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Kazunari Takahashi, Eiichi Yokoyama, Mikio Kodaka, Masahiro Kagawa, Teruo Kobayashi, Shohei Kanari

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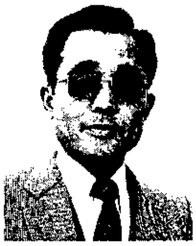
Kazunari Takahashi
Pipe Technology Sec., Manufacturing Dept., Chita Works



Eiichi Yokoyama
Staff General Manager, Pipe Technology Sec., Manufacturing Dept., Chita Works

Mikio Kodaka
Assistant Manager, Small Welded Pipe Sec., Manufacturing Dept., Chita Works

Masahiro Kagawa
Staff Deputy Manager, Equipment & Engineering Sec., Equipment Dept., Chita Works

Teruo Kobayashi
Staff Assistant Manager, Equipment & Engineering Sec., Equipment Dept., Chita Works

Shohei Kanari
Senior Researcher, Tubular Products Lab., Heavy Steel Products Research Dept., I & S Research Labs.

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1 Introduction

In the helical rolling of seamless steel pipe, fixed guide shoes have conventionally been used to control the outer diameter of the rolled shell and prevent vibration. The sliding friction of the fixed shoe and the hot shell, with which the shoe is in full contact, causes scoring and local galling of the shoe, which in turn is the source of various problems, including (1) outer surface defects of the shell, (2) lowered productivity resulting from shoe maintenance and replacement, and (3) increased unit cost of shoes. In recent years, with the continuing growth in demand for high value added products such as high-alloy steels, the solution of these problems has become an urgent matter.

Various measures have been studied, including reduction of the guide shoe load,[1] improvement of the shoe shape and/or material, and cooling of the shoe, but these solutions have proved inadequate. As a fundamental solution, the substitution of rolling friction for sliding friction, with a resultant reduction in relative sliding friction, is often proposed.

One such method is the rotary disk guide shoe. However, the effectiveness of the disk shoe in reducing sliding friction is slight and very large disks must be used when rolling large-diameter pipe (as at 16-inch-plug mill at Kawasaki Steel's Chita Works). In addition, large-scale equipment is required for size-changing.

On the other hand, with a roller guide shoe, a major reduction in sliding friction is possible with relatively small-scale equipment. In one embodiment of this concept (which has not yet been commercialized), a number of idle rollers are installed on either side of the main rolls.[2,3]

In contrast to these methods, Kawasaki Steel has developed a new-type of drive roller guide shoe. In this device, drive roller shoe (DRS), a pair of rollers to which driving force is applied, are provided at the sides of the main rolls, and guide plates are installed in the clearance between the main rolls and drive rollers. The drive roller shoe has been put into commercial operation with the elongator at the Medium Diameter Seamless Pipe Mill,[4,5,6,7] at Chita Works, and is the subject of this report.

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2 Features of Various Kinds of Guide Shoes

Schematic diagrams of the conventional fixed shoe and disk shoe[8] and the recently developed drive roller shoe are shown in **Fig. 1**. **Table 1** shows the results of a comparison of the relative velocity of the hot shell and the respective guide shoes in elongator rolling.

While the fixed shoe is in contact with the hot shell at a high sliding friction, the drive roller shoe, in which the shoes are replaced by the rollers, shows a marked

