"HC MILL"

ITS PRINCIPLES AND APPLICATIONS

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Abstract

The HC mill (High Crown Control Mill) is a new type mill aimed at drastically improving performance to control the shape (flatness) of strip in strip rolling, resulting in the improvement of plant and operational efficiency. The HC mill is a 6 high mill in which upper and lower intermediate rolls between the work rolls and back-up rolls are positioned so as to shift in their respective axial directions, opposite to each other. Several HC mills are already in operation for ferrous and non-ferrous strip rolling including two large-scale reversing HC mills. One of them was revamped from a 4 high mill and the other claims the world's highest rolling speed (1,200 m/min) as a reversing mill. Additionally, a 6 stand tandem cold strip mill with the world's highest rolling speed (2,500 m/min) has been revamped in the last stand from a 4 high mill to an HC mill. Through actual operation of those HC mills, good shape controllability and other advantages have been confirmed as well as full reliability for commercial operation. Moreover, new applications and techniques of this mill for strip rolling have been examined and developed which could never have been expected for conventional mills. This paper describes the principles, shape controllability and other advantages, operating data and applications of the HC mill in cold rolling and skin pass rolling.

List of Symbols

H_1 =	entry thickness of strip	mm
H_2 =	delivery thickness of strip	mm
r =	reduction, $r = (H_1 - H_2)/H_1$	-
B =	strip width	mm
C_h =	strip crown	mm, μm
P =	rolling load	metric ton
F =	work roll bending force	metric ton
F_o =	optimum work roll bending force (bending force necessary to produce flat strip shape)	metric ton
δ =	intermediate roll position as defined in Fig. 4	mm
L =	barrel length of work roll	mm
L_B =	effective barrel length of back-up roll	mm
C_W =	diametral initial crown of work roll	mm
λ =	wave steepness of strip	per cent

1. Introduction

Along with gage accuracy, strip shape is one of the most important factors in determining the quality of rolled products. Attainment of improved strip shape increases both productivity and product quality, and for these reasons it is desirable to use a mill which is capable of broadly controlling shape as required (large shape adjustability), and does not deteriorate the shape even under changes in rolling conditions (good shape stability). The performance of conventional mills is not satisfactory in these respects.

In order to solve these problems, a new 6 high cold rolling mill, the HC mill, has been developed by Hitachi, Ltd. The large shape adjustability and the good shape stability of this mill were initially verified by theoretical analysis and by test mill experiments. After this, a cooperative study between Nippon Steel Corporation and Hitachi, Ltd. was carried out on the practical use of the large scale HC mill installed at the Yawata Works of Nippon Steel Corp. The superior operating efficiency and productivity of the HC mill compared to 4 high mills, were proven. The operating rate of this HC mill is, at present, more than 90%.

A cold reversing HC mill with a maximum rolling speed of 1,200 m/min. was installed at the Funabashi Works of Taiyo Steel Co., Ltd. At startup in August 1976, it attained a rolling speed of 1,200 m/min., the first in the world for a cold reversing mill. At present, it continues to produce approximately 30,000 tons of strip, inclusive of thin gage, a month.

Furthermore, the 6 stand tandem cold strip mill with the world's highest rolling speed of 2,500 m/min. at the Kimitsu Works of Nippon Steel Corp. has been revamped in the last stand from a 4 high to an HC mill. After very short downtime for revamping, this tandem mill resumed operation smoothly at the end of 1977. Several HC mills, including the above, are now in operation for both ferrous and nonferrous products, and several more are under manufacturing at Hitachi, Ltd.

Recently, Hitachi delivered an HC mill -- the first large-scale HC mill for skin pass rolling -- to USIMINAS, Brazil.

2. Problems in Shape Control with 4 High Mills

The most widely used rolling mill at present is a 4 high mill, which allows free selection of the diameter of work rolls for rolling strip and the diameter of back-up rolls for bearing rolling load. Compared with a 2 high mill, a 4 high mill has the advantage of using smaller diameter work rolls in compliance with rolling requirements, and larger diameter back-up rolls to increase rigidity to cope with roll deflection. Increasing the diameter of the back-up rolls, however, does not necessarily enhance rigidity against work roll deflection because, under actual rolling conditions, considerable deformation occurs at the contact surfaces between the back-up rolls and work rolls. One method of compensating for work roll deflection is using work rolls provided with an initial crown. Also, in order to control work roll deflection as required, the work roll bending method has been developed. This roll bending method, however, does not offer sufficient control capability due to limitations in the strength of roll neck sections, and, therefore, use of rolls with initial crown suitable for the rolling conditions is unavoidable. These are the problems in shape control with the 4 high mill.

From the analysis of roll deflection with the 4 high mill, it was found that there exist undesirable contact portions (A) between work rolls and back-up rolls outside the rolling material as shown in Fig. 1; work rolls are bent excessively by the force generated at the undesirable contact portions (A), and therefore the amount of work roll deflection depends on not only rolling load but also strip width. Moreover, the roll bending force applied to control the work roll deflection has only limited effect due to restriction by the back-up rolls at undesirable contact portions (A).

To overcome these problems, it is best to remove the undesirable contact portions (A). The HC mill does this.

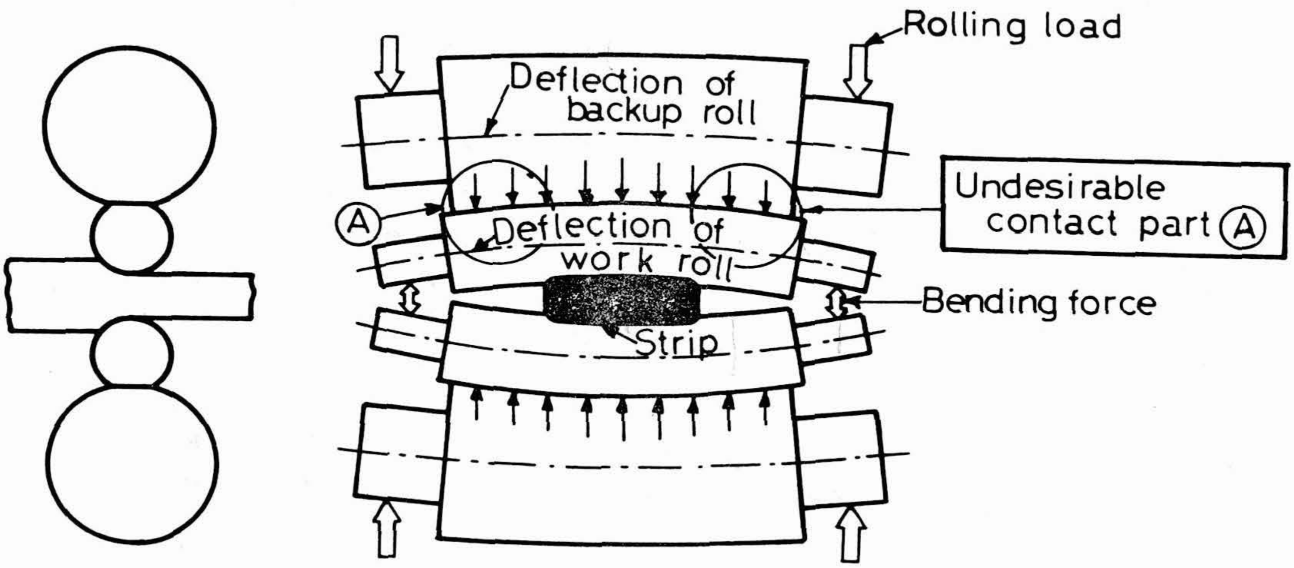


Fig 1 Deflection of rolls in 4 high mill

3. Principles

A 4 high mill with back-up rolls from which undesirable contact portions (A) are eliminated is shown in Fig. 2. With stepped back-up rolls as shown in Fig. 2, the change "ΔC_h" in the strip crown which may correspond to the change in the strip shape becomes considerably smaller compared to that of a conventional 4 high mill, as shown in Fig. 3(a), because of the minimal change in work roll deflection even though the change "ΔP" in the rolling load takes place. This proves that, with the conventional 4 high mill, the pressure at contact portion (A) causes excessive work roll deflection.

Fig. 3(b) shows the change "ΔC_h" of the strip crown in relation to the change "ΔF" in roll bending force. The effect of roll bending force is larger with stepped back-up rolls. As described above, considerable effect can be obtained by eliminating the undesirable contact portion (A) .

However, there is still a problem with stepped back-up rolls where frequent roll changes are required for various strip widths. The HC mill, as described below, has solved this problem. The outline of the HC mill is shown in Fig. 4. By providing upper and lower intermediate rolls between the work rolls and back-up rolls, and by shifting these intermediate rolls in opposite directions, the roll edge can be set at an arbitrary point " δ " in compliance with the strip width. Thus, with the HC mill, undesirable contact portions Ⓐ can be eliminated.

Shown in Fig. 5 are photographs of the HC mills at the Hitachi Research Laboratory of Hitachi, Ltd., at the Yawata Works of Nippon Steel Corporation, and at the Funabashi Works of Taiyo Steel Co., Ltd. Table 1 shows the specifications of these mills.

