KAWASAKI STEEL TECHNICAL REPORT
No.9 (March 1984)

Development of an Edge Grinding Device for Hot Rolled Stainless Steel Coil

Suenobu Shiiba, Kazushige Akita, Tadashi Yamazaki, Shinji Kosaki, Yasuyuki Niwa, Akihiko Kamiya, Ryuzo Sato

Synopsis :
In order to eliminate mill edge cracking of stainless steel hot strips in cold rolling, a new edge grinding device has been developed. The device removes microcracks by grinding the mill edge by 0.5mm instead of trimming them by 20 to 25mm. The grinding wheel is set perpendicular to the strip pass line and rotates in a downward cutting direction. Other characteristics are adoption of compressive contact through a coil spring which is indispensable for smooth grinding; the holding of a constant grinding depth by maintaining a steady grinding current; the stopping of wheel rotation when grinding is suspended for preventing a grinding wheel breakage due to thermal stress; and the installation of such devices as a wheel diameter detector and an edge shape detector. The yield of cold rolled strip of AISI430 stainless steel has been improved by as much as 3%.

The body can be viewed from the next page.

Development of an Edge Grinding Device for Hot Rolled Stainless Steel Coil*

Suenobu SHIIBA ** Kazushige AKITA ** Tadashi YAMAZAKI **
Shinji KOSAKI ** Yasuyuki NIWA** Akihiko KAMIYA ***
Ryuzo SATO ***

In order to eliminate mill edge cracking of stainless steel hot strips in cold rolling, a new edge grinding device has been developed. The device removes microcracks by grinding the mill edge by 0.5 mm instead of trimming them by 20 to 25 mm. The grinding wheel is set perpendicular to the strip pass line and rotates in a downward cutting direction. Other characteristics are adoption of compressive contact through a coil spring which is indispensable for smooth grinding; the holding of a constant grinding depth by maintaining a steady grinding current; the stopping of wheel rotation when grinding is suspended for preventing a grinding wheel breakage due to thermal stress; and the installation of such devices as a wheel diameter detector and an edge shape detector. The yield of cold rolled strip of AISI 430 stainless steel has been improved by as much as 3%.

1 Introduction

The problem caused by the cold rolling of hot rolled stainless steel coils without trimming the mill edges beforehand is edge cracking ascribable to the micro-cracks at the mill edges. For instance, when the mill edges of a hot rolled stainless steel coil are ground by 0.5 mm prior to cold rolling to eliminate these micro-cracks, a mother coil of 4.5 mm thick can be cold rolled down to 0.4–0.7 mm in thickness without applying any intermediate annealing and thereby greatly improving the production yield.

In 1975, Hanshin Works of Kawasaki Steel Corporation which began research to improve the production yield in its stainless steel cold rolling tried to put the mill edge grinding to practical use in order to reduce the material loss resulting from trimming the mill edge of hot rolled coil.

Although the measures for eliminating the micro-cracks[1] such as weld-cutting and machining were being studied, Hanshin Works adopted disk grinding wheels, in which the spindles were arranged parallel to the strip travelling direction. After various trials, these were found to give the best results. This paper explains how the research developed and describes the edge grinding device which resulted from this research.

2 Outline of the Coil Edge Grinder and Its Main Specifications

Figure 1 is a line arrangement diagram of a coil buildup line. **Figures 2** and **3** are side view schema of the coil edge grinder and a schematic diagram of section A-A from Fig. 2, respectively.

The main specifications of the coil edge grinder are indicated in **Table 1**.

3 Measures Taken to Solve Problems Encountered in the Development of the Coil Edge Grinder

The requirements for grinding the mill edges of a hot rolled coil travelling at a speed of 40 m/min by about 0.5 mm by grinding wheels[2] involved various problems that were not experienced in the conventional grinding methods. The main problems, which were encountered in the development of the coil edge

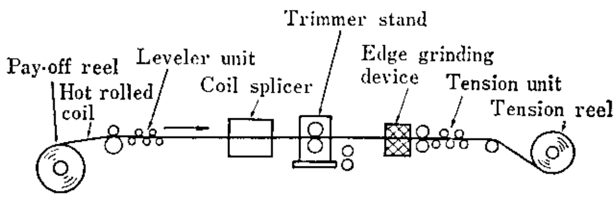

Fig. 1 Schema of edge grinding device

* Originally published in *Kawasaki Steel Giho*, **13** (1981) 2, pp. 313–319
** Hanshin Works
*** Chiba Works

