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Wire Rod Rolling Technology of Different Steel Grades and Sizes at a Same Time

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Abstract

Up to the present, in multi-strand wire rod mills (called "multi-strand mill" below) with a series of rolling machines through which plural strands passed, mills were generally operated by grouping the same steel grade and the same product sizes. However, with the recent strict delivery demands of customers and an environment that is progressing toward small lot, multi-sizes, the frequent roll-size changes occur and result in inevitable decreases of production capacity. Nippon Steel Corporation has modified rolling guidance equipment to allow rolling of a multiple of steel materials that have different properties, established engineering for tension control, developed a tracking system using an automatic billet number reader, and established rolling technology of different steel grades and sized of wire rod before other companies.

1. Introduction

In multiple-strand wire rod mills, the technology for rolling rods of different steels and sizes in different strands at the same time had been a dream for many years. This technology substantially improves the constraint of operation by the production of different steels in small lots and reduces the size change time, helping multiple-strand wire rod mills exploit their high productivity to the fullest. Unless this technology is established, wire rod mills with some strands alone equipped with special heat treating equipment, such as SCS (slow cool system) at the Kamaishi Works and DLP (direct lead patenting) at the Kimitsu Works, can roll rods needing such special heat treatment in only one or two strands so equipped, resulting in a productivity loss of about 30 to 50% (refer to **Fig. 1**).

Nippon Steel established this technology ahead of other wire rod manufacturers in 1983. The application rate of the technology was initially low at about 6% due to problems peculiar to the simultaneous rolling of rods of different steels and sizes in different strands and the risk of the occurrence of billets charged and rolled in a wrong sequence (hereinafter referred to as misapplied billets). The application rate was then increased to 70% as shown in **Fig. 2** by drastically improving the problems involved, such as material guidance, rolling sizes, quality, and tracking to prevent the occurrence of misapplied billets.

These problems with the simultaneous rolling of rods of different steels and sizes in different strands, and their technical solutions are described below.

2. Technology of Simultaneously Rolling Rods of Different Steels and Sizes in Different Strands

2.1 Problems with simultaneous rolling of rods of different steels and sizes in different strands

Multiple-stand wire rod mills consist of a multiple-strand rough rolling train and multiple single-strand finish rolling trains. Generally, all stands continuously roll the steel. In the multiple-strand roughing train, the steel is twisted through 90° at the exit side of a

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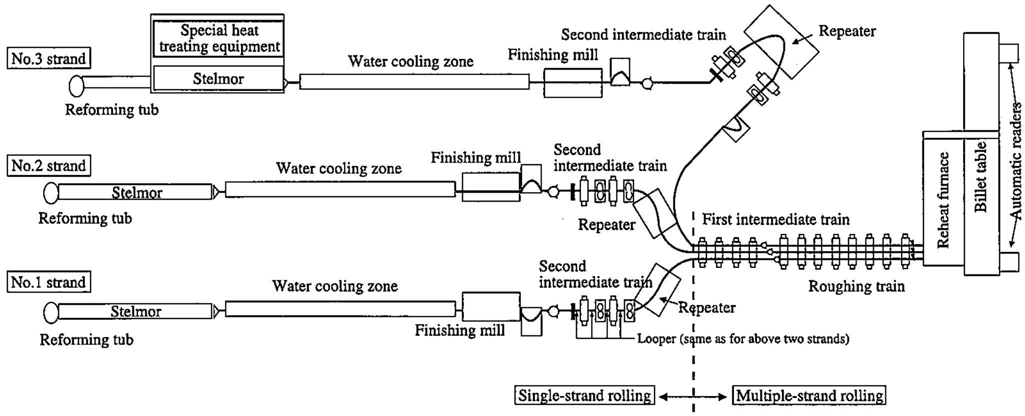

