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Development of Automatic Packaging Systems for Sheets and Coils

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Abstract:

Steel sheets and coils are shipped packaged with paper and/or metal for protection against rust and damage in transit and storage. As steel sheets and coils are very large, they were difficult to package automatically. Nippon Steel is making strenuous efforts at automation to rationalize operations and relieve workers from arduous, dirty and dangerous jobs, and in this line has worked on the development of automatic systems for packaging steel products. The company has recently developed automatic sheet and coil packaging systems. These developments complete the automation of packaging for almost all types of steel products at Nippon Steel. The sheet packaging system can fully automatically package with paper stacked sheets measuring 400 mm high by 1,250 mm wide by 3,500 mm long in maximum dimensions. The coil packaging system can perform the paper wrapping and folding of coils with simple mechanisms.

1. Introduction

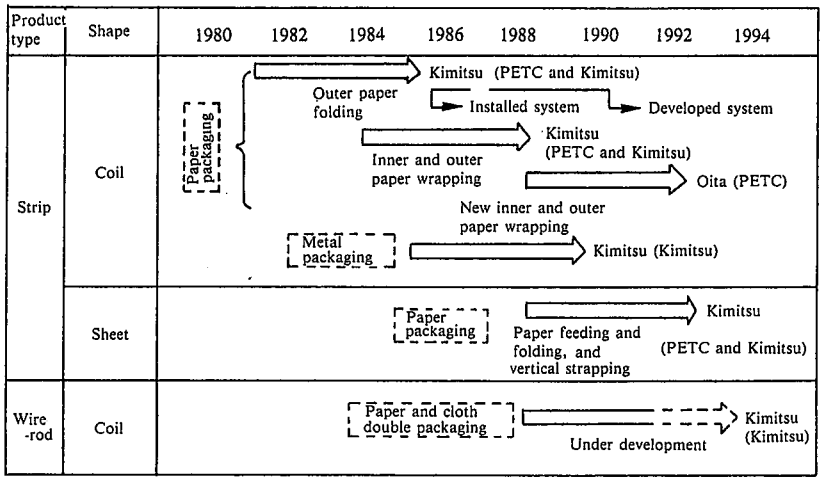
The steel industry has made positive efforts at mechanization and automation from the standpoint of cost reduction. The recent labor shortage and shunning of dirty, difficult and dangerous jobs by young workers have further accentuated the needs for automation. Simple mechanization seems to have reached its limit. Automated or intelligent controls and mechanisms that can simulate subtle human tasks are now in demand. The packaging of steel products is one category of such operations. Packaging does not demand much skill of human workers, but human dexterity and delicate adjustment are necessary to wrap a large steel product with a few tens of square meter of paper and folding the paper without wrinkles. These tasks were traditionally considered difficult to automate. To improve labor productivity and reduce work load in this field, however, Nippon Steel has carried out the development of automatic packaging systems for its steel products.

This report outlines the history of development of automatic packaging systems at Nippon Steel, and describes in detail the development of automatic packaging systems for sheets and coils.

2. Nippon Steel's Challenge at Automation of Packaging

Steel products, such as sheets, coils, and wire rods, must be shipped packaged with paper, cloth, or metal to protect them against rust and damage in storage and transit. The packaging of steel products is different from that of other industrial products in the following respects:

*1 Technical Development Bureau
*2 Yawata Works
*3 Oita Works
*4 Kimitsu Works



PETC: Plant Engineering & Technology Center, Kimitsu: Kimitsu Works, Oita: Oita Works

Fig. 1 History of development of automatic steel product packaging techniques at Nippon Steel

(1) The size and weight of steel products are very large. (For example, coils measure up to 2.3 m in outside diameter and weigh up to 27 tons.)
(2) The size range of steel products is very wide. (For example, stacked sheets measure 50 to 400 mm in thickness, 500 to 1,280 mm in width, and 1,500 to 3,500 mm in length.)
(3) Steel products are packaged with various materials in various styles. (Many types of packaging materials and styles are used.)