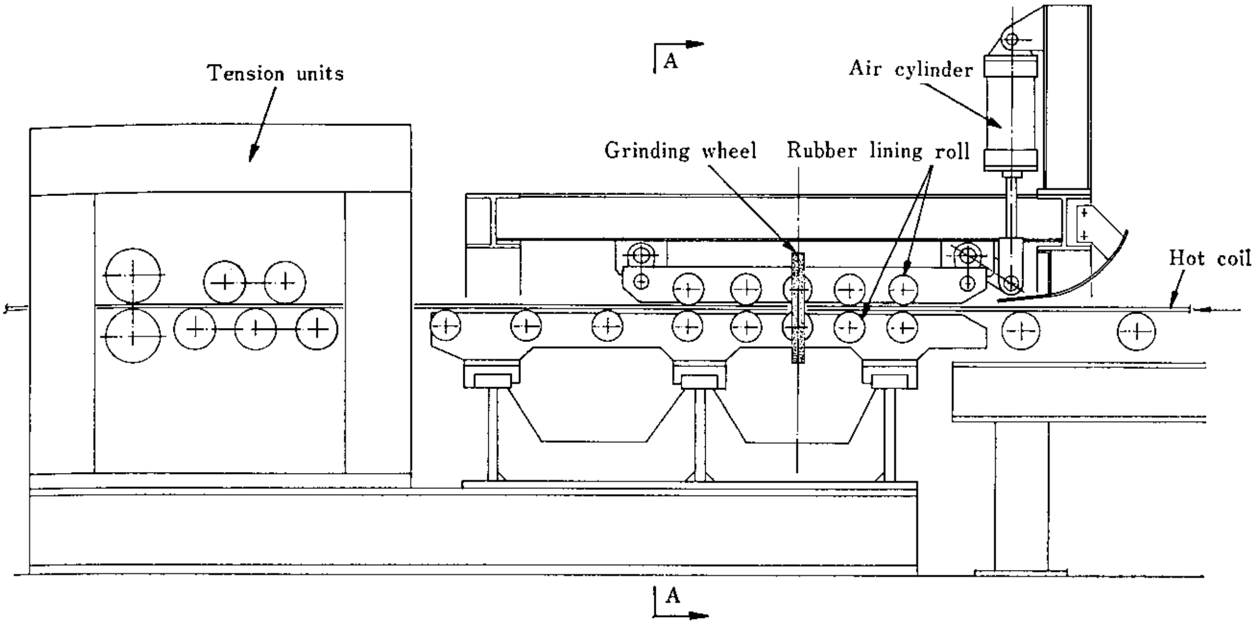

Fig. 2 Arrangement of edge grinder

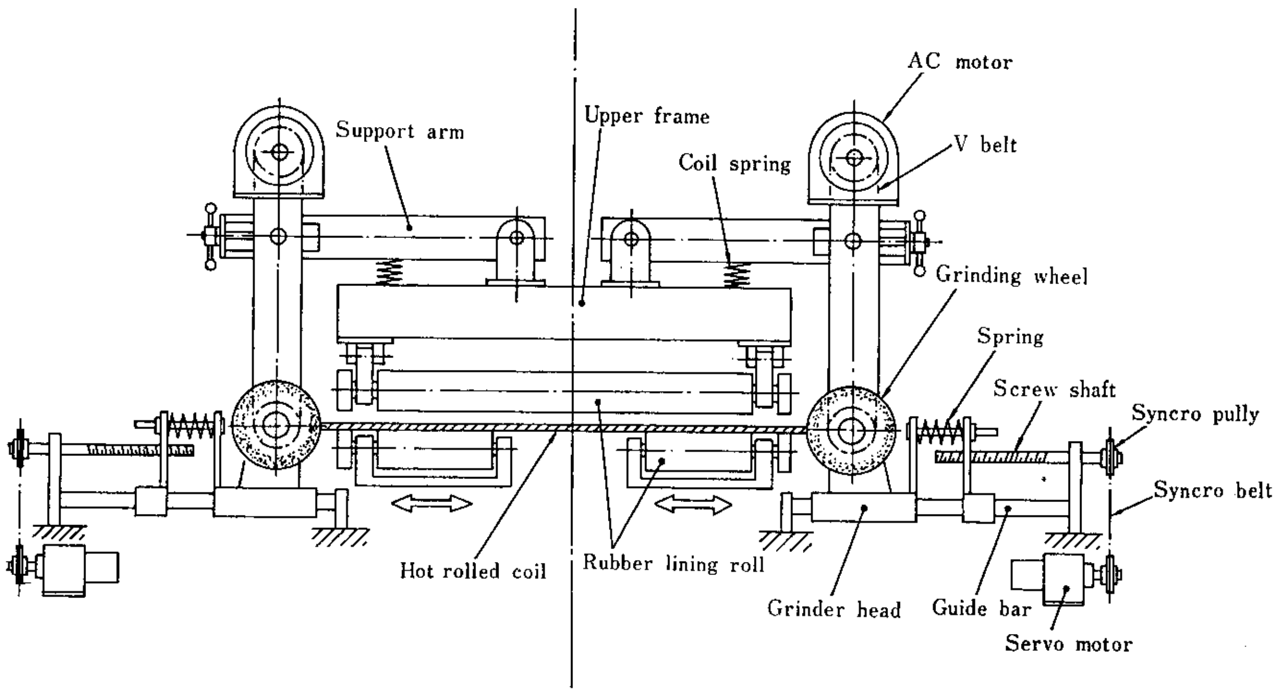

Fig. 3 A-A section shown in Fig. 2

grinder, and the measures taken to solve them will now be explained.

3.1 Selection of Type of Grinding Wheel and Determination of Grinding Direction

The results of the investigations[3,4] and the grinding experiments using grinding wheels of a disk type and flat type are illustrated in **Fig. 4**. The results showed that the former had the following disadvantages by comparison with the latter.

(1) The strip being ground vibrated a lot, causing greater grinding noise.
(2) The strip being ground needed to be guided

Table 1 Specification of edge grinder

Equipment	Item	Specification
