam | Chain | Sliding contact | Pallet |
|---|---|---|---|---|
| Reliability | normal | normal | good | better |
| Turn and cross | Complex | Complex | Simple | Simpler |
| Meet the rhythm of production (60 seconds) | Difficulty (>100s) | Difficulty (>100s) | Sure | Sure |
| Intelligence difficulty | Complex | Complex | Simpler | Simple |
| Foundation Depth | Deep | Deep | Shallow. Cable ditch is required | Double-layer：deep Double-row：shallow |
| Step-by-step construction | Not good | Not good | Not good | Good |

| Item | Walking beam | Chain | Sliding contact | Pallet |
|---|---|---|---|---|
| Workshop ground | pits on the ground. | wide pits on the ground. | Needspecial treatment. | Onlytwo cracks on the ground. |
| Hydraulic station | Extra large | Big | Very small | Very small |
| Impact to surface of coil | scratch and deforms | scratch and deforms | Good | Good |
| Grade crossing the road | Road interruption | Road interruption | Road interruption | Road interruption |
| Equipment manufacturing, installation, maintenance | Complex | Complex | Simple | Simple |
| Civil construction volume | Big | Larger | Smaller | Small |
| Operating expenses | Highest | High | Low | Low |
| Estimated total project investment (Transportation distance 400 meters) | Extremely high | high | Lower | Low |

From the comparison we can see that although walking beam, chain conveyor, and sliding contact wire technologies have been used for many years, they all have obvious limitations and cannot meet needs of intelligent, fast-rhythm, low-cost, and high reliability transportation of modern steel plants. Pallet type has outstanding advantages in existing technologies, so it has been widely used.

Although the preferred pallet transportation technology has met the fast-rhythm requirements of newly built hot strip mills in recent years, this technology still has the following major defects:

(1) When cross workshop or cross road with the same levels or interchanges, it increases investment and the road is interruption, affecting the logistics of the factory area.

(2) On average a set of roller tables is required for every 3.6 meters, with at least one gear motor and three sensors installed on the roller tables. The longer the transportation distance, the heavier the equipment, and the more motors and sensors required. Taking a transportation distance of about 400 meters (about 800 meters round-trip) as an example, its total equipment weight is about 2000 tons, the number of motors reaches 279, and the number of sensors is more than 876. Not only the workload of cable laying is large, but also reduces the reliability of equipment. If one set of roller table is broken, the entire transportation system will be stopped.

(3) The workload of civil construction is still significant. To ensure the smooth passage of pallets, strict installation accuracy is required between each roller table. There are a large amount of cable laying and management work. The equipment foundation is not only needs to consider the installation of the roller table, but also needs a deep cable trench next to it.

(4) The roller is severely worn and the equipment maintenance workload is heavy. Due to uneven settlement of the foundation, equipment installation errors, and eccentric loads, almost all rollers and pallets used in pallet type transportation have experienced varying degrees of wear. Even pitting, peeling, and even severe wear and tear of the roller rims that detach from the parent body had occurred. Therefore, roller replacement, chain lubrication, and sensor adjustment and replacement have become frequent contents of equipment maintenance work.

## 3 Supercapacitor powered coil transportation technology and engineering application

### 3.1 Supercapacitor powered self-driving coil car [2,6]

The supercapacitor powered self-driving steel coil car developed by Beijing Shougang International Engineering Company (BSIET) adopts supercapacitor power supply and wireless remote control. Its main

equipment components: car body, wheel group, saddle, supercapacitor, control cabinet, wireless communication system, safety protection system, etc. As shown in Figure 8.

**Fig.8 Steel coil transport car with supercapacitor power supply**

### 3.2 Technical characteristics and innovation points of supercapacitor powered self-driving coil car.

(1) For the first time in the field of metallurgical heavy-duty transportation, supercapacitor was used for power supply. The specialized supercapacitors, series coil cars, and automatic charging devices were invented. This technology has been granted patents in Europe, the United States, South Korea, and other countries.

(2) The use of rail can reduce transportation power consumption, simplifies control measures, simplifies construction, reduces civil engineering costs, and convenient cross road transportation. It is suitable for internal heavy-duty logistics transportation within plant.

(3) BSIET has developed an intelligent control system, a remote equipment monitoring system, and an equipment fault warning system. The system has achieved the function of automation, informatization, and intelligence. It ensured the implementation of intelligent warehousing and intelligent plants. The operation data of the capacitor car is transmitted in real-time to the data center, which can achieve equipment fault diagnosis and early fault alarm functions through big data analysis. By establishing an equipment status monitoring center customers can be provided with advanced fault diagnosis and alarm, and value-added services can be provided through mobile maintenance and inspection.

(4) The material flow and information flow are smooth and simple. The physical information system is reasonable, which fully meets the requirements of metallurgical interface technology for "connection matching, coordination buffer and stability". The auxiliary specialized equipment is complete. It optimized for the production process of the steel coil warehouse, promoting the implementation of intelligent warehouse management.

(5) By use this technology the energy consumption is the least. The braking energy can be recovered. The supercapacitor is pollution-free throughout its entire life. It fully satisfied with the concept of green, environmental protection, low-carbon, and energy-saving.

(6) It can be used for cross-span vehicles, can replace non-contact power supply heavy-duty transportation technology and pallet transportation technology.