As it was impossible to meet all these peculiar packaging characteristics of steel products with any single existing packaging machine, Nippon Steel took up the development of new packaging machines for steel products. **Fig. 1** shows the history of the company's development efforts in this undertaking. After many years of endeavor, the development of automatic packaging techniques is now complete for almost all types of steel products at Nippon Steel. A metal packaging machine[1] for strip coils is a system that has fully automated the forming, feeding, and installing of doughnut-shaped or ring-shaped metal protectors to be placed on paper-wrapped packages. The system is smoothly operating now. A new, fully automatic system for wrapping wire-rod coils first with cloth and then with paper is also complete. Its production version is now under installation.

The outer paper feeding, wrapping, and folding for coils are already automated also at other steelmakers[2,3]. On the other hand, the inner paper wrapping and metal packaging of coils, the paper packaging of sheets, and the automatic packaging of wire-rod coils have been realized by Nippon Steel for the first time in the steel industry. Nippon Steel's automatic paper packaging systems for sheets and coils are described below.

3. Technical Problems with Automatic Paper Packaging

Paper packaging must ensure seal tightness against rust and provide good appearance without wrinkles, sags, and tears. The following technical problems had to be solved in the development of automatic paper packaging systems:

(1) Development of techniques to adequately handle paper for wrapping steel products without wrinkles, sags and tears, which is larger than in conventional automatic packaging lines (for copy paper and toilet paper, for example)
(2) Development of techniques for stably handling paper with properties widely varying according to environmental conditions such as moisture and temperature
(3) Development of a packaging formula which is not a mere mechanization of manual tasks but a system best suited to automation
(4) Development of a compact and efficient installation capable of accommodating diverse product sizes and packaging styles

4. Development of Automatic Sheet Packaging System

4.1 Former sheet packaging tasks

A sheet packaging work flow is shown in **Fig. 2**. Sheets are cut to length and stacked to the shipping weight. At the next packaging line, the stacked sheets are wrapped with rust-preventive paper, enclosed with a protective metal sheet, secured to wooden skids, strapped, and labeled before they are shipped out. All these packaging steps but paper wrapping have been automated to some degree either in actual installation or in paper. Paper wrapping alone still depends on manual labor and requires the workers to work in a demanding half-rising posture, as shown in **Photo 1**. This is the area where automation was most eagerly called for.

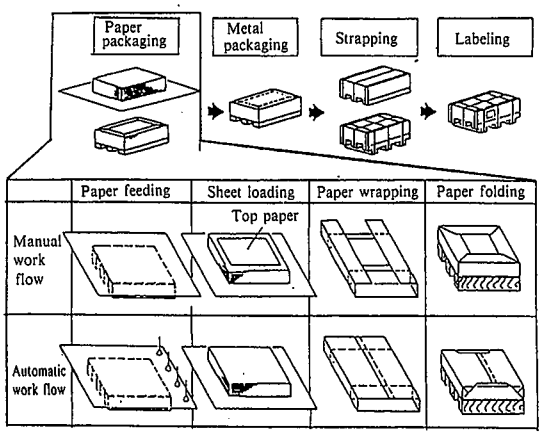


Fig. 2 Sheet packaging work flow

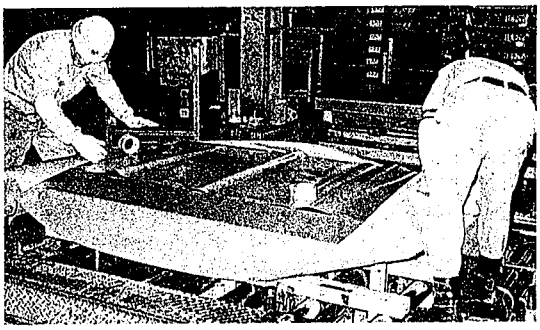


Photo 1 Paper packaging of stacked sheets by workers

4.2 Study of paper packaging method adapted to automation

In the conventional procedure relying on manual labor, top and bottom paper sheets were used, and were taped together at the top of the packages. As the conventional paper wrapping method involved many complicated steps, the new method illustrated in **Fig. 2** was devised for automatic paper wrapping. Only one sheet of wrapping paper is used to reduce the number of tasks. Paper of a given width can be used to wrap stacked steel sheets of slightly different sizes by adjusting the top flap length. This gives the additional advantage of saving the number of paper sizes to be kept in stock.