Edge grinder	Grinding motor	A.C.7.5kW, 2p, 220V, 3 600rpm.
	Grinding wheel	O.D. 305mmϕ
		I.D. 50.8mmϕ
		Width 38mm
	Spindle revolution	3 100rpm
	Grinding pressure	0~50kg by Spring
	Guide roll	Rubber lining roll O.D. 90mmϕ
	Grinding direction	Down cut at vertical
	Grinding speed	3 000m/min
	Line speed	Max. 40m/min
	Coil width	1 040mm~1 270mm
	Coil thickness	3.0mm~4.5mm
Servo mchanism	Servo motor	D.C.1.5kW. 3 000rpm. Reduction ratio 11 : 1
	Servo amp	Power transistor. D.C.146V. Speed control Ratio 500 : 1
		Speed fluctuation ratio 1 000 : 1

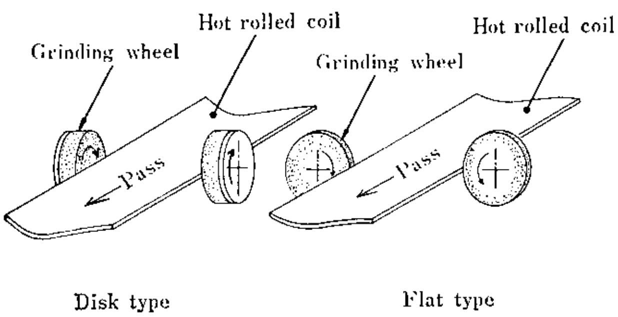

Fig. 4 Grinding wheel form

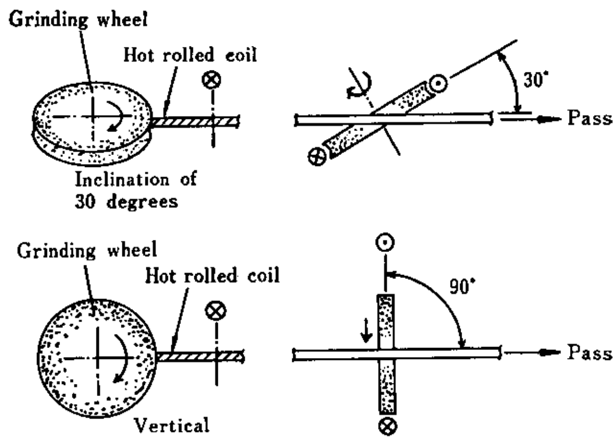

Fig. 5 Grinding direction

accurately.
(3) More grinding power was required.