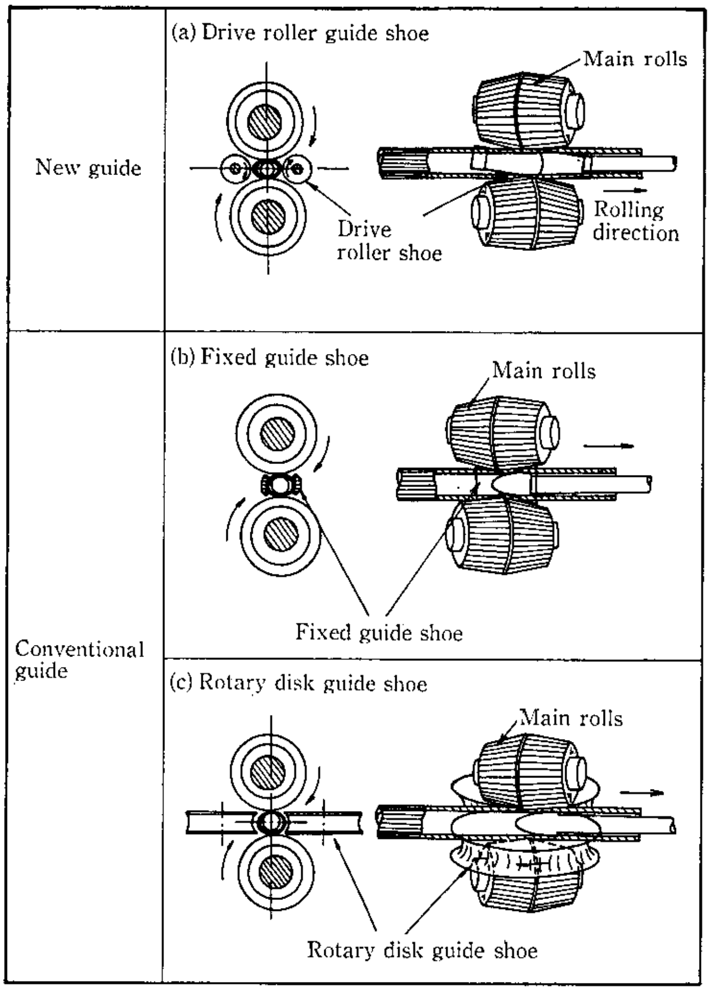
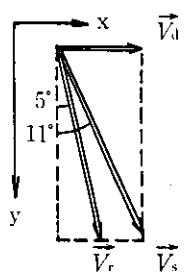


Fig. 1 Schematic diagrams of new roller guide shoes and conventional guides for cross helical rolling mill

Table 1 Relative velocity between shell and shoe in elongator rolling

Type of guide shoe	Direction	Index of relative velocity	
Drive roller	x	$0.55\,(\lvert\vec{V}_s-\vec{V}_r\rvert/\lvert\vec{V}_s\rvert\sin 11^\circ)$	 x : Longitudinal direction y : Circumferential direction $\vec{V}_s$: Velocity of shell $\vec{V}_r$: Velocity of drive roller shoe $\vec{V}_d$: Velocity of rotary disk shoe 11°: Main roll feed angle 5°: Roller shoe feed angle
	y	0	
	Total	$0.10\,(\lvert\vec{V}_s-\vec{V}_r\rvert/\lvert\vec{V}_s\rvert)$	
Fixed	x	1.00	
	y	1.00	
	Total	1.00	
Rotary disk	x	0	
	y	$1.00\,(\lvert\vec{V}_s-\vec{V}_d\rvert/\lvert\vec{V}_s\rvert\cos 11^\circ)$	
	Total	$0.98\,(\lvert\vec{V}_s-\vec{V}_d\rvert/\lvert\vec{V}_s\rvert)$	

decrease in sliding friction. This is because friction in the circumferential direction, which accounts for the greatest part of sliding friction, has been markedly decreased. Further, since the contact surface between the hot shell and shoe changes continuously with the drive roller shoe, the decrease in mechanical strength accompanying the local temperature rise at the shoe surface is suppressed, preventing scoring and local galling.

In rotary disk guide shoe, although the contact surface between the hot shell and the disk shoe also changes continuously, sliding friction in the circumferential direction still remains. The decrease in friction, with the disk shoe, therefore, is not sufficient to represent a solution to the fundamental problem.

3 Composition of Drive Roller Shoe Equipment

A layout of the roller shoe equipment is shown in **Fig. 2**; the main rolls are omitted from the diagram. Roller shoes are positioned at the right and left of the main rolls, which are arranged top and bottom in the actual equipment. The roller shoes are driven by motors, installed at the outlet side of the rolling mill via a drive train comprising a ball joint and transmission gear. The shoe base to which the roller shoe is secured is arranged to open and close in the right and left directions when the swing block is rotated in its entirety. The shoe base and roller shoe are changed as a unit.