4.3 Development of paper feeding and wrapping machines

The paper feeding machine consists of pinch rolls, a cutter, and a pullout device. Vacuum pads are employed to grip the end of paper paid out from a paper roll. Operated in combination with auxiliary air blow, they can reliably grip and withdraw paper independent of the effect of paper roll set and moisture.

In the wrapping step, the paper is scooped at the front and rear with two wrapping devices and is placed around the stacked sheets by sweeping the sides and top surface of the stacked sheets while taking care not to slack the paper. The sides and corners of the stacked sheets are the same like sharp knife edges, and will tear the paper or degrade the seal performance of the paper if the paper is placed around the stacked sheets with any undue force. A brush is attached to the end of each wrapping device to softly sweep and handle the paper without tearing and wrinkling. The ends of the paper are joined more simply and faster by a hot melt than conventional adhesive tape.

4.4 Development of paper folding machine

Paper folding is divided into folding of the four corners and folding of the resultant top and bottom gussets. A Σ-shaped metal plate is inserted into the paper corner to be folded. When the stacked sheets measure as much as 400 mm in height, the paper overhang reaches 550 mm, including the overlap width, and droops down, making it difficult to fold the corners stably. As shown in **Fig. 3**, paper support cars are provided at the four corners of the stacked sheets to support the corners of the paper being folded. The paper can thus be supported securely and folded at the same time.

The top and bottom gussets are folded by the fold-down plate and fold-up device as shown in **Fig. 4**. The bulging of the gussets due to recovery is prevented by the holding bar. The holding bar is wrapped by the gussets, but can be withdrawn without disturbing the folded gussets when the stacked sheets are transferred out of the folding station. Use of a hold-up plate for the bottom gusset was tried for further simplification of the mechanism, but this only resulted in increasing the side deflection. The above-mentioned method was finally adopted to secure results that are comparable to those of manual folding (see **Fig. 5**).