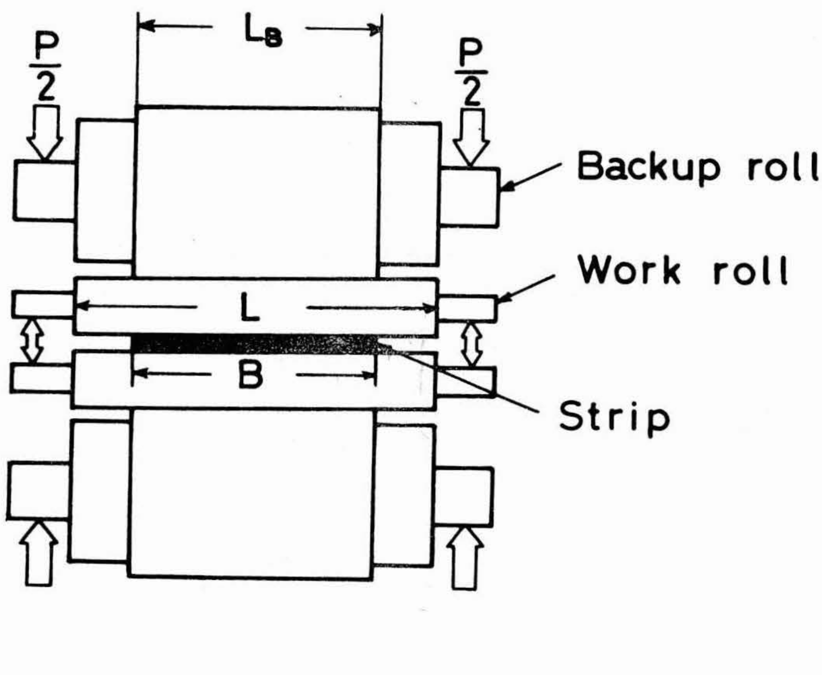


Fig 2 4 high mill with backup roll of which barrel length is equal to strip width

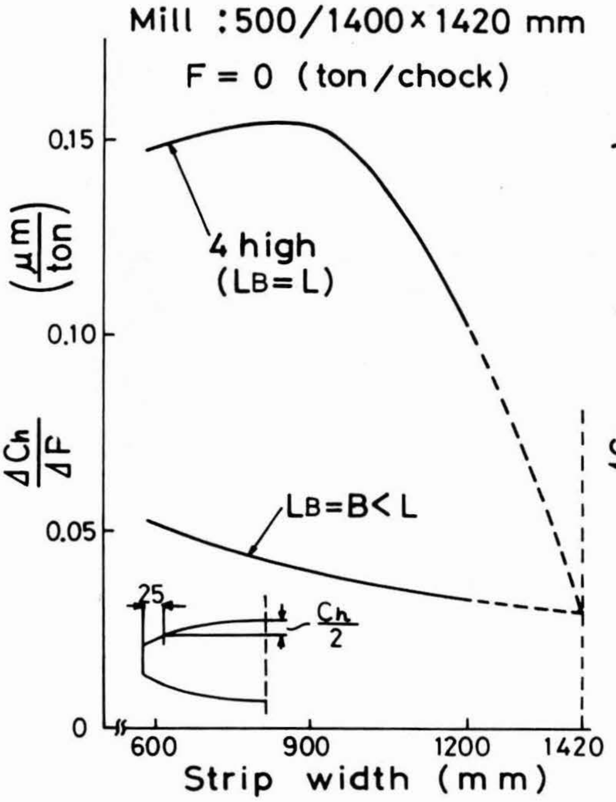


Fig 3 (a) Calculated values of $\Delta C_h/\Delta P$

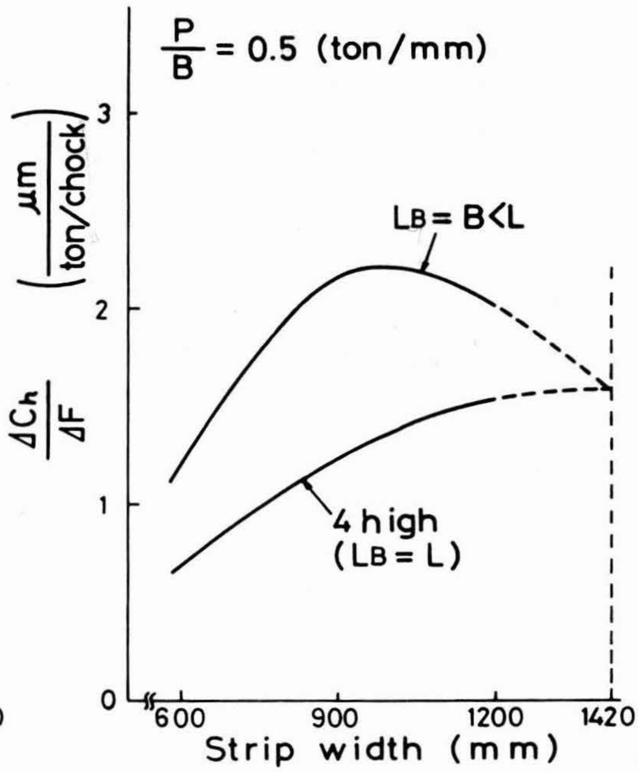


Fig 3(b) Calculated values of $\Delta C_h/\Delta F$

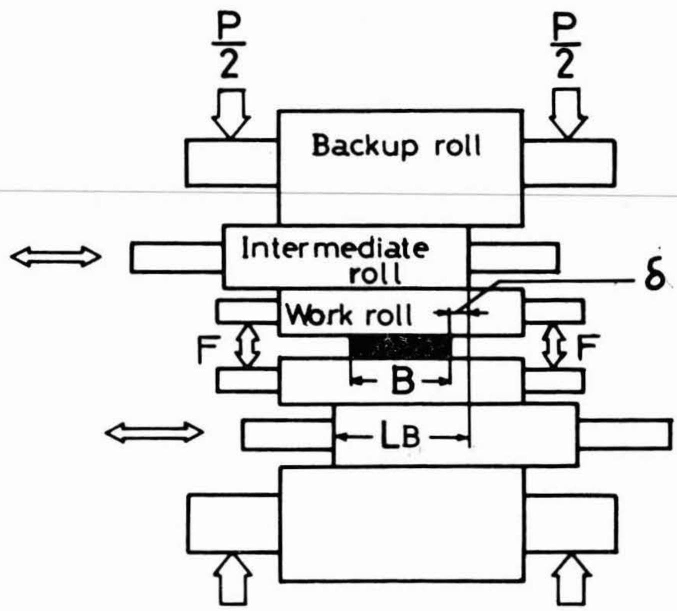
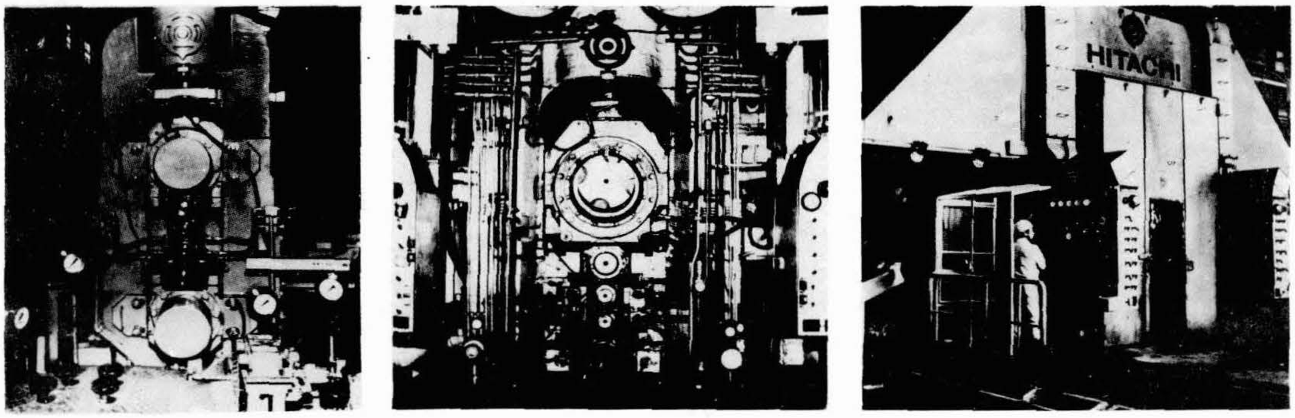


Fig 4 HC mill with intermediate rolls which are shifted in opposite axial directions



(a) Hitachi Res. Lab. Hitachi Ltd.

(b) Yawata Works Nippon Steel Corp.

(c) Funabashi Works Taiyo Steel Co. Ltd.

Fig 5 Photographs of HC mills

Table 1 Major specifications of HC mills

		Hitachi Research Lab. Hitachi Ltd.	Yawata Works Nippon Steel Corp.	Funabashi Works Taiyo Steel Co.
Roll diameter	W.R.	100 mm	320 mm	440 mm
	I.R.	130 mm	530 mm	510 mm
	B.R.	300 mm	1420 mm	1345 mm
Roll barrel length		400 mm	1420 mm	1420 mm
Roll shift stroke		155 mm	485 mm	420 mm
Mill motor		DC75 kW 750/1500 rpm	DC 1500 kW x 2 180/360 rpm	DC 1900 kW x 2 330/870 rpm
Max. rolling speed		90 m/min	600 m/min	1200 m/min

W.R.: Work roll, I.R.: Intermediate roll, B.R.: Back-up roll.

4. Shape Control Function

Fig. 6 shows analytical results of shape adjustability in the test mill — the effect of such rolling conditions as reduction and strip width on the optimum roll bending force "Fo." The optimum roll bending force is the force that produces flat strip. In the test mill, the possible roll bending force "F" is 0--2 tons/chock, and if "Fo" is not within this range, flat strip cannot be obtained. The results of the experiment and the analysis with the HC mill are shown in Fig. 6(a): both values coincide well. The initial roll crown is 0 for each roll, but "Fo" is within the controllable range under almost all conditions, resulting in consistently flat shape. On the contrary, with the 4 high mill, as "Fo" varies widely with the change of reduction and strip width as shown in Fig. 6(b), it is necessary to change the initial work roll crown for different rolling conditions to keep "Fo" within the controllable range.

In Fig. 6(a), "Fo" is 2.4 tons/chock, according to the analysis, when strip width is 300 mm and the reduction is 0.3, which exceeds the upper limit of the roll bending force. But "Fo" can be brought to 0.12 tons, which is well within the controllable range, by merely shifting the intermediate roll position "δ" = -20 mm, as shown in Fig. 6(a). It is obvious that shifting the intermediate rolls is extremely effective in controlling shape.

Fig. 7 shows the results of experiments carried out with the HC mill at the Yawata Works on the effectiveness of shape control by intermediate roll shifting. As shown in the photographs, it is possible to widely control the shape from center buckle to edge wave merely by shifting "δ" from -100 mm to +100 mm. For example, it is even possible to control shape by shifting "δ" in the positive direction when the roll bending force is not sufficient to adjust center buckle due to an excessive thermal crown of the rolls. Shifting of the intermediate rolls, then, is an extremely effective shape control method which is not possible with conventional 4 high mills.

With the HC mill, moreover, shape control by the roll bending force is greater than with the 4 high mill. Fig. 8 shows the relationship between the roll bending force change "ΔF" and the wave steepness change of strip "$\Delta\lambda$." The shape control function of the roll bending force increases as "δ" is shifted toward the negative side. As shown in the figure, the shape control function of the roll bending force at "δ" = -100 mm is three times larger than that at δ= +100 mm, which is similar to a 4 high mill.

Thus, as the shape can be controlled by shifting "δ" and changing "F," the shape control function of the HC mill is remarkably superior compared to the 4 high mill. These effects are due to the elimination of the undesirable roll contact portions (A) with the HC mill.