Specifications of the drive roller shoe are shown in

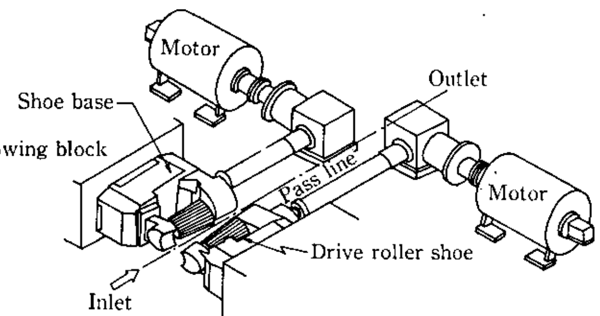


Fig. 2 Schematic illustration of drive roller shoes

Table 2 Specifications of drive roller shoe for industrial use

Roller dia. (mm)	ϕ 195, ϕ 260, ϕ 350, ϕ 425
Roller feed angle (deg)	5°
Roll material	SCM 435
Drive	D.C. motor 110 kw
Shell dia. of before rolling (mm)	ϕ 185 ~ ϕ 378
Shell dia. of after rolling (mm)	ϕ 199 ~ ϕ 433

Table 2. Roller shoe diameters D_S, used in rolling pipe sizes 7″ to 16¾″ at the Medium Diameter Seamless Pipe Mill, are 195, 260, 350 and 425 mmϕ, based on the following three points:

(1) When the minimum gorge E and minimum shoe distance H are set during the rolling of various sizes, no interference should occur between the roller shoes and the rolling rolls.
(2) To minimize the clearance between the roller shoes and the rolling rolls, the roller shoe diameter should be as large as possible.
(3) Common use of the roller shoe should be promoted as far as possible for rolling multidiameter pipes.

The roller shoe has a 5° feed angle, and is driven by a DC motor in consideration of controllability and maintainability.

4 Problems in the Present Guide System and Their Solutions

In rolling with roller shoes, both ends of thin-walled hot shells are liable to suffer plastic collapse and deform into flare shapes. When the flare protrudes into the clearance between the roller shoes and the rolling rolls, it may cause sticking and pipe-end cracking. In the application of the drive-roller-shoe concept to the commercial rolling mill, the solution of this problem was an important point. This paper describes the results of installing a guide plate in the clearance between the roller shoes and the rolling rolls, and of an experimental investigation of the effect of the driving force of the roller shoe.

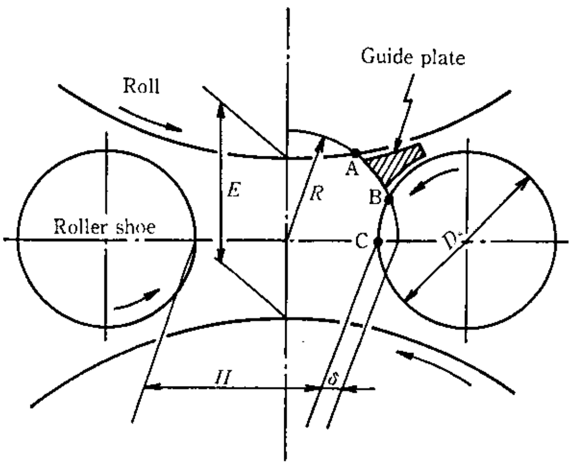
4.1 Introduction of Guide Plate

4.1.1 Design of guide plate

The guide plate was designed for pipe sizes 7″ to 16¾″ in consideration of the following two points:

(1) No interference should occur between the guide plate, the rolling roll, and the roller shoe **(Fig. 3)** when the minimum gorge E and minimum shoe distance H are set for each rolling of various sizes.
(2) On the basis of investigation of the sticking condition of hot shell and the shape of pipe-end flares, the device is so constructed that only the flare portion of the thin-walled hot shell will come into contact with the guide-plate, and the other rolled portion will not **(Fig. 4)**.

Contact between the guide plate and the hot shell being rolled occurs only briefly at the pipe end, minimizing scoring and wear of the guide plate. Further, even if surface defects occur on the hot shell outside-surface due to scoring, this portion will be removed as crop, eliminating the problem as a practical consideration.