Fig. 1 Layout of multiple-strand wire rod mill

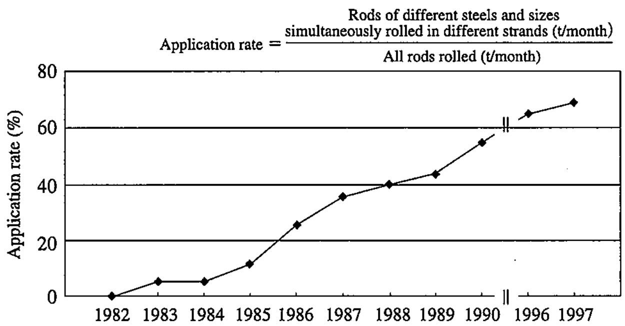

Fig. 2 Change in application rate at Kamaishi Works

Table 1 Comparison of rolling characteristics between low-carbon and high-carbon steels

Steel	Low-carbon steel	High-carbon steel
Rolling characteristics	Small deformation resistance	Large deformation resistance
	Small friction coefficient	Large friction coefficient
	Small spread	Large spread
	↓	↓
	Large elongation	Small elongation
	Small twist angle	Large twist angle

stand and guided into the next stand. Low-carbon steel and high-carbon steel, for example, greatly vary in rolling characteristics as shown in **Table 1**. When rolling steels with different rolling characteristics in this way, it is necessary to establish technology for stably guiding them and absorbing their elongation difference.

At conventional multiple-strand wire rod mills, the stands in the multiple-strand roughing train roll the billets to the same reduction in area. The mill can stably operate if the stands basically roll the same size. When the mill simultaneously rolls different sizes in different strands, it is necessary to change the reduction in area at some point in the process. This requires technology for integrating the rolling size series to roll the billets to the same reduction in area as long as possible and for eliminating the effect of rolling to different reductions in area on the dimensional variations of the rolled steel.

When rods of different steels and sizes are simultaneously rolled in different strands, billets are naturally charged separately into the reheat furnace at the same intervals. These billets must be tracked throughout the process to prevent the occurrence of misapplied billets.

2.2 Technology for simultaneously rolling rods of different steels in different strands

In simultaneous rolling of rods of different steels in different strands, steels with different rolling characteristics are rolled at the same time. As shown in **Figs. 3** and **4**, for example, low-carbon steels only need to be twisted to smaller angles because their deformation resistance is low and they are greatly elongated because their width spread is small. High-carbon steels exhibit completely opposite tendencies. The simultaneous rolling of such different steels in

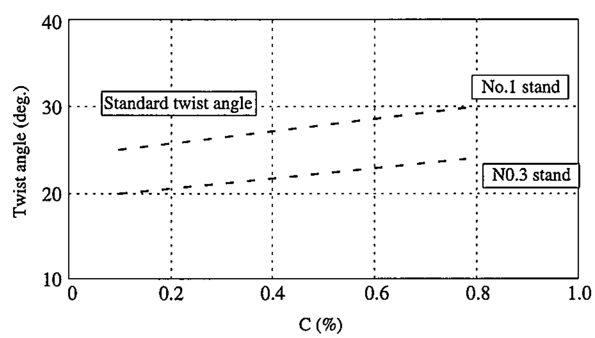

Fig. 3 Relationship between carbon content and twist angle

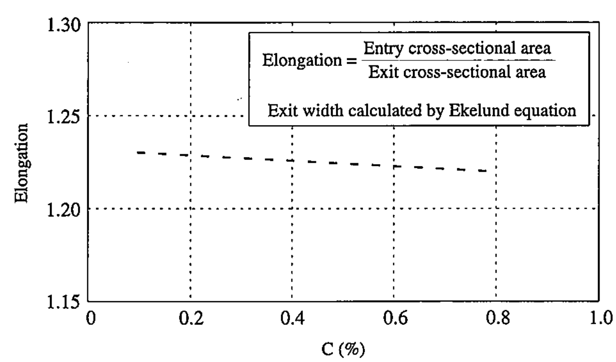

Fig. 4 Relationship between carbon content and elongation

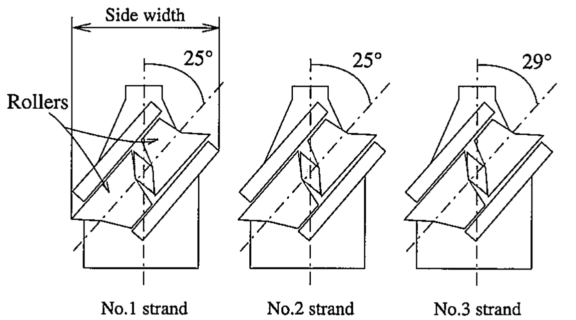

Fig. 5 Guides capable of adjusting twist angle

different strands calls for the adjustment of the twist angle in each stand and the absorption of tension variations between the stands.