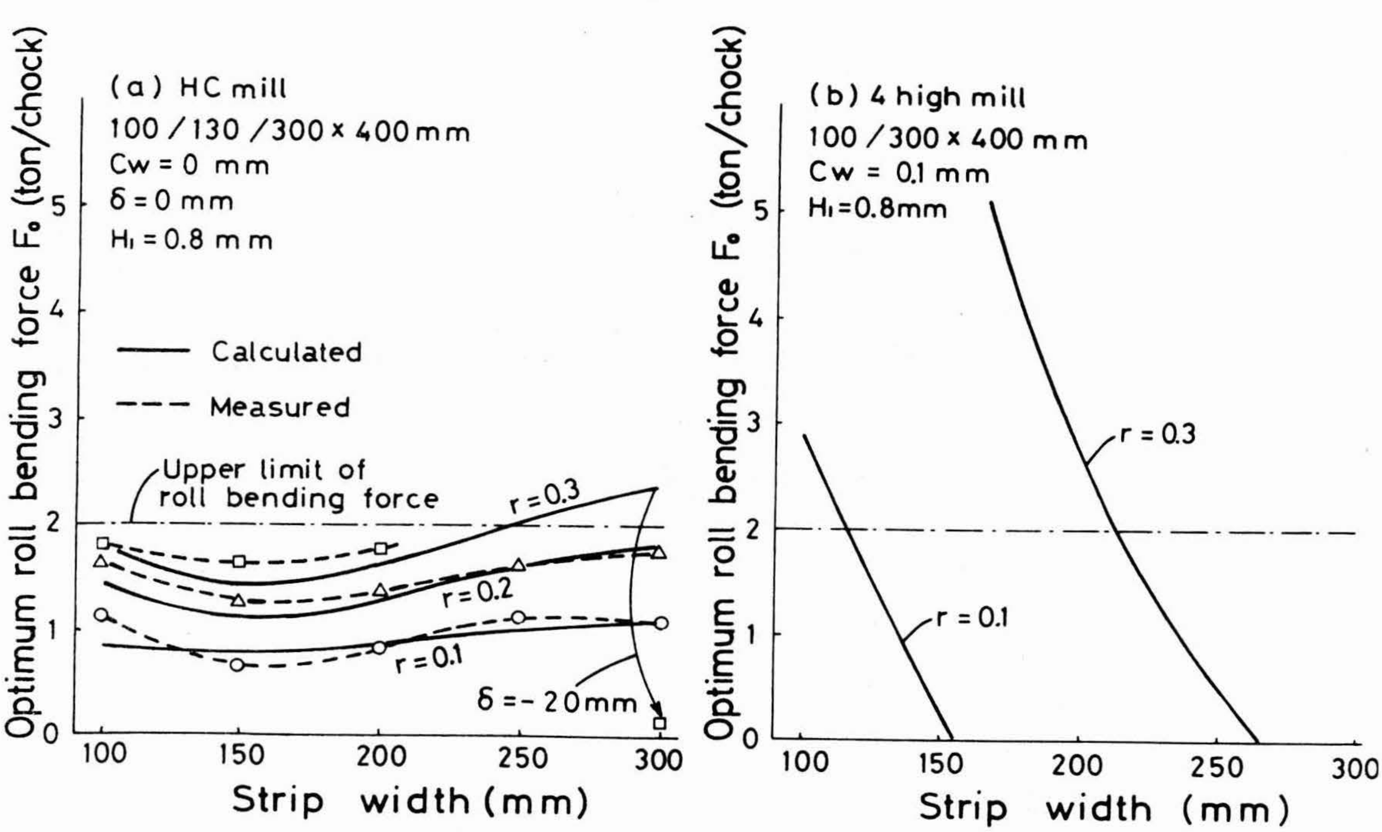


Fig 6 Optimum work roll bending force

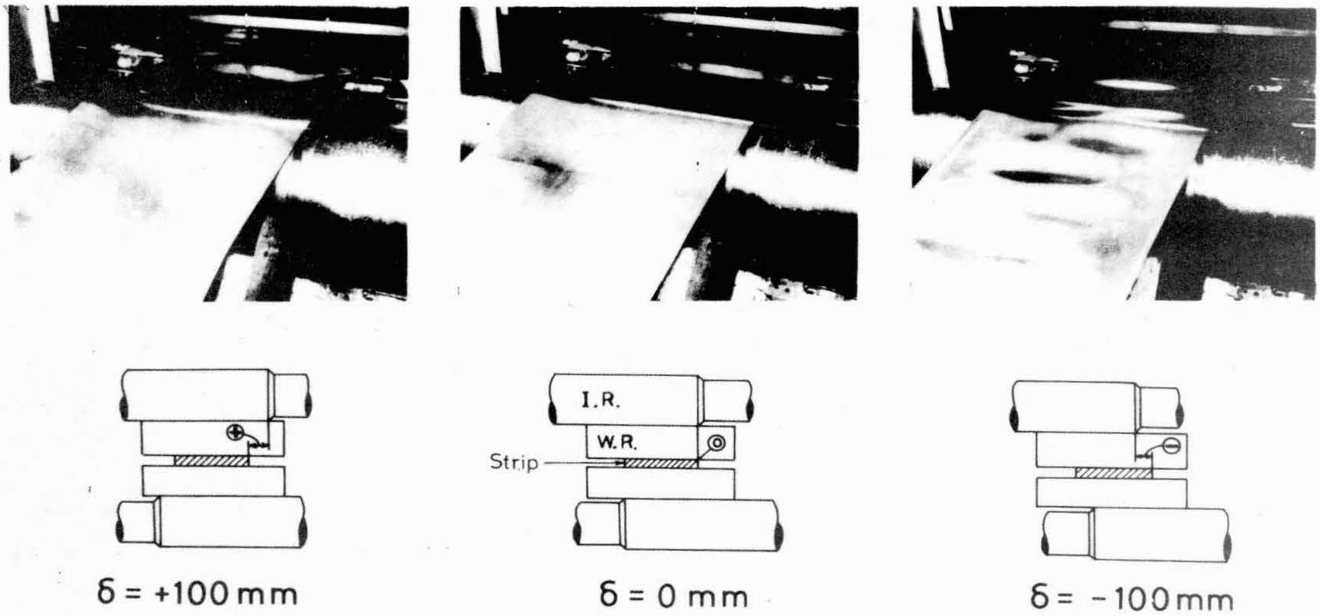


Fig 7 Shape change by intermedate roll shifting

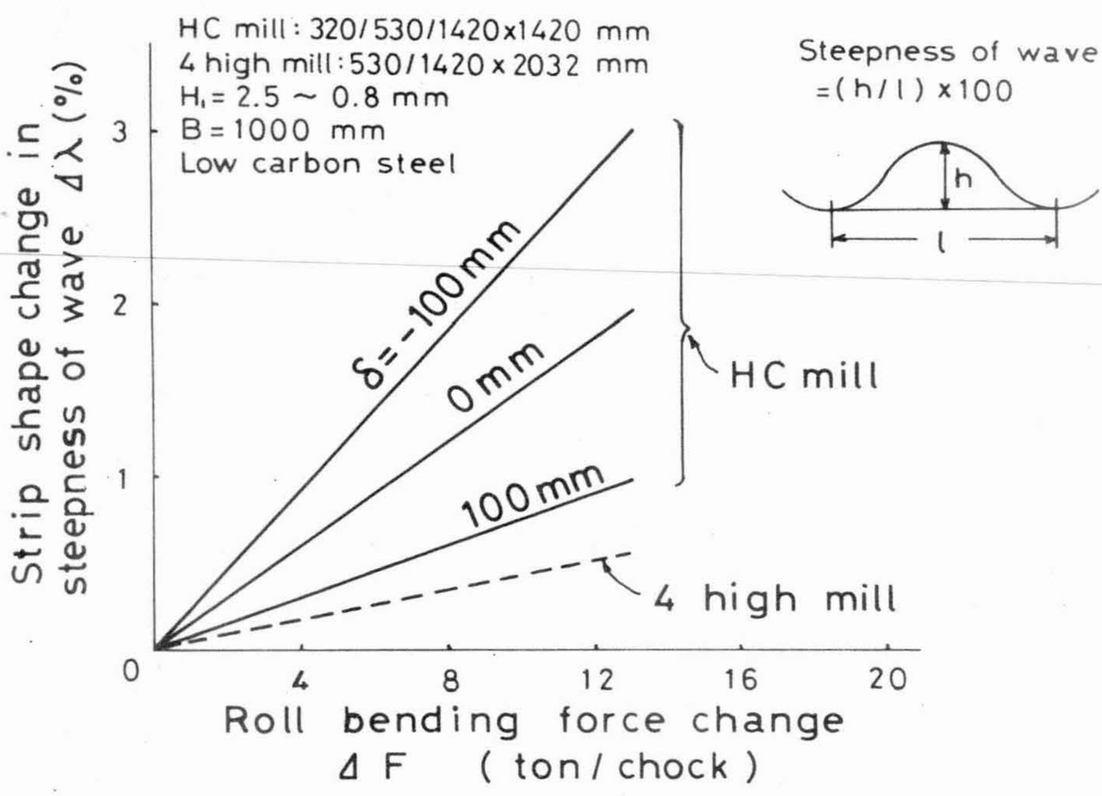


Fig. 8 Shape adjustability of roll bending force

5. Shape Stability Function

In general, with increased rolling load in a 4 high mill it is necessary to increase the roll bending force to product flat strip because edge wave greatly increases. Fig. 9 shows the relationship in the HC mill between rolling load "P" and required optimum roll bending force "Fo" that produces flat strip. These figures have been derived from calculations carried out for the test HC mill. It can be seen that the inclination of the straight lines are remarkably different in accordance with the intermediate roll positions, which are the values of " δ." When " δ " = -24 mm, the inclination becomes negative, which means that roll bending force must be reduced as rolling load increases, unlike the case with a 4 high mill. Furhter, a "δo" value exists around " δ " = -20 mm, where "Fo" does not change even though the rolling load changes.

Mill rigidity (modulus) is infinite where the variation of strip thickness in the direction of rolling is 0 relative to the change in the rolling load. With the HC mill, infinite width rigidity can be obtained at " δ " = " δo" where the change in the shape (strip crown) is 0 relative to the change in the rolling load. Fig. 10 shows the results of the change in strip shape relative to the change in the rolling load obtained with the test HC mill. Fig. 10 (a) shows an example of " δ " = +78 mm (a condition close to a 4 high mill), under which edge wave becomes remarkable as reduction (rolling load) increases even though the maximum roll bending force of 2 tons/chock is applied. Fig. 10(b) also shows the results of rolling at the infinite width rigidity condition where " δ " = -21 mm and "Fo" $\cong$ 0 ton. This shows very little change in shape, resulting in flat strip. This means that the HC mill offers good shape stability. Also with a large HC mill, infinite width rigidity exists as shown in Fig. 11.