E : Minimum of gorge
H : Minimum of shoe distance
D_s : Diameter of roller shoe
R : $H/2+\delta$
$\overset{\frown}{AB}/\overset{\frown}{BC}$ = Const $\rightarrow \delta$

Fig. 3 Sectional view of drive roller shoes

4.1.2 Flare prevention effect of guide plate

Pipe-end flare becomes more conspicuous as the reduction of hot shell wall thickness becomes greater and as the ratio of wall thickness to the outside diameter of the hot shell becomes smaller. Further, the tail end is more liable to develop flaring than the leading end. An example of the prevention of tail end flaring by the guide plate in elongator rolling with the roller shoe is shown in **Photo 1**, which indicates that the use of the guide plate prevents flare generation and results in a satisfactory pipe-end shape.

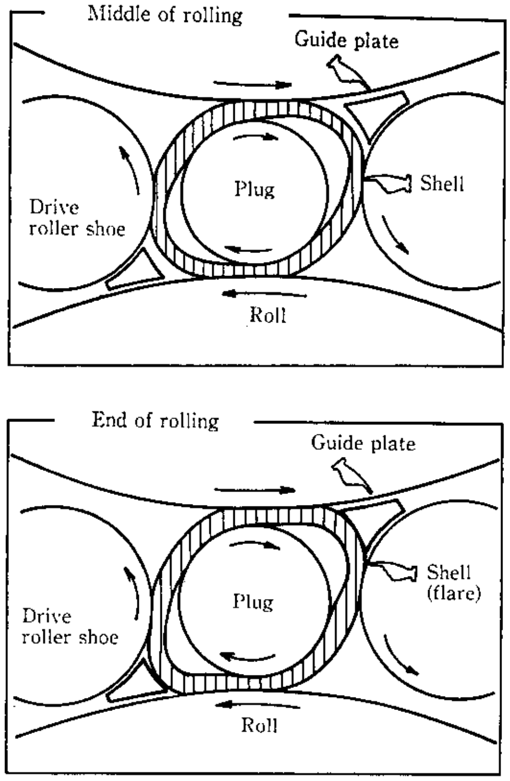


Fig. 4 Layout of guide plate

4.2 Driving Force Control

4.2.1 Concept of driving force

Deformation of the shell in elongator rolling is shown in **Fig. 5**. The roller type shoe comes in contact

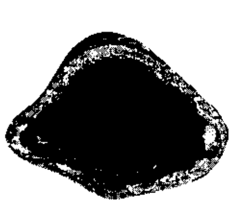
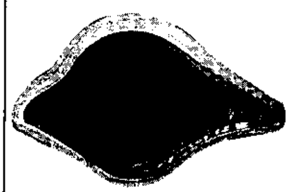
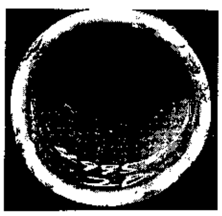
Rolling condition \ Shell size (mm)	Before rolling ϕ 185 × 23.4 t After rolling ϕ 199 × 15.1 t	Before rolling ϕ 185 × 19.1 t After rolling ϕ 199 × 10.2 t
Drive roller shoe without guide plate		
Drive roller shoe with guide plate		