To allow the twist angle to be adjusted in each stand, compact twist roller guides whose width can be held within the strand spacing as shown in **Fig. 5** were adopted. The adoption of the twist roller guides enabled the simultaneous rolling of low-carbon steel and high-carbon steel that require twist angles of 25° and 29°, respectively, in the No. 1 strand, for example.

One problem with the simultaneous rolling of different steels is the difference in their deformation characteristics like elongation. When low-carbon and high-carbon steels, for example, are simultaneously rolled, troubles are minimized by rolling with inter-stand tension in the roughing train and first intermediate mill trains that have little effect on the final rolled size. When the mill speed is adjusted to suit the low-carbon steel with large elongation, it becomes necessary to absorb the tension variations of the high-carbon steel rolled under conditions different from the conventional conditions. This requirement was met by installing repeaters between the first and second intermediate trains and loopers between the stands in each second intermediate train.

Despite the above-mentioned measures, however, small loop variations are considered to occur between the stands. Roller guides were additionally installed at the exit side of each stand to prevent the steel from being scratched or otherwise damaged in contact with the mill equipment.

2.3 Technology for rolling different sizes

Rolling different sizes in strands in caliber rolling like that of wire rods are generally performed according to a pass schedule that uses common passes for different sizes in the roughing train and different passes for different sizes in the first intermediate and subsequent trains. Because of multiple-strand wire rod mills roll multiple strands in the first intermediate train, it is difficult to roll different sizes in different strands at the same time.

Formerly, the first intermediate train with multiple strands had two series of pass schedules as shown in **Fig. 6**. These pass schedules were then consolidated to match the small size series as shown in **Fig. 7**. The reason is that if the sizes in the first intermediate train are consolidated into the large size series, the small sizes exceed the allowable reduction in area in the second intermediate and subsequent trains where they are each rolled in a single strand. If the sizes are consolidated into the small pass schedule, on the other hand, the other sizes under-fill the passes in the finishing train, making it difficult to obtain the target sizes. Attention was thus focused on the fact that the desired pass filling rate can be achieved by no-tension control between the stands.

The second single-strand intermediate train was equipped with side loopers so that it could roll the steel without tension by controlling the speed of the stand after each side looper as shown in **Fig. 8**. As a result, the pass filling rate in the second intermediate train improved by a few percent (refer to **Fig. 9**). The dimensional variations at the exit side of the second intermediate train also improved (refer to **Fig. 10**). High-accuracy diameter gages and storage CRT units to present analog displays of dimensional measurements were installed ahead of the finishing train to make reliable dimensional compensations.