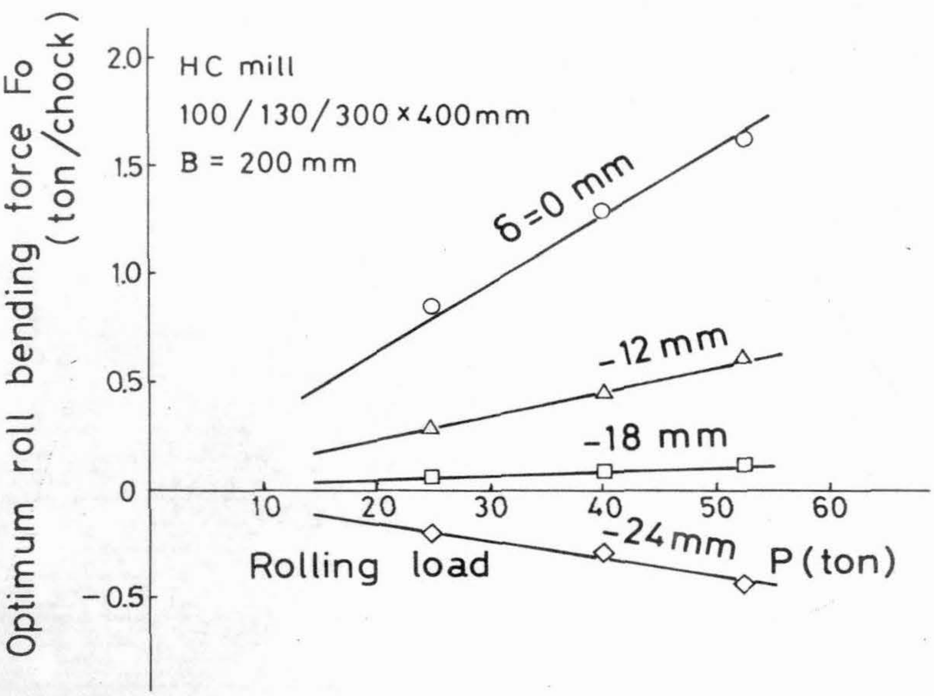
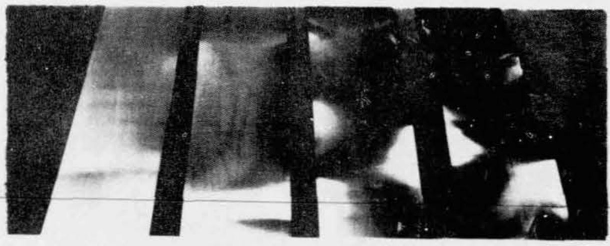


Fig 9 Relation between rolling load and optimum roll bending force (calculated)

(a)

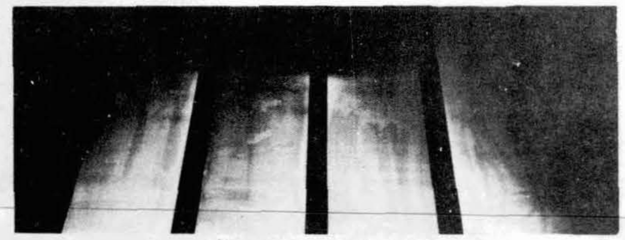


(a) (b) (c) (d)

δ = +78 mm , F = 2.0 ton/chock

	a	b	c	d
Reduction (%)	4	8	16	27
Rolling load (ton)	26	38	49	60

(b)



(a) (b) (c) (d)

δ = -21 mm , F = 0.15 ton/chock

	a	b	c	d
Reduction (%)	4	9	20	30
Rolling load (ton)	25	38	52	64

HC mill 100 / 130 / 300 x 400 mm
Strip thickness 0.8mm, width 200 mm
Front and back tension 8 kg/mm²

Fig 10 Relation between rolling load and strip shape

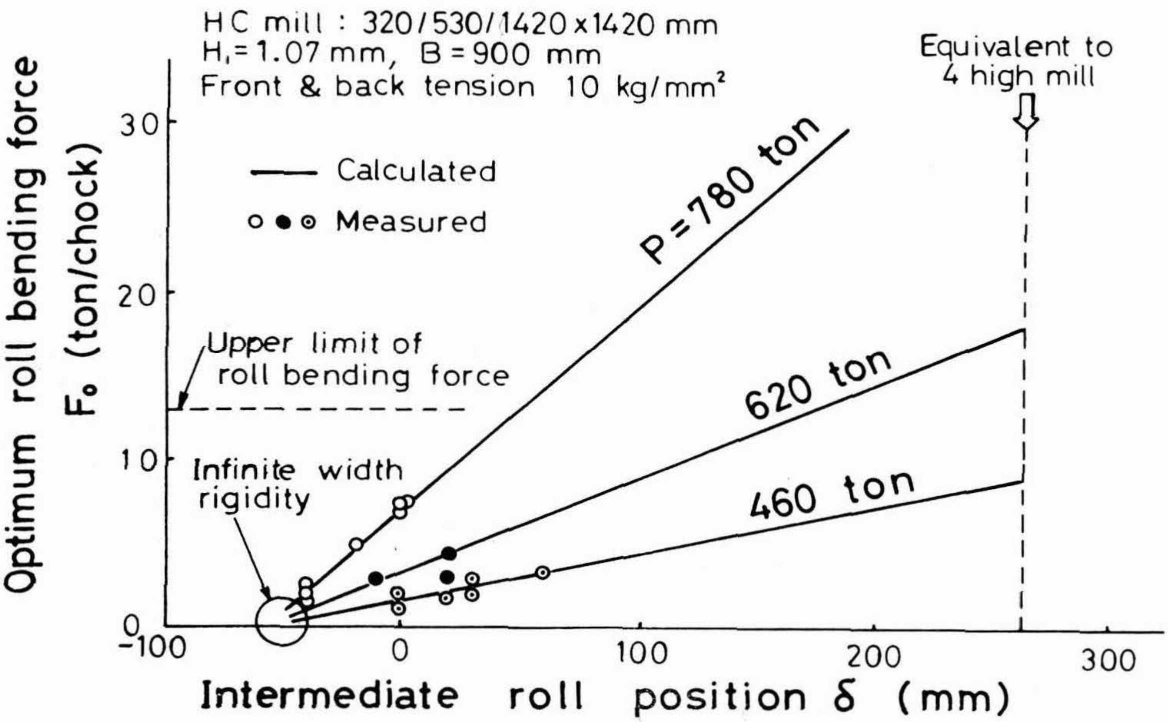


Fig 11 Existence of infinite width rigidity in large HC mill

6. Advantages

The HC mill improves not only the quality of the rolled product but also productivity and operating efficiency of the rolling mill which were never experienced in conventional mills. These improvements are described below.

6.1 Heavy reduction rolling is possible without disturbing the strip shape because the HC mill has large shape adjustability and good shape stability. Therefore, the number of passes in a reversing mill can be reduced and productivity considerably improved. In a tandem mill, not only fewer stands need be used, but also thicker strip from the hot rolling mill can be handled. These factors greatly reduce manufacturing costs.

6.2 With the HC mill, smaller diameter work rolls can be used because of good strip shape stability. This increases the effectiveness of heavy reduction and saves energy because of the lower rolling power required. Further, rolling of harder and thinner strip is possible.

6.3 The initial roll crown required for the 4 high mill is not required for the HC mill, which means a large reduction in the number of spare rolls. This also eliminates the bothersome preparation, maintenance and change of rolls to fit the rolling schedule.

6.4 The pass schedule can be determined regardless of shape because of good shape stability and large shape adjustability.

6.5 Conventional 4 high mills produce strip with conspicuously reduced strip thickness at its edges (edge drop). Edge drop can be reduced with the HC mill under the conditions of certain "δ" and "F" parameters. Less edge drop reduces the amount of trimming and enhances yield. Edge cracking is also reduced and operating efficiency increased because strip breakage during rolling is greatly reduced.

6.6 The operating efficiency of subsequent processes can be increased because of the high quality of the strip produced.

7. Operating Data

7.1 Heavy reduction

Fig. 12 shows a comparison of rolling schedules between the HC mill and the 4 high mill carried out at the Yawata Works of Nippon Steel Corporation. It can be observed that the number of passes for the HC mill can be reduced by one to three passes compared to the 4 high mill.

7.2 Strip shape

Superior shape adjustability and stability of the HC mill have been confirmed with all HC mills immediately after start-up. Strips of good shape with wave steepness of less than 1 per cent (in most cases less than 0.5 per cent) have been produced consistently as the operators gained experience with the facilities. Fig. 13 shows the wave steepness of the strip in the heavy reduction schedule shown in Fig. 12. As can be seen in the figure, the steepness is less than 1 per cent even under heavy reduction with the HC mill.

7.3 Energy savings by small work roll diameter

Fig. 14 shows a comparison of total horsepower hour/ton of the HC mill (using small diameter work rolls) to a conventional 4 high mill. The HC mill consumes approximately 10 per cent less energy.

7.4 Kinds of initial work roll crowns and the number of rolls required.

Examples of the kinds of initial crowns and the number of rolls required are shown in Table 2. Here, straight rolls are used for all kinds of rolling with the HC mill. The number of work rolls is thus reduced to less than half that needed for the conventional 4 high mill.

7.5 Reduction of edge drop

Fig. 15 shows an example of the reduction of edge drop with the HC mill. As the figure indicates, the yield rate is increased by reducing the amount of trimming required.