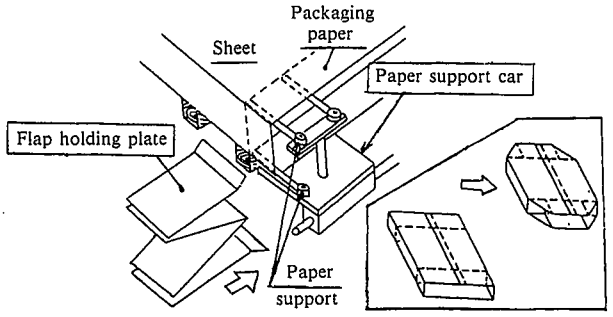


Fig. 3 Flap folding mechanism for stacked sheet side

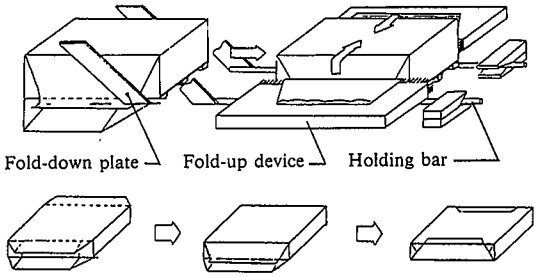


Fig. 4 Schematic illustration of paper folding work flow

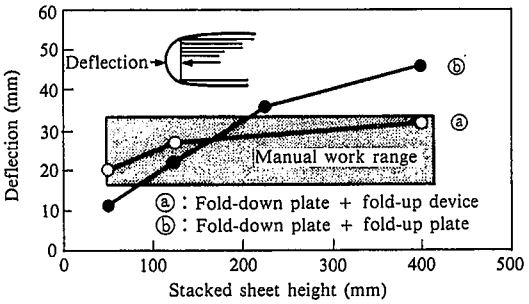


Fig. 5 Paper folding method and stacked sheet side paper deflection

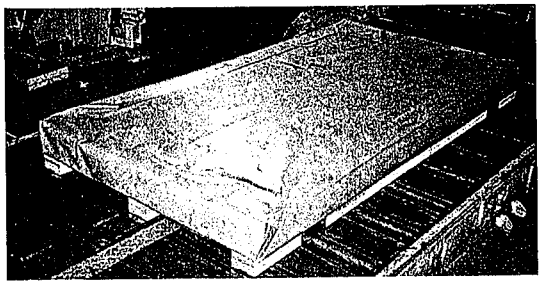


Photo 2 Appearance of sheet stack automatically packaged with paper

An unprecedentedly large sheet packaging machine that is compact and has simple motions and mechanisms was successfully developed as noted above. Sheet packages with consistently good quality can be produced, irrespective of sheet size, as shown in **Fig. 5** and **Photo 2**.