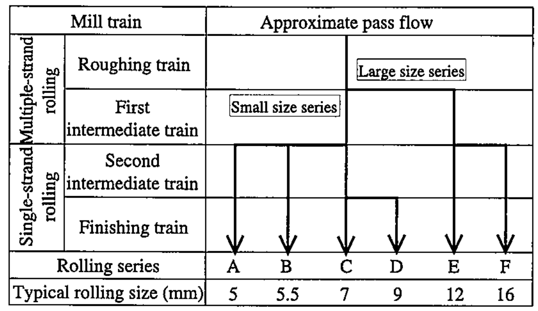

Fig. 6 Pass schedules for intermediate train before consolidation

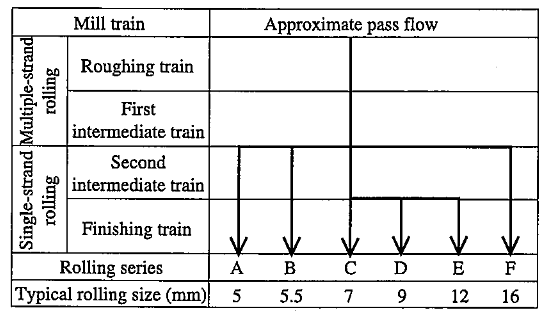

Fig. 7 Pass schedules for intermediate train after consolidation

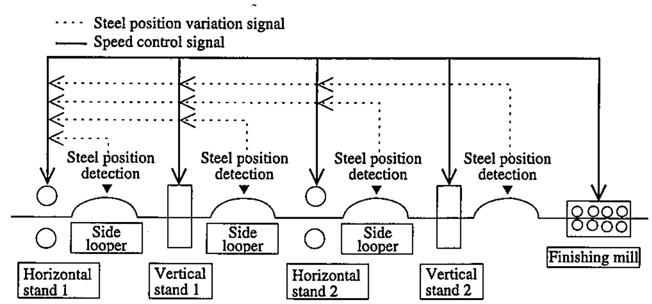

Fig. 8 Schematic of loop control

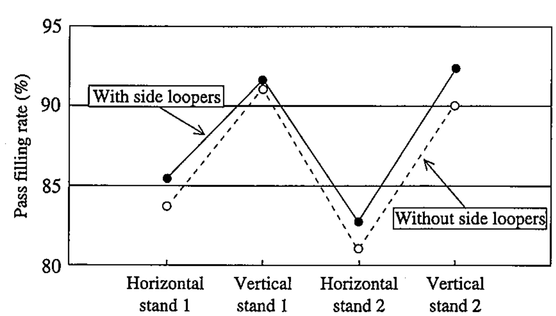

Fig. 9 Change in pass filling rate

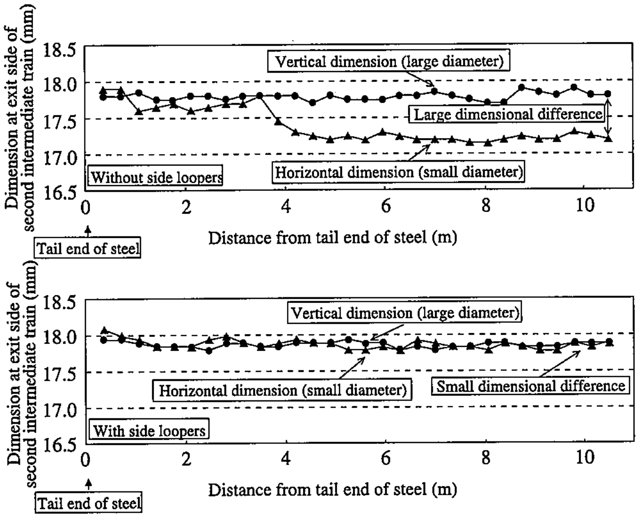

Fig. 10 Dimensional variations at exit side of second intermediate train

2.4 Check of quality assurance of unsteady-state portion

The above discussion is concerned with the steady-state portion of the steel held between the stands. In actual rolling, there also is the unsteady-state portion left free at one end as shown in **Fig. 11**. The results of simulation conducted to see how the unsteady-state portion would vary in dimension during simultaneous rolling of different steels and sizes in different strands are described below.

The simulation was performed on the rolling of 0.2%C steel to a diameter of 13 mm and 0.7%C steel to a diameter of 10 mm. Since the speed in the roughing and first intermediate trains was adjusted to suit the 0.2%C steel, the 0.7%C steel was subjected to tension

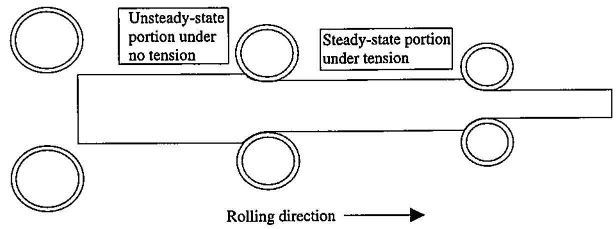

Fig. 11 Tension of steel in intermediate train

between the stands.