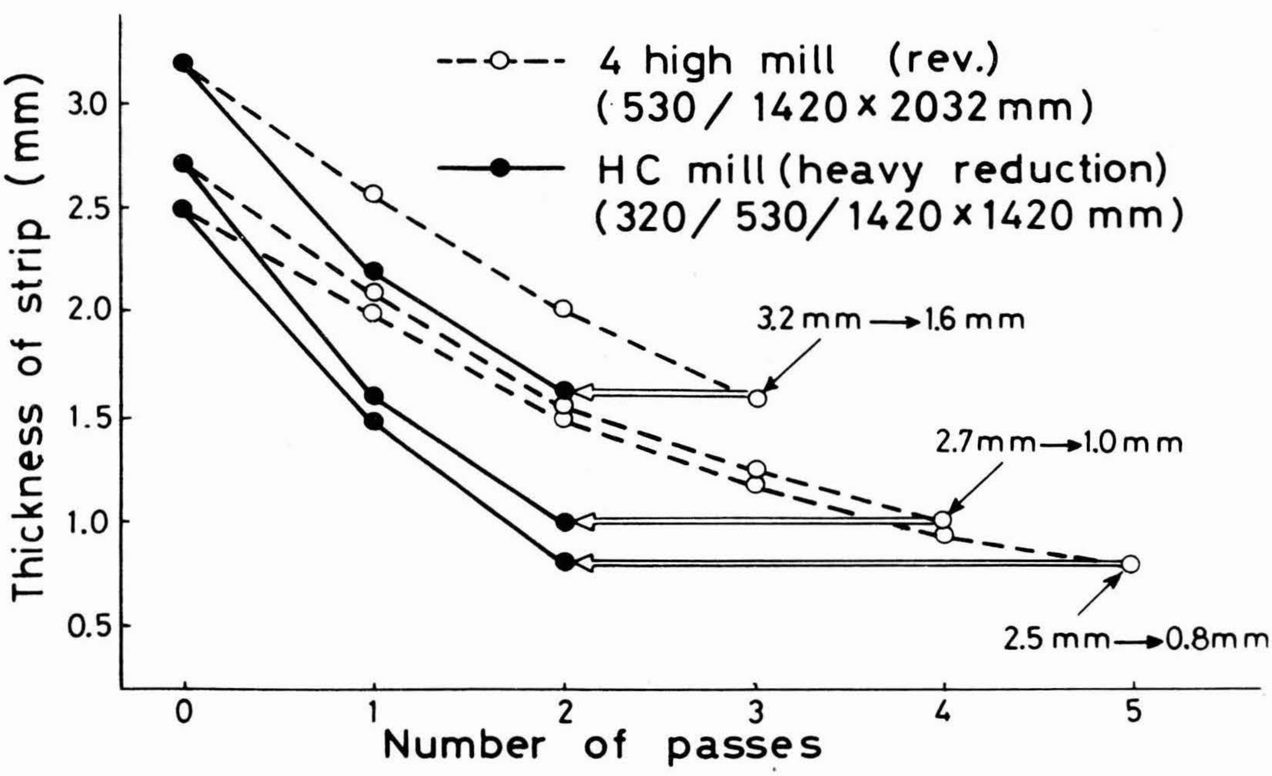


Fig 12 Schedule of heavy reduction in HC mill

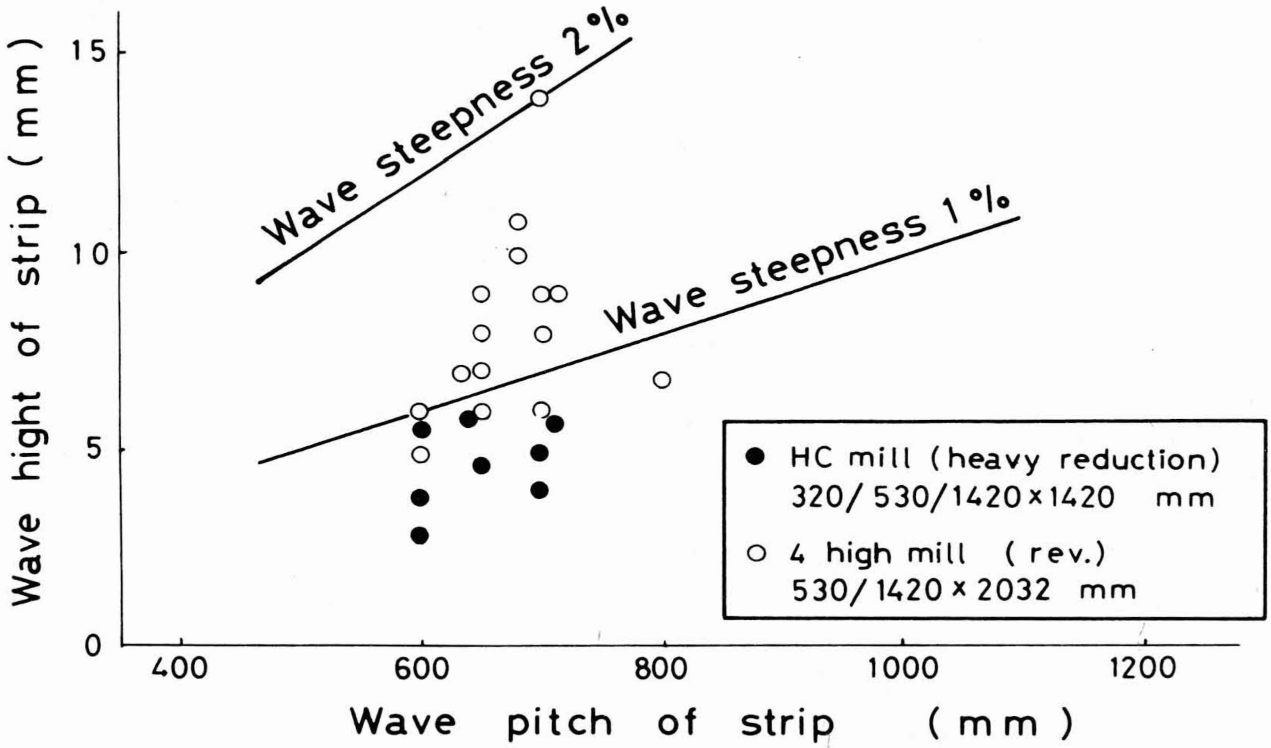


Fig 13 Wave steepness of rolled strip

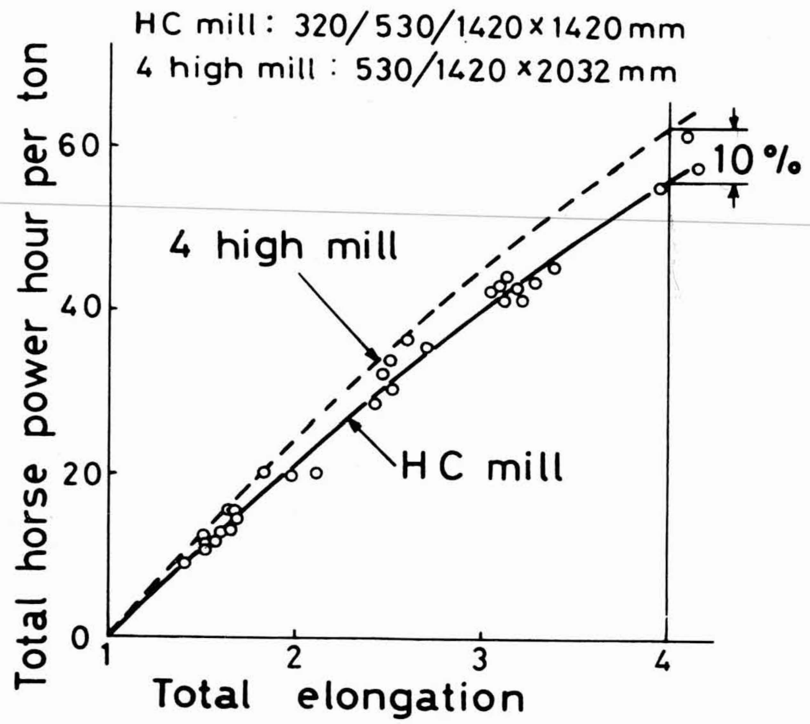


Fig 14 Comparison of energy consumption between
4 high mill and HC mill

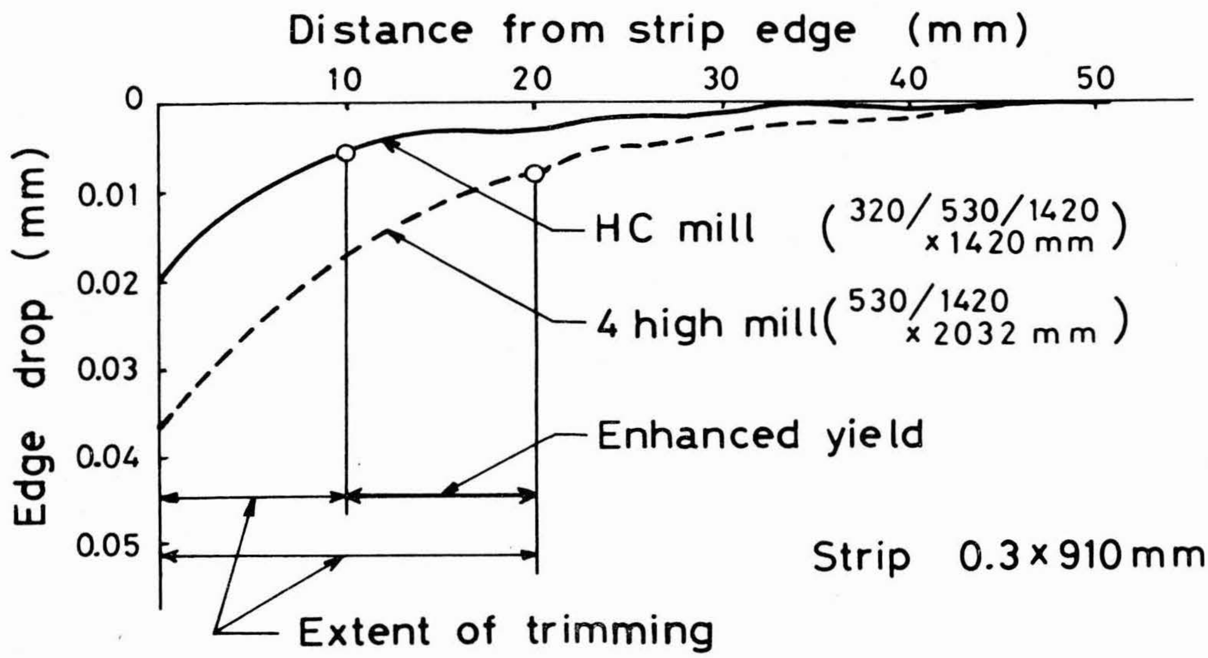


Fig 15 Improvement of edge drop in HC mill

Table 2 Roll initial crown and number of work rolls

	Roll initial crown (mm)	Number of work rolls
4 high mill	W.R.: 0, $\frac{5}{100}$, $\frac{10}{100}$, $\frac{15}{100}$, $\frac{20}{100}$ B.R.: Straight roll	16 pairs
HC mill	W.R., I.R., B.R. } Straight roll	6 pairs