Photo 1 Effect of guide plate on flare at rolling end

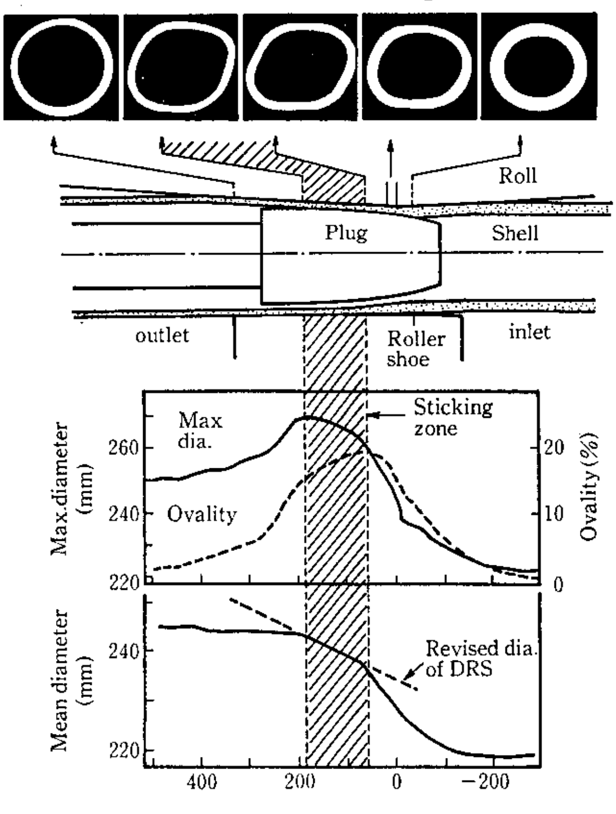


Fig. 5 Schematic diagram of deformation of the shell during elongator rolling

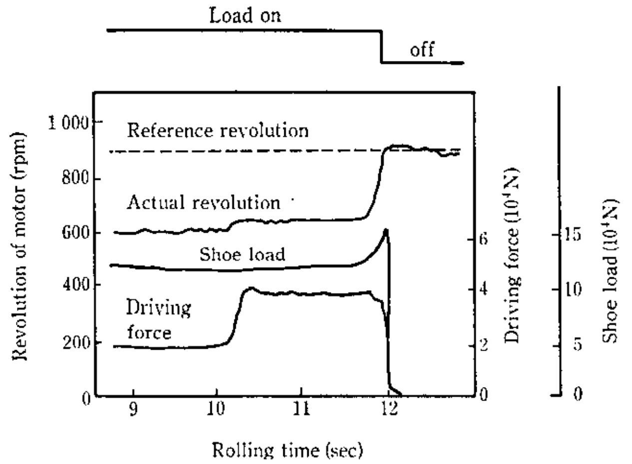


Fig. 6 Revolution control of drive roller shoes

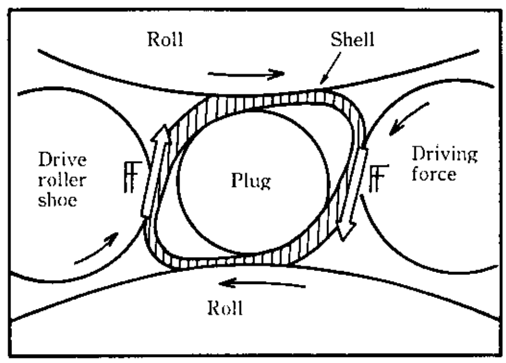


Fig. 7 Driving of drive roller shoes

with the hot shell with a low degree of sliding, and, as a result, in the area where the hot shell is most widely expanded, namely, the area where the load applied from the hot shell to the roller shoe is supposed to be greatest, the roller shoe is considered to be in contact with the hot shell in a state of sticking friction. This can be surmised from the fact that the ratio of driving force to roller shoe load, i.e., the coefficient of friction, has reached a value of 0.2 or above (**Fig. 6**).

An example of tail end control by the roller shoe is shown in Fig. 6. To prevent the application of torque to the hot shell in the direction reverse to the rotation direction, the reference revolution of the roller shoe is set at a relatively high value so that the circumferential velocity of the roller shoe is faster than the predicted circumferential velocity of the hot shell. On the other hand, the actual revolution of the roller shoe during rolling is lower than the reference revolution, indicating that the roller shoe is in a state of synchronized rotation with the hot shell.

As shown in **Fig. 7**, therefore, the drive roller shoe, while rotating in synchronization with the hot shell, applies a preset driving force F by way of tension. This driving force is most effectively transmitted while the hot shell and the roller shell are in synchronized rotation in a condition of sticking friction.

4.2.2 Flare suppression effect of driving force

Photo 2 shows a comparison in pipe end shape after rolling when the driving force is changed in a model mill without guide plates. The results indicate that the application of driving force has the effect of suppressing flare.

The flare generation index of the commercial drive roller shoe fitted with guide plates is shown in **Fig. 8**. At a driving force of 0, flaring occurs, but with the application of even slight driving force, flaring can be consistently prevented.

The relation between the driving force and guide plate abrasion is shown in **Fig. 9**. As driving force is increased, guide plate abrasion is markedly reduced. Since flare is a cause of guide plate abrasion, this further demonstrates that the application of driving force has a flare suppression effect.