The inter-stand tension of the 0.7%C steel in the steady-state portion was estimated first. The results are given in **Fig. 12**. The tension ratio (stress applied to the steel in the rolling direction in Tf to the average deformation resistance Km) in the roughing and first intermediate trains was a maximum of about 0.01. This tension disappeared in the second intermediate train and finishing train.

The effect of the inter-stand tension on the transverse dimensional variations between the steady-state portion and unsteady-state portion was simulated. The results are given in **Fig. 13**. The transverse dimensional difference between the unsteady-state portion and the steady-state portion in the roughing and first intermediate trains where the steel was subjected to the effect of tension increased to about +0.10 mm. At the exit side of the second intermediate train in which the steel was rolled under no tension, this effect was almost eliminated, and the transverse dimensional difference decreased to about +0.01 mm.

The results of actual rolling performed to check the simulation results are given in **Fig. 14**. The transverse dimension at the exit side of the first intermediate train (No. 12 stand) where the steel was

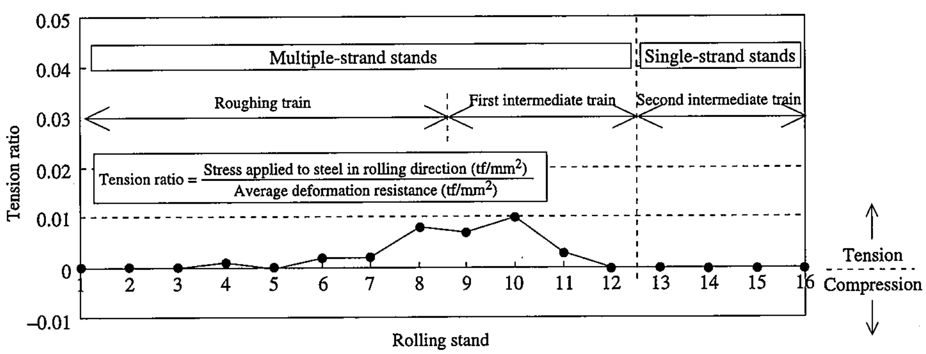

Fig. 12 Estimation of tension

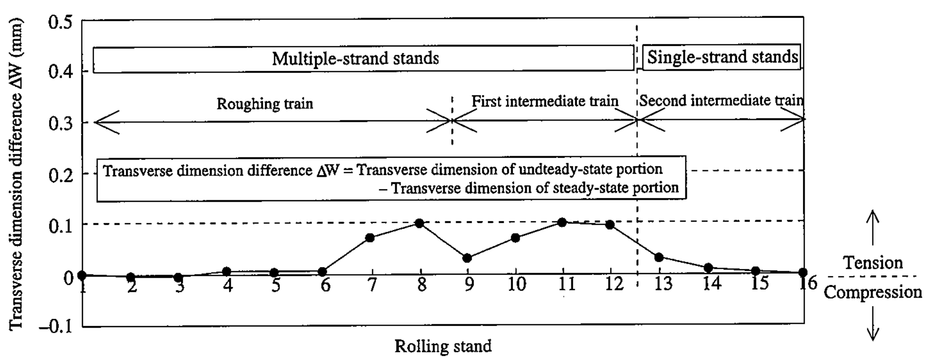

Fig. 13 Estimation of effect of transverse dimension

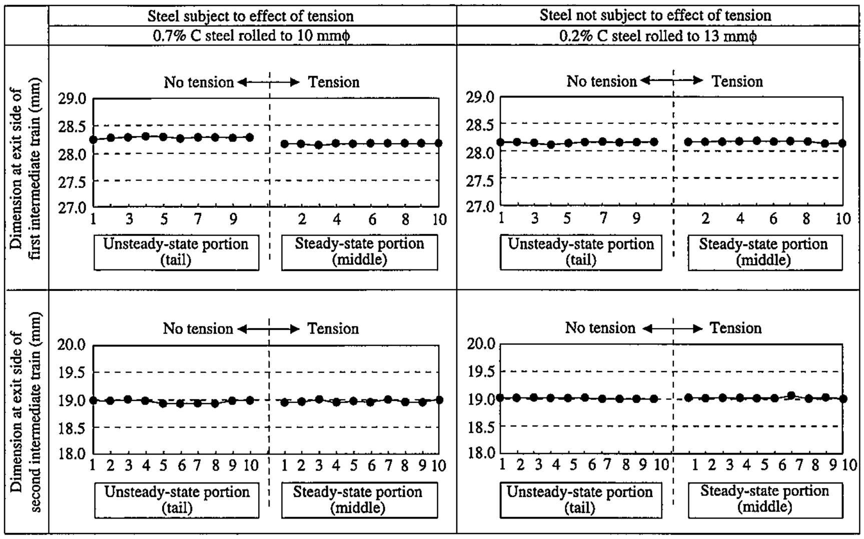

Fig. 14 Results of investigation of rolled rods

rolled under tension like in the simulation was about 0.20 mm larger for the unsteady-state portion than the steady-state portion. At the exit side of the second intermediate train (No. 16 stand) where the steel was rolled under no tension, the transverse dimension became almost the same for both the unsteady-state portion and the steady-state portion. When the final products were investigated, the unsteady-state portion was dimensionally stabilized in the second ring of the rod. This verifies the ability of the technology developed for simultaneously rolling rods of different steels and sizes in different strands to assure the same quality levels as when rods of the same steel and size are rolled in different strands.

2.5 Through-process tracking technology (prevention of occurrence of misapplied billets)