Therefore, adoption of the flat type grinding wheel was determined upon.

Two methods for bringing the grinding wheel into contact with the strip edge were examined, one with a 30° wheel inclination and the other without wheel inclination, that is perpendicular to the strip pass line, as shown in **Fig. 5**.

In the former case, although the grinding noise was lower and there was less strip vibration than the latter, the center of the wheel wore in a hyperbola-like form, resulting in a rounded strip edge which was unsuitable for cold rolling. Therefore, the perpendicular contact model was selected.

It was also decided to provide two grinding wheels, one at each strip edge, to grind both edges simultaneously, and to rotate the wheels in the downward cutting direction in order to control strip vibration.

3.2 Selection of Grinding Wheel

The grinding ratio which means the amount of scale ground from the strip edge to the amount worn from the grinding wheel was adopted as a yardstick for grinding wheel selection[5,6]. This ratio is useful for discovering the amount ground per unit cost of one grinding wheel and comparing it with other cases. However, the grinding speed is not taken into account[7] and it has been said that the cost of a grinding wheel generally accounts for 4 to 6% of the total grinding cost. Therefore, taking account of the results of the experiments, the grinding ratio was aimed to somewhere around 7–10 adopting a grinding wheel, of abrasive type A, grain size 36 and bonding degree P.

3.3 Grinding Power

The power required for grinding was estimated when the grinding motor was selected.

The following equations[8] were adopted to calculate the grinding power.

$$F_t = E \cdot \Delta \cdot b \cdot v / V \quad \cdots\cdots (1)$$

$$P = F_t \cdot V / 612\,000 \quad \cdots\cdots (2)$$

F_t: Grinding resistance in grinding direction (kgf)
E: Specific grinding energy (kgf·cm/cm^3)
Δ: Grinding quantity (cm)
b: Grinding wheel width (cm)
v: Strip travelling speed (cm/min)
P: Grinding power (kW)
V: Peripheral speed of grinding wheel (cm/min)

When the strip to be ground is of AISI 304 and the chips from the grinding are coarse,

$$E = 1.55 \times 10^5 \text{ kg·cm/cm}^3 \text{ [3,8]}$$

then, according to the above eqs. (1) and (2),

$$F_t = 1.55 \times 10^5 \times 0.05 \times 0.35 \times 4\,000 / 300\,000 = 36.2$$

$$P = 36.2 \times 300\,000/612\,000 = 17.7 \text{ kW}$$

The result of the experiments, however, showed that 50% of the estimated power above was sufficient for the grinding. Therefore, 7.5 kW was adopted for the coil edge grinder.

3.4 Method of Compressive Contact of Grinding Wheel with Strip Edge

To obtain compressive contact of the grinding head with the strip edge, a coil spring has been finally adopted between the grinding head and the screw shaft, as shown in Fig. 3. The purpose of using such a coil spring is to grind the strip edge smoothly even when an excessive concavity (3 mm deep and less than 20 mm wide) or a notch exists at the edge. The spring is also necessary to absorb the minute vibrations of the grinding head caused by the crushing of abrasives during the grinding. The selection of the spring was made in accordance with the analyses and experiments conducted during the designing of the grinding quantity control system which will be explained later. As a result of the adoption of the spring, it has been found that the spring has a great effect and may be indispensable for smooth grinding.

3.5 Control of Grinding Amount

The forwards and backwards movement of the grinding head should be controlled to ensure that the grinding head follows the meandering of the strip edge and thus maintain a constant grinding depth.