Sheet size	
Width	500-1,250 mm
Length	1,470-3,500 mm
Stack height	50-400 mm

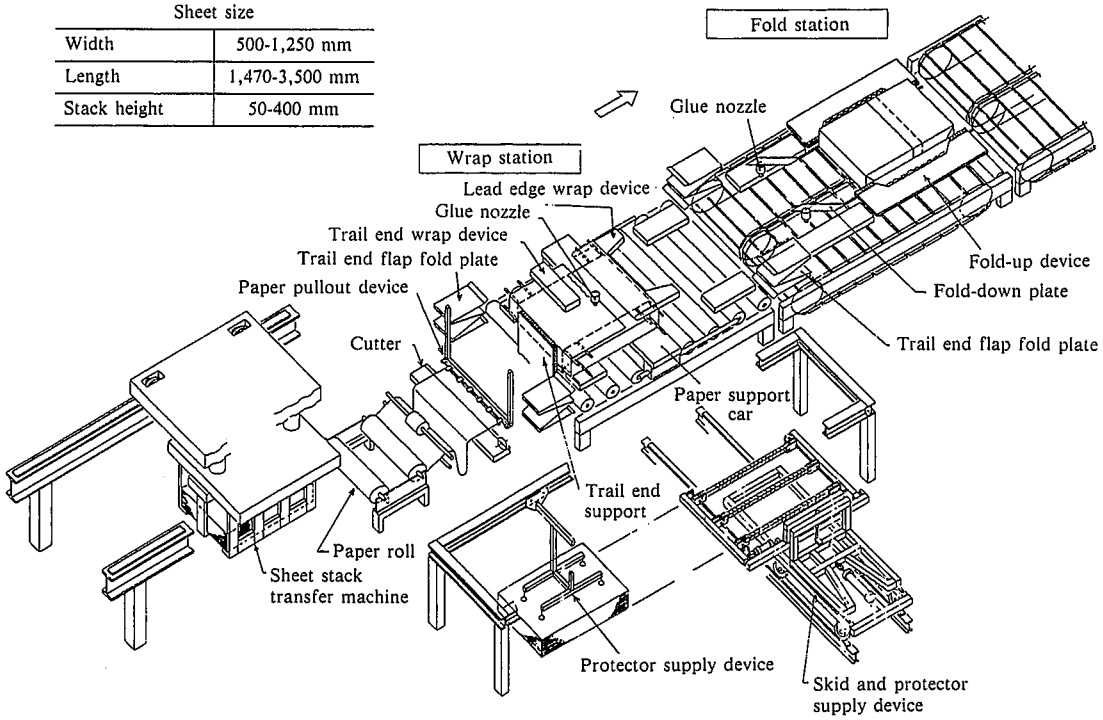


Fig. 6 Automatic sheet packaging system

4.5 Production-version system

An automatic sheet packaging system was built on the basis of the aforementioned developments. The system consists of two stations — the paper supplying and wrapping station including wooden skid and protector dispenser, and the paper folding station, as shown in **Fig. 6**. Once their size data are entered, stacked sheets can be automatically packaged, except for the transfer machine operation and protective material preparation, and can be automatically processed at intervals of about 3 min, including transfer. In June 1992, the system smoothly started up at the cold strip mill of Nippon Steel's Kimitsu Works. The packaging of sheets that was formerly performed by two workers in a demanding half-rising posture can now be performed by a single worker who is usually supposed only to enter relevant data and monitor the system operation.

5. Development of Automatic Coil Packaging System

5.1 Present coil packaging tasks

Coils were conventionally packaged with paper by hand as shown in **Fig. 7**. The outer paper packaging of coils is already automated at some steelmakers, including Nippon Steel. The wrapping and folding of the outer paper are separately performed at different stations, however. The paper is applied to the outer circumference of a coil on the wrapping machine. On the next folding machine, each end of the outer paper is pinched, gusseted, folded, and pressed with many plates. In this way, the conventional coil paper packaging method is complicated in mechanism and control. A totally new coil packaging system with simpler mechanism and control was developed.

5.2 Development of inner paper wrapping machine

A key point in the wrapping of the coil with inner paper is the degree of tightness to which the paper can be applied to the eye of the coil. From this viewpoint, an idea was conceived of

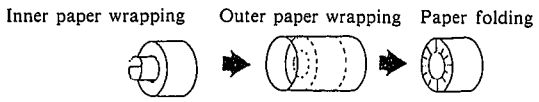


Fig. 7 Coil paper packaging work flow

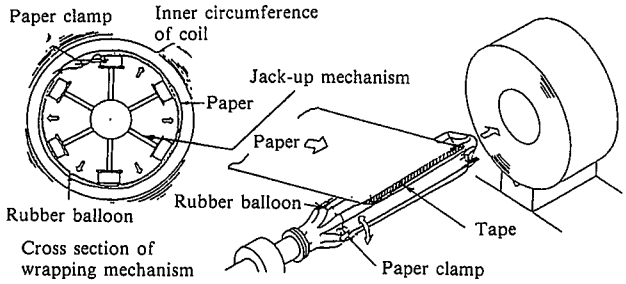


Fig. 8 Inner paper wrapping mechanism

installing the inner paper over rubber balloons and bringing the inner paper into tight contact with the eye of the coil using the air pressure of the rubber balloons.

The inner paper wrapping machine (see **Fig. 8**) is very simple in mechanism and composed of rubber balloons with jacks to suit specific inside diameters and of a paper end clamp made of rubber string to preclude interference with the rubber balloons. When the inner paper is fed to the inner paper wrapping station, the end of the paper at which a half width of the tape is already applied is automatically gripped by the clamp and wrapped around the rotating rubber balloons. After the inner paper is inserted into the eye of the coil, the clearance between the rubber balloons and the inner surface of the coil and the angular position of the clamp are set, and the clamp is disengaged. The inner

paper comes off the clamp under its own weight. The rubber balloons are inflated with appropriate air pressure to uniformly attach the inner paper to the inner surface of the coil and tape the inner paper across the width of the coil at the same time. With this very simple mechanism, the inner paper wrapping machine realized the automation of inner paper wrapping of coils for the first time in the steel industry.

5.3 Development of outer paper wrapping and folding machines

Conventional automatic outer paper wrapping and folding machines wrapped and folded the outer paper by separate devices, and were complicated in mechanism and control. Paying attention to the gussets naturally formed when the outer paper is wrapped around the coil as the coil is rotated, the authors developed a mechanism for reliably and accurately folding the gussets. The mechanism is as shown in **Fig. 9**.