As a conventional measure for preventing the occurrence of misapplied billets during a rolling (charging) lot change, billet ends were marked or billets were greatly spaced so that the operator could visually confirm the lot change. This method is difficult to accommodate the simultaneous rolling of rods of different steels and sizes in which billets for different lots are alternately charged into the reheat furnace in such combinations as 1 billet of steel A to 1 billet of steel B, 1 billet of steel A to 2 billets of steel B, 1 billet of steel A to 3 billets of steel B, or 1 billet of steel A to 4 billets of steel B. Through-process tracking technology (refer to **Fig. 15**) was also developed to prevent the occurrence of misapplied billets with the technology of simultaneously rolling rods of different steels and sizes in different strands.

The points for preventing the occurrence of misapplied billets on which the authors focused when they developed the through-process tracking technology are described below.

(1) Tracking of billets as carried from the billet storage yard to the billet tables for charging into the reheat furnace
(2) Tracking of billets on the billet tables
(3) Tracking of billets from the billet tables to the reheat furnace

2.5.1 Tracking of billets from billet storage yard to billet tables

The automatic crane to supply billets from the billet storage yard to the billet tables of the reheat furnace receives the heat number, quantity, and position information of billets from a business computer, carries the billets, and sends the results by inductive radio to the business computer. The business computer checks the received information against the tracking information, and stores the received information as the billet table information if it is correct and outputs an abnormal warning if it is incorrect.

2.5.2 Tracking of billets on billet tables

On the billet table, the information marked at the end of each billet is automatically read, sent to the business computer, and checked against the billet table information in the business computer to prevent the occurrence of misapplied billets. A reader incorporating a CCD camera automatically reads the information marked at the ends of the specified number of billets. A sensor counts the billets so that the reader does not mistake the shadows at the ends of the billets for the clearances between the billets. The number of the billets counted is checked against the number of billets read and displayed on the CRT screen to prevent the occurrence of misapplied billets.