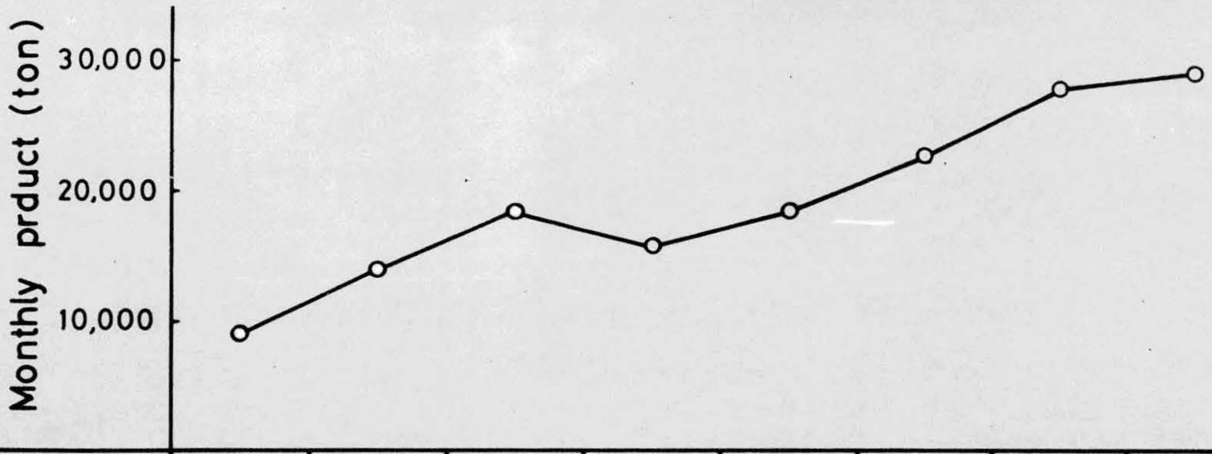
8. Operating Experience

The production progress of the HC mill at Taiyo Steel Co., Ltd. is shown in Fig. 16. Production increased sharply as the number of work shifts increased, which confirms the performance stability of the mill. Both HC mills at Nippon Steel Corp. and Taiyo Steel Co., Ltd. are fitted with Hitachi's high performance hydraulic roll positioning device (Hitachi-HYROP). Fig. 17 shows an example of gage deviation measured at Taiyo Steel Co., Ltd. The figure shows that high gage accuracy is maintained throughout the entire coil length.

Further, it has been confirmed that the HC mill reduced edge cracking. Generally, it has been difficult to increase productivity especially of thinner strip of around 0.15 mm thickness on a conventional 4 high mill because of the difficulty of controlling shape and frequent strip breakage due to edge cracking. With the HC mill, however, strip breakage was reduced by several times compared to breakage with a conventional 4 high mill.

As shown in Fig. 18, the distribution of contact pressure between the work rolls and intermediate rolls and the intermediate rolls and back-up rolls are not equal on the right and left sides, and the contact pressure is highest at the shoulder of the intermediate rolls. A radius of 500 to 1,500 mm was employed for the shoulder shape of the intermediate rolls to reduce stress concentration without affecting the shape control function. The hardness of the rolls, determined from the standpoint of spalling is shown in Table 3. These figures were adopted throughout the model and rolling tests, and are now used in all HC mills destined for commercial operation.

An example of intermediate roll shoulder shape before and after rolling 1,084 tons of products on a reversing HC mill is shown in Fig. 19. There is minimal change in shoulder shape and approximately 0.045 mm of wear. Roll performance is shown in Table 4. Roll performance in the HC mill is not large even though the number of rolls in the mill is more than that of the 4 high mill.



	1976 Sep.	Oct.	Nov.	Dec.	1977 Jan.	Feb.	Mar.	Apr.
Number of shifts	48	71	89	82	93	84	93	90
Mean product dimensions(mm)	0.4×920	0.4×920	0.4×920	0.38×900	0.4×930	0.4×930	0.44×980	0.45×980

Fig 16 Monthly product at Funabashi Works of Taiyo Steel Co. Ltd.

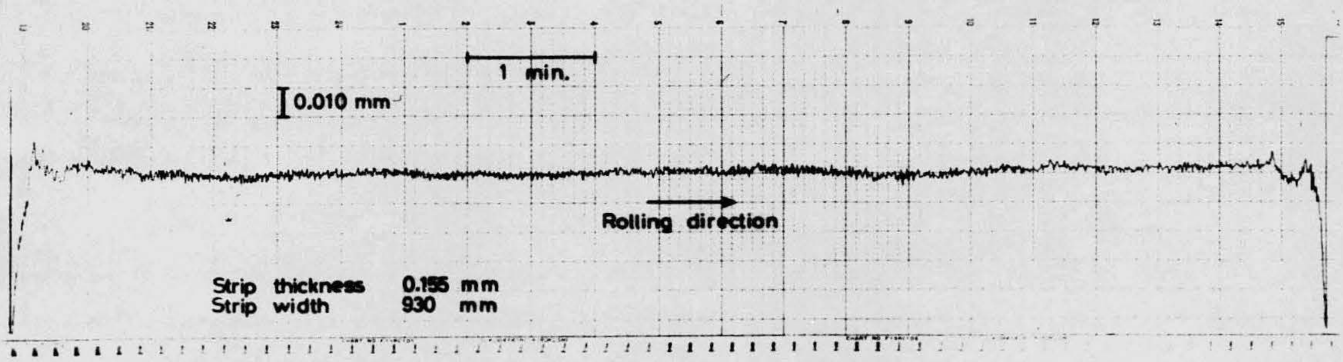


Fig. 17 Delivered gage deviation

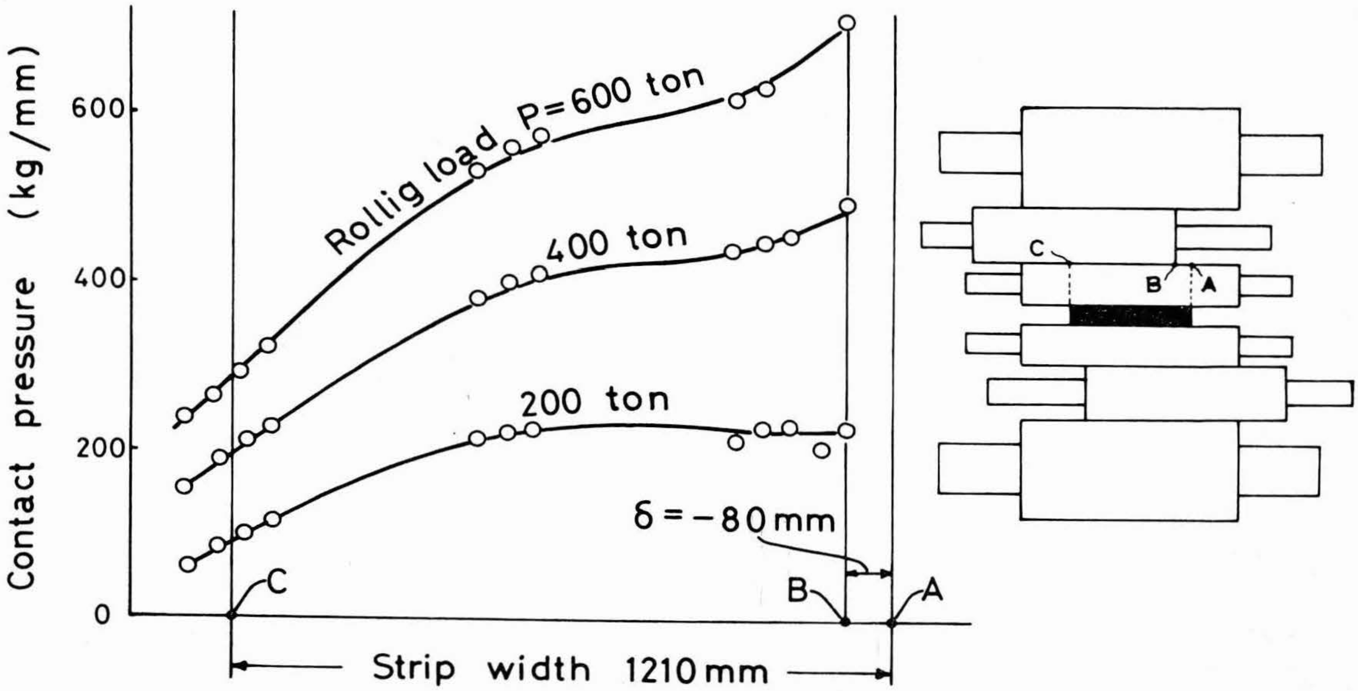


Fig 18 Contact pressure between work roll and intermediate roll

Table 3 Hardness of rolls

	Shore harness
Work roll	90 - 95
Intermediate roll	72 - 78
Back-up roll	60 - 70

Table 4 Roll performance

	Nippon Steel Corp.		Taiyo Steel Co.
	4 high mill	HC mill	HC mill
Work roll	0.39 kg/ton	0.10 kg/ton	0.20 kg/ton
Intermediate roll	___	0.13	0.13
Back-up roll	0.07	0.07	0.10
Total	0.46	0.30	0.43
Mill specifications	530/1420 x 2032 mm	320/530/1420 x 1420 mm	440/510/1345 x 1420 mm
Rolling speed	505 m/min	600 m/min	1200 m/min
Product dimensions	0.6 x 1000 mm	0.6 x 1000 mm	0.45 x 980 mm

Roll performance: roll consumed amount (kg)/rolled product (ton)

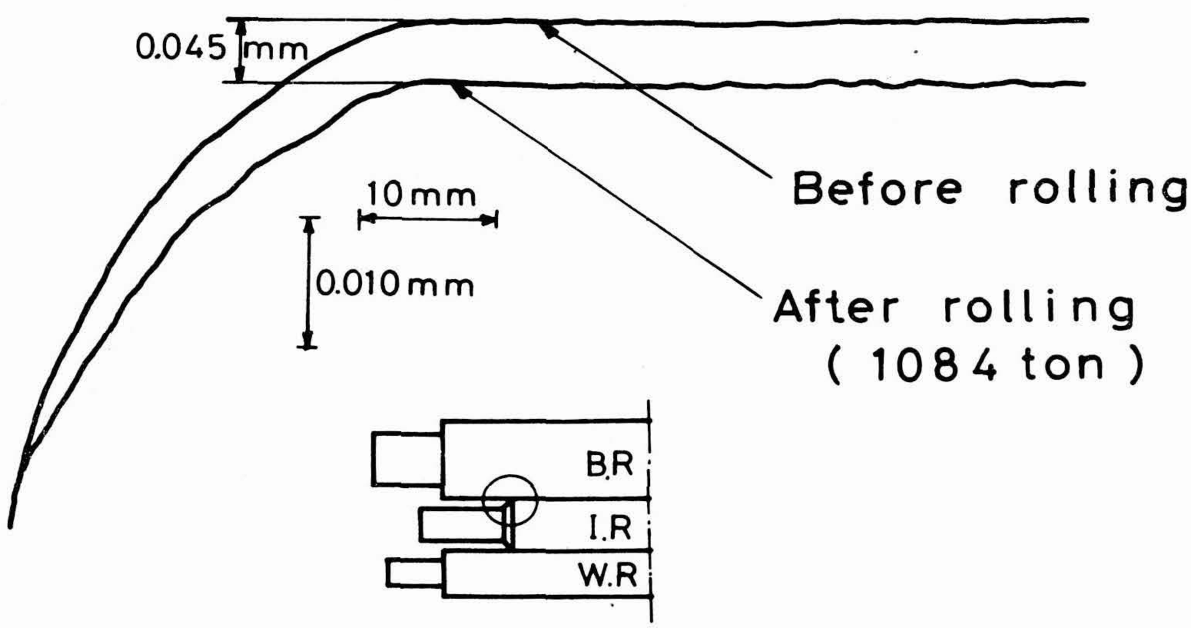
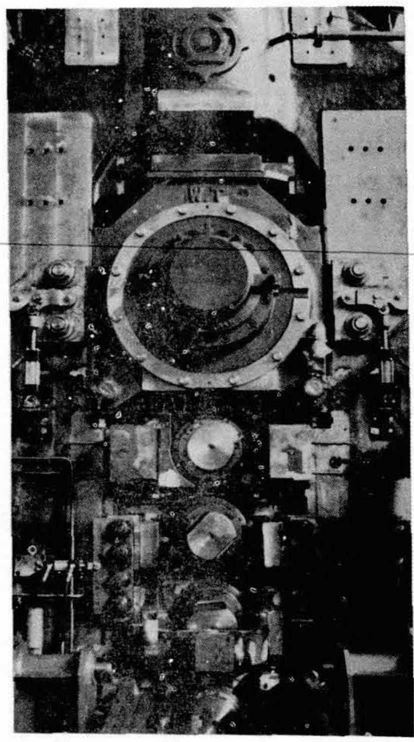