The outer packaging paper formed into inverse channel shape along the transfer table is drawn by the paper feed device and fed onto the coil at the same speed as the peripheral speed of the rotating coil. The paper is tightly wrapped around the outer circumference of the coil by the pinch roll on the top of the coil and the exit guide made of artificial lawn. Since the artificial lawn guide naturally sweeps the outer circumference of the coil, no adjust mechanism is required with respect to the change in the outer diameter of the coil.

The paper gussets naturally formed by the difference of speed between the inside and outside circumferences of the coil are scooped by the gusset raising device and folded down by the press roll into a regular pattern. The brush roll imparts appropriate resistance to the outer paper and reliably produces the gussets. The gusseted and folded paper is sequentially bent into the eye of the coil along the idle rolls shown in **Photo 3** and is taped to the inner paper. The taping device is of the hold-down roll type.

The automatic coil paper packaging system is very simple in mechanism as noted above. If the rotation speed of the gusset raising device is properly adjusted, an optimum number of gussets from the point of view of coil appearance can be selected to suit the coil diameter.

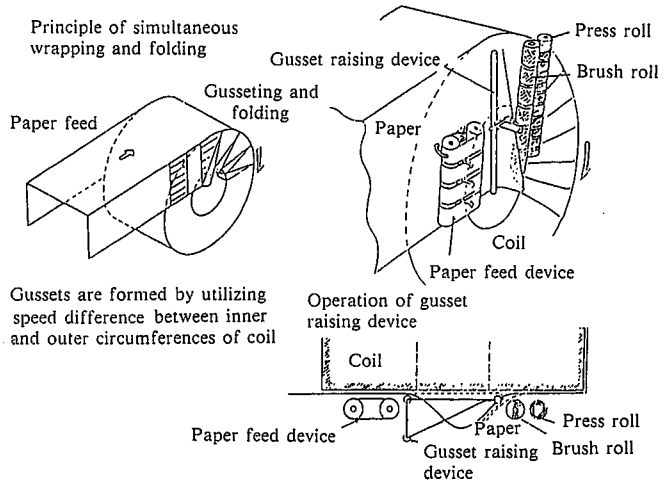


Fig. 9 Outer paper gusseting and folding mechanism

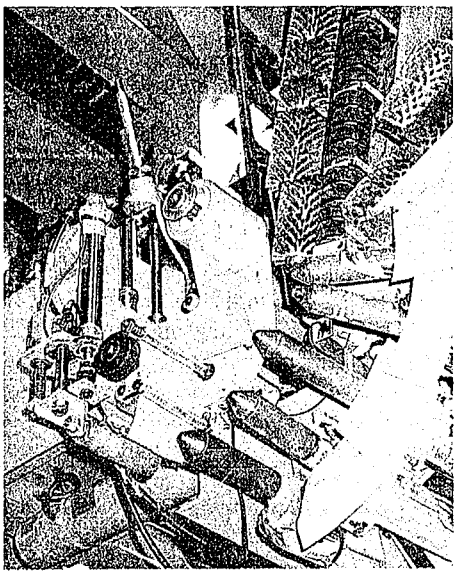
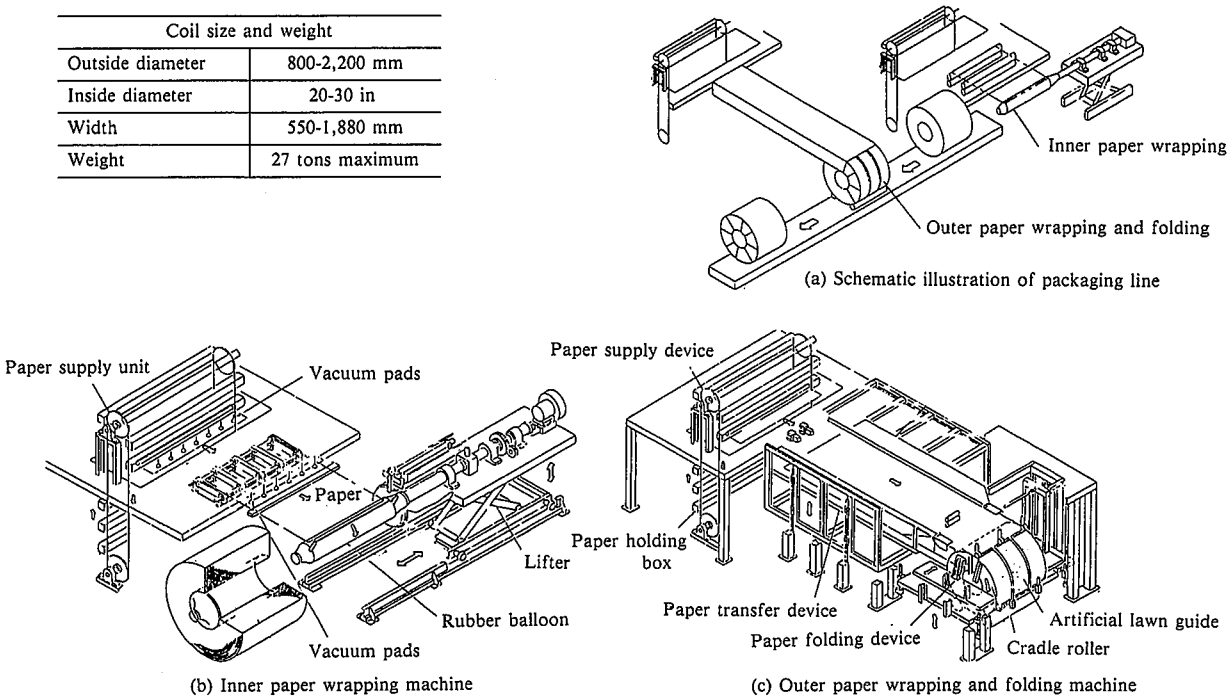