### 3.3 Comparison of supercapacitor powered coil car and double row pallet technology

Taking a real project (the world first case) as an example, the comparison is shown in table 2:

**Table 2 Comparison of capacitor powered coil car and pallet technology**

| Item | Pallet | Capacitor powered car |
|---|---|---|
| Equipment weights | ～3000t | ～700t |
| Installed capacity | 1620.8kW | 763.7kW |
| Reliability | more possible fault | reliable |
| Turning and Crossing | Rotary table, moving table | Rotary table, moving table, curved rail |

| Item | Pallet | Capacitor powered car |
|---|---|---|
| Meet production rhythm (90 s) | sure | sure |
| Intelligence difficulty | hard | easy |
| Equipment foundation | Shallow (about 500mm for double row type) | Very shallow (Laying rails is sufficient) |
| The difficulty of step-by-step implementation | Better | Best |
| Impact on workshop floor | Wide pit covered by plate | Only 2 rails |
| Coil Surface protection | Good | Good |
| Cross the road | Complex, road disruption | Can directly pass through, simplest |
| Equipment installation, debugging, and maintenance | complex | simple |
| Civil construction quantity | large | Small |
| Operating expenses | high | low |
| Overall Investment | high | low |

From the comparison we can see that the new self-driving capacitor powered coil car system has the following advantages: shallow equipment foundation, light equipment weight, convenient installation/ debugging/ maintenance/ repair, clean and beautiful workshop, low investment, and low operating costs.

### 3.4 Real applications of supercapacitor powered self-driving coil cars

In 2017, the world first self-driving steel coil car transportation system using supercapacitor power supply was put into use on a 2050mm hot rolling line in Shangang China. Not only did it save 1/3 of the overall project investment, but also achieved energy consumption (per ton per kilometer) that is 28% of pallet type transportation, 5% of chain type, and 3% of walking beam transportation. It is significantly superior to traditional steel coil transportation methods. Due to the flexibility of the capacitor car itself, if a single capacitor car malfunctions, it can be lifted off the transportation line without stopping the transportation system, which effectively ensures the production of the main rolling line. In addition, the operation and maintenance costs of the equipment have also been greatly reduced than pallet type.

In 2019 a MCCR hot rolling line and in 2020 a high-strength galvanizing line also adopted this technology in Shougang China. It is clearly demonstrating more prominent advantages than the double-row pallet system used by the company's 2250mm and 1580mm hot rolling plants. It successfully solved the problem of intersection between coil transportation and roads and achieved an organic connection between coil transportation and social transportation through an intelligent traffic control system (Fig.9). Not only has truck transportation been cancelled, but it has also been efficiently integrated with the warehouse management systems of two steel coil warehouses, achieving unmanned intelligent warehouse management (Fig.10). Figure 9 shows the scene of steel coil transportation and road level crossing. Figure 10 shows the connection with the intelligent unmanned warehouse management system. The self-driving coil car transportation technology powered by supercapacitors may bring fundamental changes to the internal logistics and transportation methods of enterprises.

In 2020 a 1650mm hot rolled steel coil transportation system, in 2021 a cold rolled coil production line and in 2022 a "lighthouse factory" project using the new technology have also been put into use one after another. In 2023, a DUE production line in Yunnan China and a hot rolled line in Shandong gave the orders to this technology. In recent years, more and more hot-rolled and cold-rolled strip mills have adopted this technology.

**Fig.9 Coil transportation and road level crossing**

**Fig.10 Unmanned operation between capacitor car and overhead crane**

### 3.5 Upgrading and renovation of existing strip plants

The self-driving coil car powered by supercapacitors has prominent characteristics such as short construction period and low overall project investment. It is particularly suitable for renovation projects of existing lines that require strict construction period. Compared with pallet type it has obvious advantages, and the downtime of the rolling line can be reduced by more than 1/4.

Taking a 2160mm hot rolling line as an example, the designed annual production capacity of the production line is about 4.2 million tons. The transportation mode is traditional: fast chain, walking beam, slow chain, and trucks. Although the transportation rhythm has been increased from 135s to around 110s at present, but the fastest rhythm of the rolling line has reached 90s, means that the transportation system is still a bottleneck. Moreover, the frequency of existing equipment failures has always been high, resulting in high maintenance costs and difficulty. If the supercapacitor powered self-driving coil car technology is adopted for renovation of this line, not only can the construction period be shortened to less than 15 days, but the transportation rhythm can be matched with the rolling line (<90 seconds), which can achieve unmanned intelligent transportation and cancel truck transportation. It is expected that after the renovation is completed, not only is the annual production increase to over 5 million tons, but the production cost can be significantly reduced. Taking into the factors such as electricity consumption, maintenance, spare parts, increased production capacity, and replacement trucks, the annual economic benefits exceed more than 30 million RMB yuan, while the social benefits are also very considerable.

## 4 Conclusion

(1) A necessary condition for building an intelligent metallurgical factory is to achieve intelligent interface technology. Self-driving coil car powered by supercapacitors with wireless communication are currently very few methods that can achieve this goal.

(2) The successful applications for 5 years have proved the progressiveness, economy, and reliability of the new technology.

(3) The use of rail can greatly reduce energy consumption, simplify control, simplify construction, reduce civil engineering costs, and facilitate level crossing transportation.

(4) Compared with other existing methods, supercapacitor powered car system can effectively reduce engineering investment, shorten construction period, effectively reduce transportation costs of metallurgical enterprises, and enhance their competitiveness.

(5) The development trends of coil transportation are: transport mode is shifting from mechanical handling (walking beam, chain, pallet, etc.) to rail type (steel wheeled vehicle), from traditional industrial control to fully utilizing wireless communication, big data, and artificial intelligence technologies.

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