Fig 19 Shape of intermediate roll shoulder

9. Advantages of the HC Mill in Skin Pass Rolling

As skin pass rolling is the final rolling process, the quality of strip such as shape, mechanical properties and surface finish are ultimately determined by this process. Therefore, it is desirable for skin pass mills to have enough functions to satisfy the purposes of skin pass rolling.

The HC mill for USIMINAS, Minas Gerais, Brazil, is the first of its type to be used as a large-scale skin pass mill. It was designed to realize the above functions of skin pass rolling and the HC mill itself. The photograph shows a completed HC mill in the Hitachi Works of Hitachi, Ltd.



Front view of the HC Mill

The main specifications and features of this mill are as follows:

9.1 Main specifications

Mill type	: Six (6) high HC Mill
Roll size	: $538^{\phi}/538^{\phi}/1420^{\phi}x1680^{L}$
Intermediate roll stroke	: 595 mm
Drive	: Work roll pinion stand drive
Screwdown	: HYROP-M
Rolling speed	: 1200 m/min
Material to be rolled	: Low carbon steel
	Thickness : 0.2 to 2.5 mm
	Width of strip: 500 to 1570 mm

9.2 Advantages and features of the HC mill for skin pass rolling

1) Wide function for strip shape control
This HC mill has two functions for strip shape control: one is intermediate roll shifting with a long stroke to cover a wide range of strip widths, the other is roll bending.

Thanks to these functions, the HC mill is able to roll strip with good shape using straight rolls without roll crown under a wide range of rolling forces.

2) Achieving two functions of skin pass rolling at same time
The two main functions of skin pass rolling are to improve strip shape and to give uniform mechanical properties to the strip. These mechanical properties are normally controlled by elongation of strip during rolling.

In a conventional 4 high mill it is difficult to achieve both functions at the same time. For elongation control, adjusting the rolling force is the most effective method especially for skin pass rolling sheet-gage material. However, if the rolling force is changed in order to keep elongation constant, then strip shape is changed, making it impossible to maintain good shape.

On the other hand, with the HC mill, as deformation of the work rolls does not change with a change in the rolling force, it is possible to control elongation without spoiling strip shape.

3) Study of work roll diameter
From the viewpoint of obtaining good strip shape, it is desirable to use 585- to 610-mm-diameter work rolls in wider 4 high skin pass mills. However in case of the HC mill, 420-mm-diameter work rolls are adequate to keep good shape. In this mill 538-mm-diameter work rolls are used as they best meet the product mix and interchangeability of work rolls with existing mills.

4) Other features

a) Pass line adjusting device
It is not necessary to change liners (filler plate) when changing rolls. The screw type pass line adjusting device can compensate for the full range of roll diameters and keep the pass line constant.

b) Roll change
Either the top and bottom work rolls or the top and bottom of both work rolls and intermediate rolls can be changed simultaneously by a side shift type changing car.

10. Application and Development of HC Mill

Based on the superior properties of the HC mill and the technology obtained in practical rolling operations, the following applications and development of this mill have been examined for various purposes.

10.1 The former stands of the cold tandem mill

Heavy reduction rolling capability of the HC mill may reduce the number of mill stands or increase the gage of hot rolled strip. The latter is expected to result in remarkable energy and resources saving in the preceding processes in addition to higher production capacities of hot strip mills and pickling lines by increasing the gage.

10.2 The last stand of the tandem cold strip mill
The quality of the cold rolled product will be improved. The gage control at the last stand will become free from shape control.

10.3 Temper mill and skin pass mill
The quality of the cold rolled product will be improved. Roll costs will be reduced through using only straight work rolls without initial crowns. A single stand temper mill is expected to take the place of the conventional two-stand temper mill.

10.4 Hot strip mill
The HC mill may be effective in hot rolling, especially in finishing stands for the improvement of strip crown, strip shape and edge drop.

Summary

This paper has described the principles of the HC mill and the confirmation of its superior shape adjustability and stability functions. Further, operating advantages such as higher product quality, operating efficiency, productivity, and strip quality in skin pass rolling have also been explained.

A list of the HC mills delivered to date is given in Table 5.

Table 5 Supply list of HC Mills

NO.	CUSTOMER	MILL SIZE	ROLLING SPEED & TYPE OF DRIVE	MILL MOTOR	PRODUCT-MATERIAL THICKNESS WIDTH	START-UP
1	HITACHI RESEARCH LABORATORY, HITACHI, LTD.	100/130/300mmø x 400mmL Single stand reversing mill (test mill)	200 m/min. Intermediate roll drive	DC 75 kW 750/1,500 RPM	Mild steel, aluminum, etc. 75-300 mm	1972
2	YAWATA WORKS, NIPPON STEEL CORPORATION	320/530/1,420mmø x 1,420mmL Single stand reversing mill	600 m/min. Intermediate roll drive	DC 2 x 1,500 kW 180/360 RPM	Mild steel and silicon steel 0.25-3.2mm 500-1,270mm	Aug., 1974
3	KATAGI ALUMINUM LTD.	250/250/500mmø x 750mmL Single stand reversing mill	450 m/min. Work roll drive	DC 300 kW 400/1,200 RPM	Aluminum and aluminum alloy 0.15-2.0mm 330-600mm	Feb., 1976
4	FUNABASHI WORKS, TAIYO STEEL MFG. LTD.	440/510/1,345mmø x 1,420mmL Single stand reversing mill	1,200 m/min. Work roll drive	DC 2 x 1,900 kW 330/870 RPM	Mild steel 0.15-2.3mm 610-1,320mm	Aug., 1976
5	SHIRAKAWA WORKS, TOKYO SPECIAL METAL LTD.	135/165/500mmø x 550mmL Single stand reversing mill	200 m/min. Intermediate roll drive	DC 280 kW 200/400 RPM	Phosphor bronze 0.2-2.0mm 400-425mm	Under Construction

NO.	CUSTOMER	MILL SIZE	ROLLING SPEED & TYPE OF DRIVE	MILL MOTOR	PRODUCT-MATERIAL THICKNESS WIDTH	START UP
6	USIMINAS USIMINAS INTENDENTE CAMERA WORKS IPATINGA, MINAS GERAIS, BRAZIL	538/538/1,420mmø x 1,680mmL Single stand skin pass non-reversing mill	1,200 m/min. Work roll drive	DC 1,100 kW 216/710 RPM	Cold rolled low carbon steel 0.2-2.0mm 500-1,570mm	Under manufacturing, will start up in Jan., 1979
7	KUBOTA SHINDO-SHO, K.K.	135/165/500mmø x 550mmL Single stand reversing mill	120 m/min. Intermediate roll drive	DC 150 kW 1,150 RPM	Stainless steel 0.5-2.5mm 200-400mm	Aug., 1977
8	KIMITSU WORKS, NIPPON STEEL CORPORATION	No.6 stand of 6 stand cold tandem mill ORIGINAL 585ø 1,420ø 1,420 L .... MODIFIED 533ø/456ø/1,345ø/ x 1,420 L.	 2,500 m/min. 2,280 m/min. Work roll drive	DC 2 - 3 x 950 kW 240/600 RPM (No.6 stand)	Mild steel 0.2-4.5mm 500-1,280mm	Dec., 1977
9	OHJI WORKS DAIDO STEEL CO., LTD.	Replace with HC Mill 120/200/500mmø x 450mmL	200 m/min. Back roll drive	DC 190 kW 630/1,350 RPM	Stainless steel Min. 0.2mm	Aug., 1978