2.5.3 Tracking of billets from billet tables to reheat furnace

When billets are charged from two or more billet tables into the reheat furnace, the heat number, quantity, and position information of the billets are sent from the business computer to a process com-

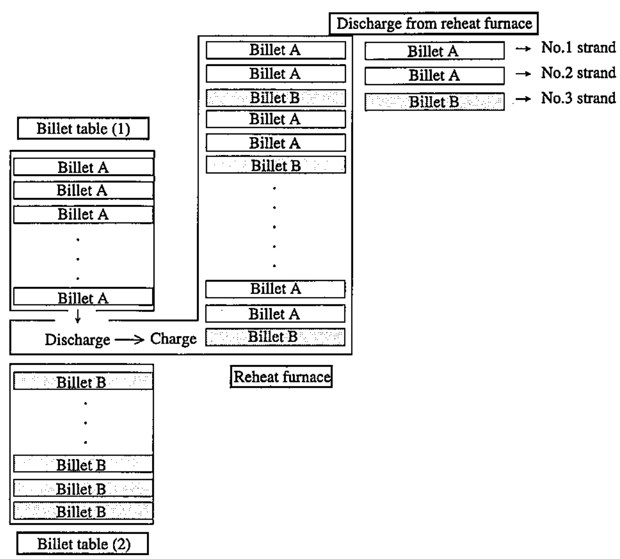

Fig. 15 Billets arranged on billet tables and in reheat furnace

puter. When the conditions are met for the billets to be discharged from a billet table, the process computer issues instructions to a sequencer to sequentially discharge the billets from the billet table. The sequencer discharges the billets from the billet table onto the charging rollers of the reheat furnace. The results are sent from the sequencer to the process computer and checked in the process computer. If the data is correct, a charge permission signal is sent to the sequencer.

As described above, the visual check tasks formerly conducted by the operator are now performed automatically and several times to prevent the occurrence of misapplied billets. An example of read data check flow diagram is given in **Fig. 16**. The above-mentioned establishment of the through-process tracking technology has allowed the automation of the complex reheat furnace charging and discharging tasks.

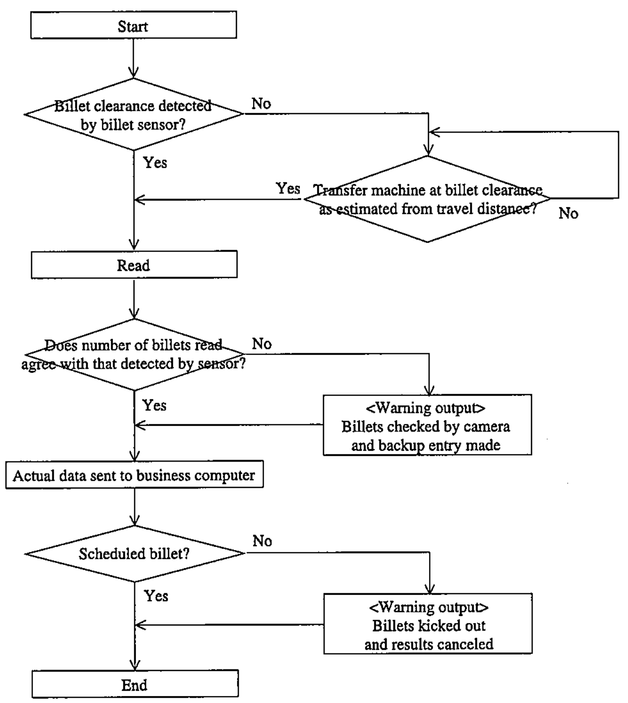

Fig. 16 Read data check flow diagram

3. Benefits of Technology for Simultaneously Rolling Rods of Different Steels and Sizes in Different Strands

The establishment of the technology for rolling rods of different steels and sizes in different strands has sharply improved the production rate of wire rod mills from conventionally low levels. The rods thus produced have the same quality levels as rods of the same steel rolled to the same size.

4. Conclusions

The technology of rolling rods of different steels and sizes in different strands has been described above. Although this technology may appear like an extension of existing technology, it is extremely difficult to simultaneously roll different steels and sizes in different strands in caliber rolling like that of wire rods. The establishment of this technology has greatly contributed to improvement in the operating rate and rolled tonnage of multiple-strand wire rod mills.

One of the future challenges is to improve the automatic reading rate of information marked on the ends of billets and to minimize operator intervention. We will work on this issue in cooperation with those concerned.