5 Operation Condition

5.1 Shoe Scoring

If rolling with the roller shoe is adopted, sliding fric-

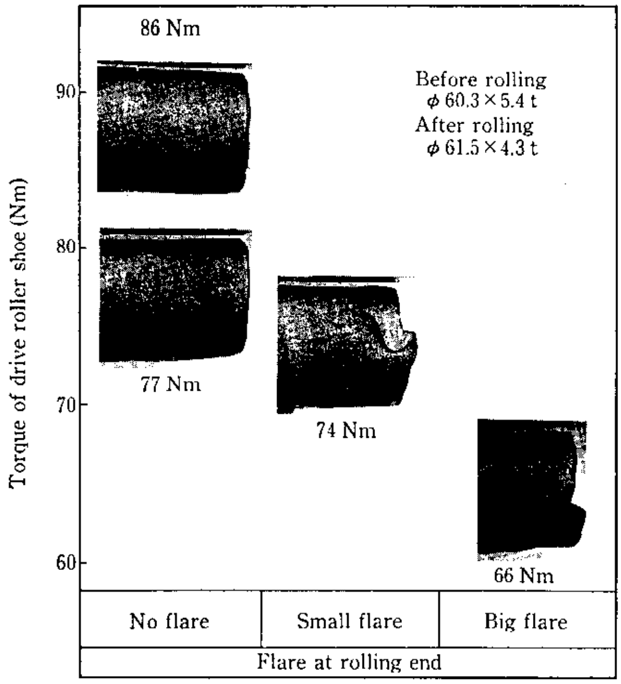


Photo 2 Effect of driving torque on flare of shell at rolling end

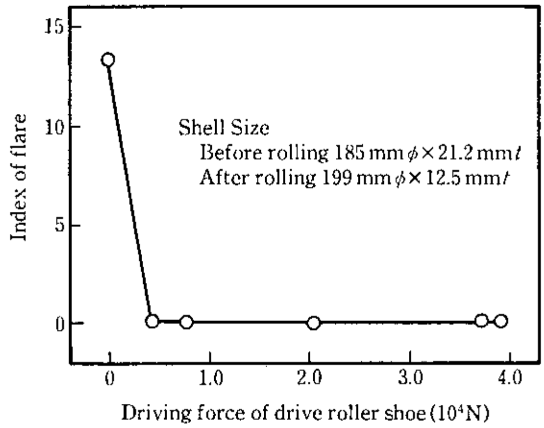


Fig. 8 Effect of driving force drive roller shoe with guide plate on flare of shell

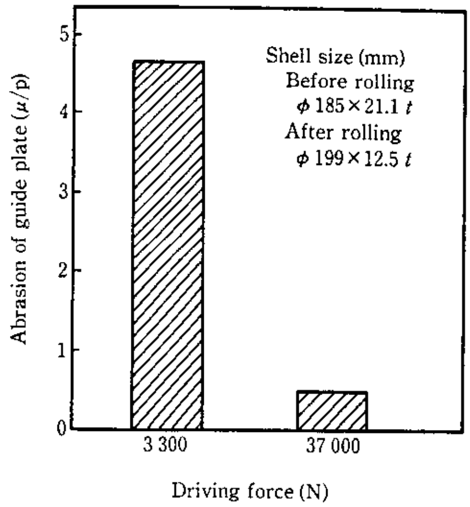


Fig. 9 Effect of driving force on abrasion of guide plate

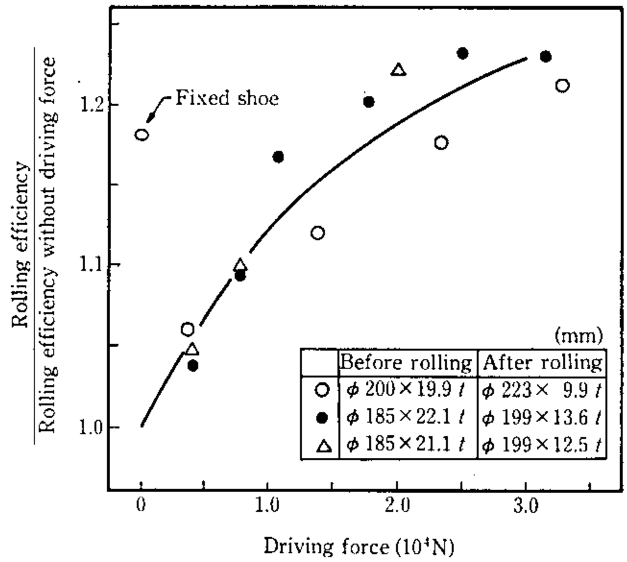


Fig. 10 Relation between driving force of drive roller shoes and rolling efficiency