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2) T. Kajiwara, et al., Hitachi Review, 1976, Vol.25, No.1
3) Nippon Steel News, No.68, Dec., 1975
4) 33 Magazine, March, 1976
5) T. Kajiwara, et al., The Okochi Memorial Prize 1976, 22
1976, Okochi Memorial Foundation
6) T. Furuya, et al., "HC-MILL" Newly Developed 6 High Cc
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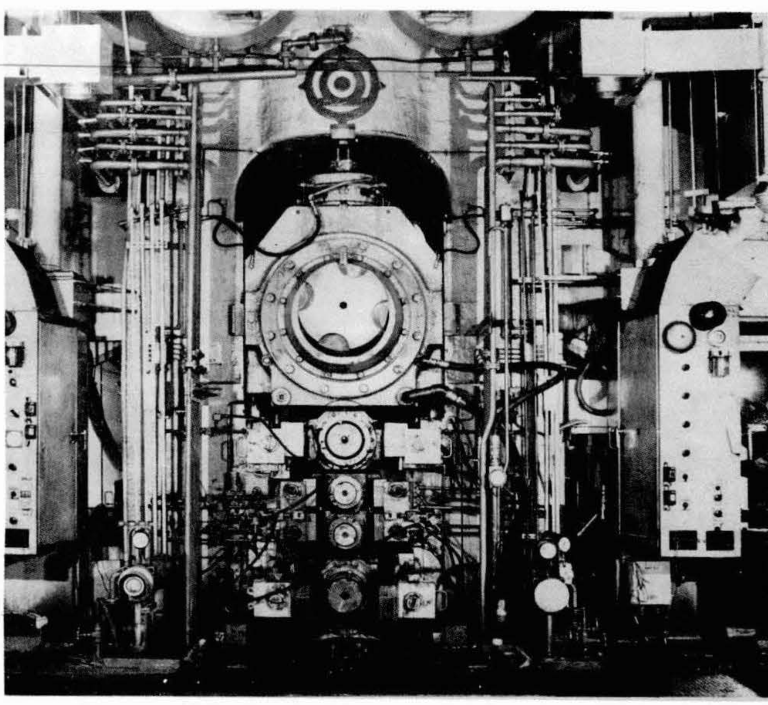
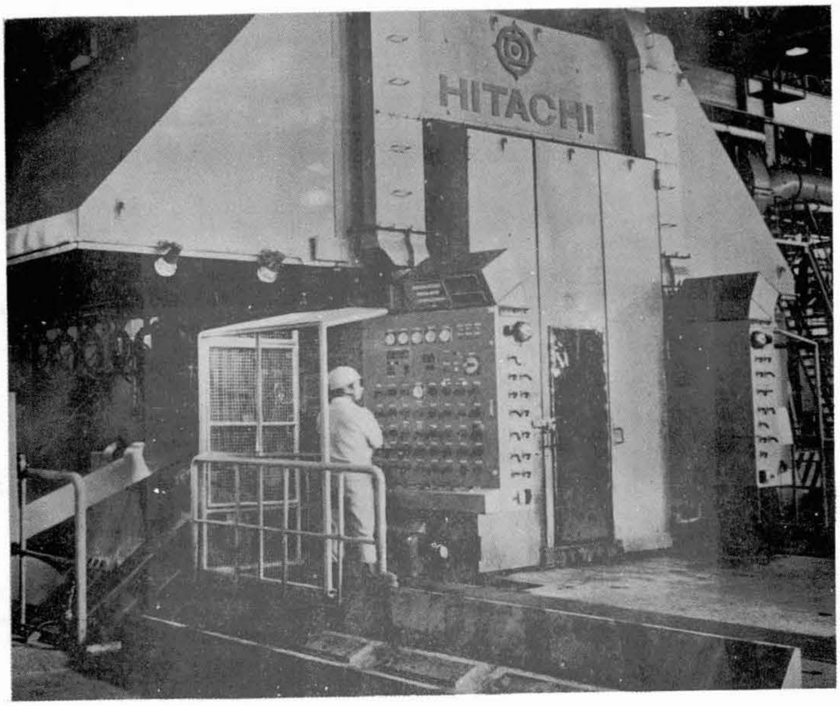
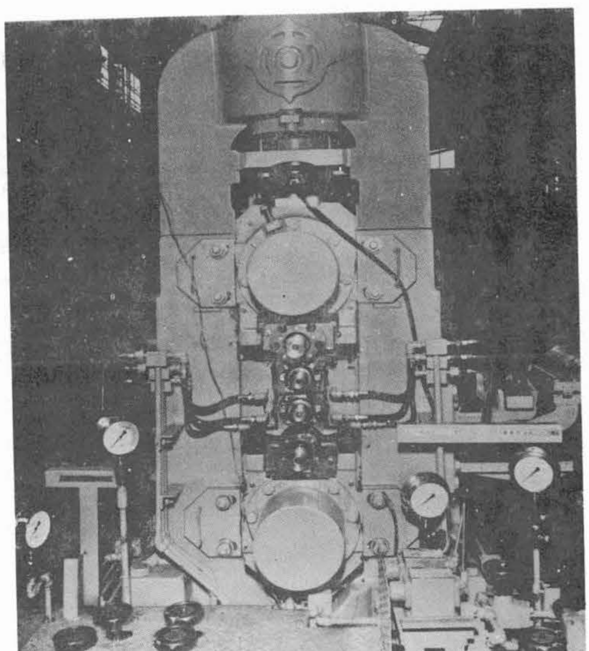
This photo is for Fig. 5(b).



For Fig. 5(c)



For Fig. 5(a)



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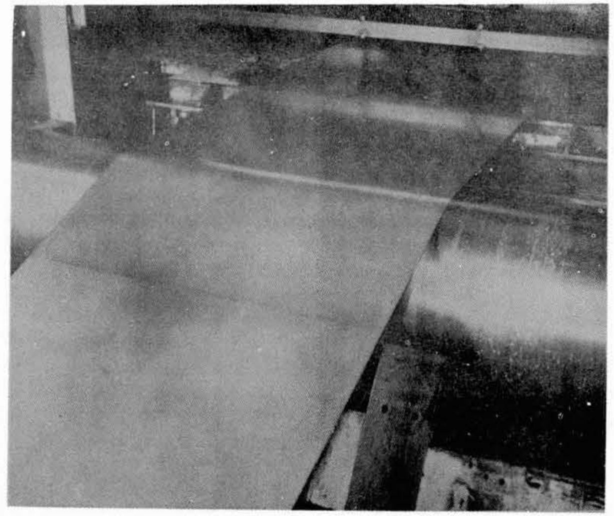
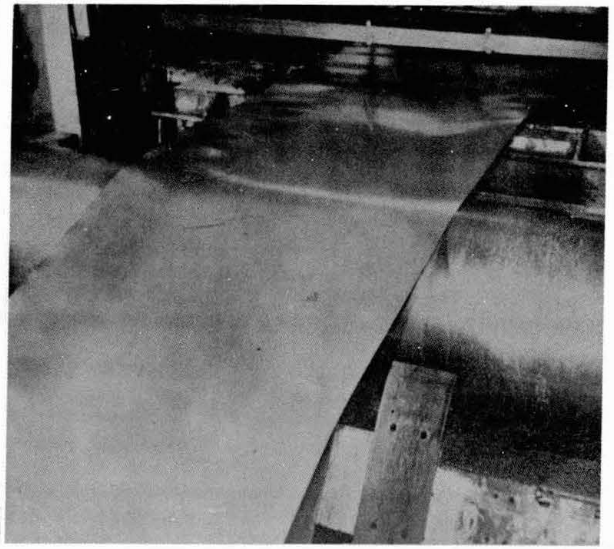
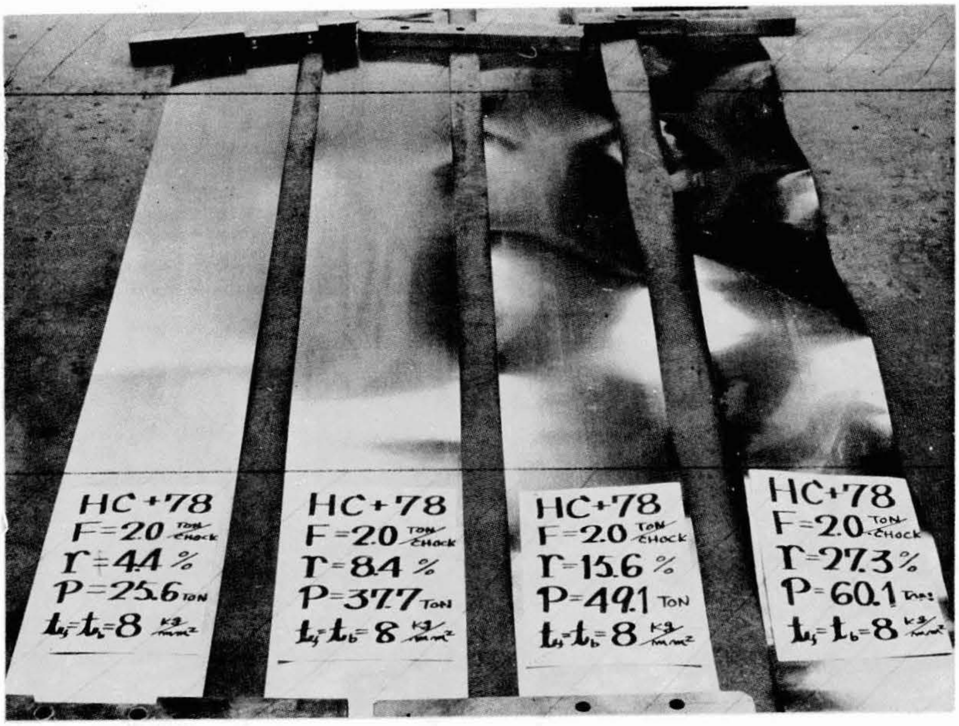
This photo is for the right-hand position (δ = -100 mm) in Fig. 7



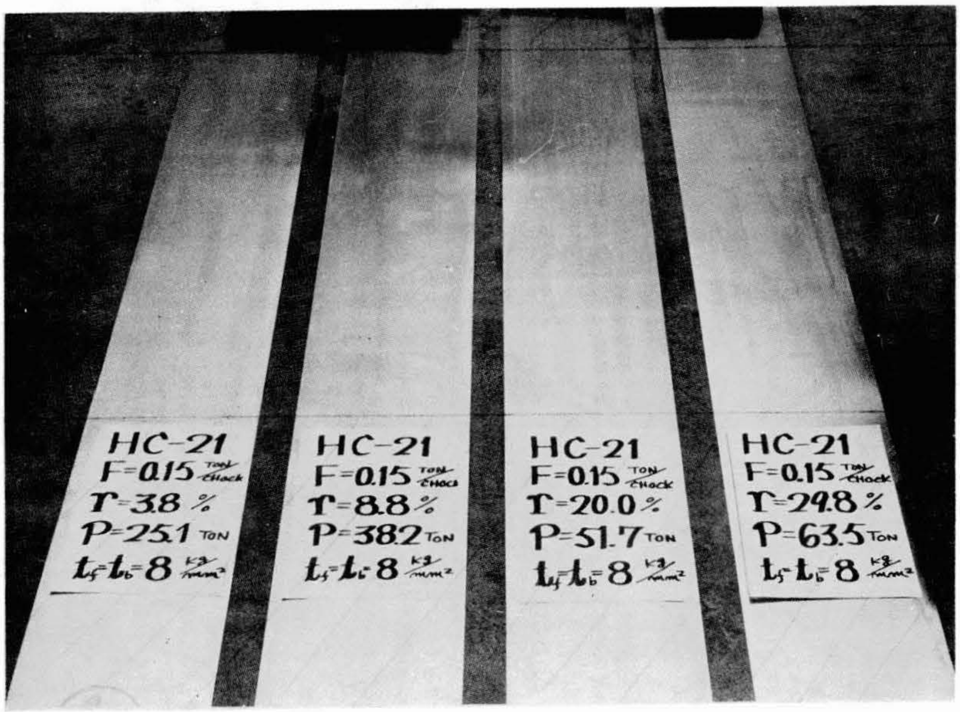
For the center position (δ = -0 mm) of Fig. 7



For the left-hand position (δ = +100 mm) of Fig. 7



For the left-hand position of Fig. 10



For the right-hand position of Fig. 10