Photo 3 Inside folding rolls and taping device

5.4 Production-version system

Fig. 10 shows an automatic coil packaging system installed at the Oita Works of Nippon Steel. The equipment was installed at an existing packaging yard and brought into operation in April 1992. A coil packaged by the system is shown in **Photo 4**. If the paper required to package 30 coils is stored in the paper holding box, the system can fully automatically package coils at intervals of about 3.5 min. Even those coils with slight telescope can be neatly packaged through sensor compensation. In the present version, the paper holding box had to be used to accommodate paper preparation because of space limitation. Full automation of the system including this paper preparation is planned as a next step.

Coil size and weight	
Outside diameter	800-2,200 mm
Inside diameter	20-30 in
Width	550-1,880 mm
Weight	27 tons maximum



(a) Schematic illustration of packaging line

(b) Inner paper wrapping machine

(c) Outer paper wrapping and folding machine

Fig. 10 Automatic coil packaging system

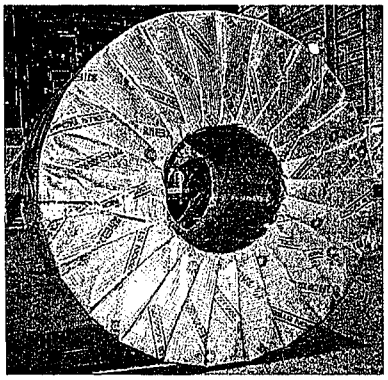


Photo 4 Appearance of coil automatically packaged with paper

6. Conclusions

Nippon Steel's efforts at automation of packaging, centering on the development of packaging systems for sheets and coils, have been introduced above. The automatic sheet packaging system is unprecedented in terms of the sheet size it handles. An automatic coil packaging system of very simple mechanism has also been realized by incorporating novel ideas. This series of development has freed workers from many arduous and monotonous tasks, and has opened the way for the automation of packaging with good package quality. Apart from packaging tasks, many dirty, difficult and dangerous jobs are still left in the steel industry. The entire Nippon Steel organization is bent upon the development of techniques to automate these tasks as well, in order to create a more comfortable work environment for its employees.

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