tion between the hot shell and the shoe is significantly reduced over the entire length of the hot shell, excluding the two ends. In alloy steel rolling, it is also possible to suppress scoring and prevent the generation of shoe marks. Compared with operation with the fixed shoe, the downtime ratio for shoe maintenance and replacement has dropped to 1/5 and the shoe-mark degradation ratio has dropped to 1/8 with the roller shoe adopted. All rejects in recent operation have been caused by piercer defects.

5.2 Rolling Efficiency

The relation between driving force and rolling efficiency is shown in **Fig. 10**, which indicates that roller shoe driving force is contributing significantly to the improvement of rolling efficiency.

5.3 Eccentricity

The relation between the driving force of the drive roller shoe and eccentricity is shown in **Fig. 11**. When driving force is slight, eccentricity tends to increase, but as driving force is increased, eccentricity improves to the same level as when the fixed shoe is used.

6 Economical Effects

As mentioned above, application of the drive roller shoe to the elongator has had the following results:

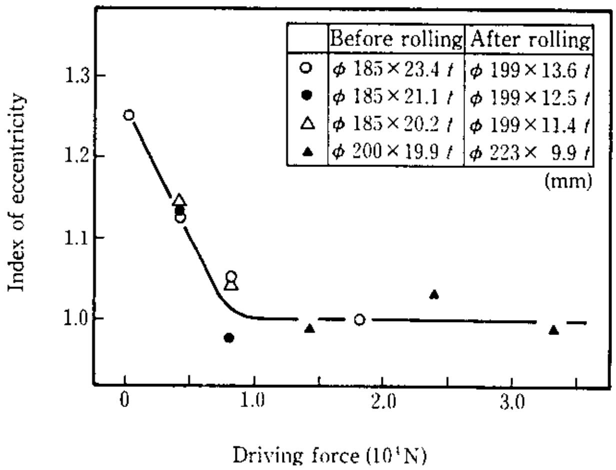


Fig. 11 Relation between driving force of drive roller shoes and eccentricity

Table 3 Results of operation with drive roller shoes (ratio to fixed shoes)

	1% Cr steel ($8\frac{5}{8}''\times 6.5$ mm$l$)	13% Cr steel ($9\frac{5}{8}''\times 11.99$ mm$l$)
Shoe cost at elongator	0.09	0.09
Shoe mark at elongator	0	0
Productivity	1.33	2.10
Outside surface defects	0.23	0.30

(1) The number of defects on the shell surface due to shoe scoring and local friction has decreased, resulting in improved yield and a decrease in the incidence of defects repairs.

(2) Productivity has improved as the need for shoe repairs and replacement has been eliminated.

(3) The unit cost of shoes has been reduced.

The advantages of the drive roller shoe relative to the fixed shoe are shown in **Table 3**, which indicates a remarkable effectiveness with alloy steel. In the future, the roller shoe is expected to make a significant contribution to the establishment of a system which will ensure increased-volume production of high value added products such as high-alloy steels.

7 Conclusions

To solve problems arising from scoring of the fixed shoes used in the cross helical rolling mill, a drive roller type guide shoe (DRS) has been developed and applied at the Medium Diameter Seamless Pipe Mill at Chita Works. The results of this development are summarized below.

(1) The drive roller shoe consists of driven roller shoes, a drive unit system, and a guide plates inserted into the clearance between the roller shoes and the main rolls.

(2) Through the combined use of guide plates and application of driving force by the roller shoes, it has become possible to significantly reduce the sliding friction between the shoes and hot shell and to prevent flaring at both ends of the shell.

(3) The driving force applied to the roller shoes is effective in the suppression of flare at both ends, improvement of rolling efficiency and of eccentricity.

(4) In comparison with the conventional fixed guide shoe, remarkable improvements in product quality, productivity, and the unit cost of shoes have been realized in commercial operation with the drive roller shoe, especially in alloy steels production.

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