Control of the grinding head position by directly detecting a grinding depth of about 0.5 mm, however, involves many problems such as change of the wheel

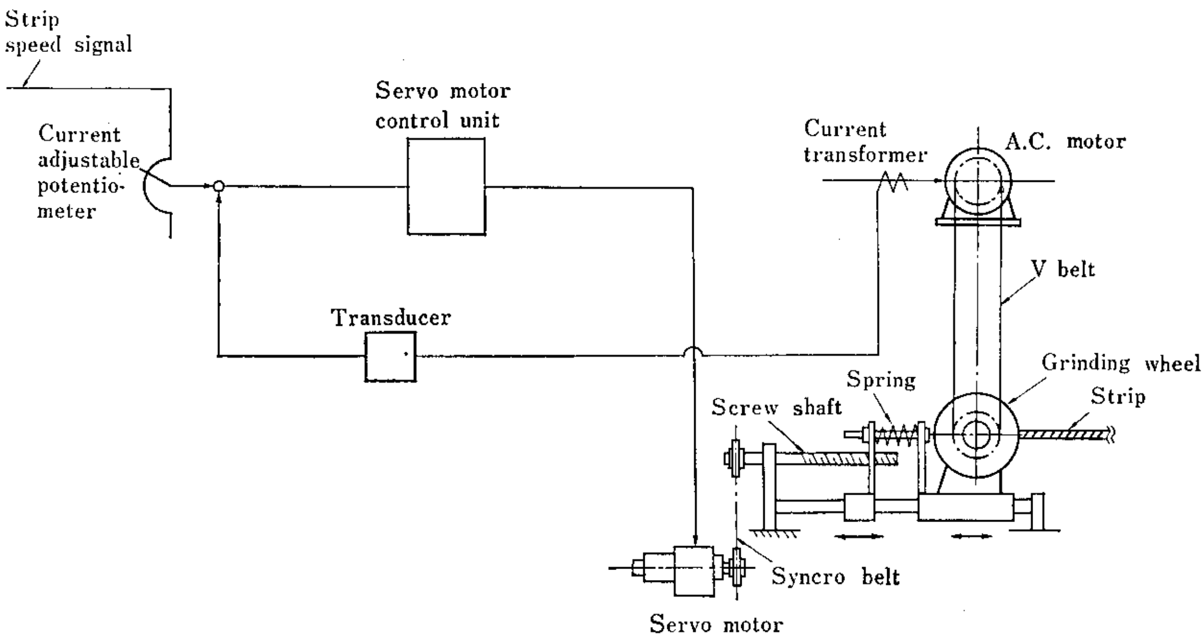

Fig. 6 Circuit diagram of automatic grinding current control

diameter, variation of grinding load, etc. which affect the stability of control. The following method has therefore been adopted. On the assumption that the grinding depth is proportionate to the grinding amount per length of time and that this grinding amount is proportional to the grinding current when the hot rolled strip speed is constant, the grinding current and the grinding depth have been made constant.

The circuit diagram of the automatic control of the grinding current is shown in **Fig. 6**.

A $\pm 5\%$ accuracy in the automatic control of the current was aimed at.

Since such problems as the primary lag of response of the grinding motor current, secondary vibration of the spring and the mass variation involved in grinding current control did not permit a high loop gain, the targeted accuracy of $\pm 5\%$ which gives loop gain cf $6\ s^{-1}$ has been finally adopted.

3.6 Reduction of Friction Loss and Weight

The friction loss and weight of the moving parts should be reduced to improve the control accuracy of the amount ground.

In order to minimize friction resistance the grinding head has been mounted on two sliding bars and linear motion ball bearings have been used at the sliding parts to enable it to follow the strip edge exactly. The forwards and backwards movements of the grinding head which control the amount of grinding are performed through the coil spring by rotating screw shafts powered by a servo motor.

Since the grinding wheel's spindle driving motor, pulleys and motor mounting frame together weigh more than 100 kg, the motor and the grinding head have been provided separately to reduce the weight and to assist the grinding head to follow the meandering strip. The movable parts are connected with pins and suspended from a horizontal beam supported by coil springs.

3.7 Measures for Coping with Grinding Wheel Breakage

As strip edge grinding continues, the temperature of the grinding wheel gradually rises. If the grinding wheel is backed to terminate the grinding without stopping the wheel rctation, only the outside surface of the wheel cools rapidly, the wheel temperature distribution becomes uneven, thermal strain is caused and the wheel cracks from the periphery, resulting in destruction of the wheel. This was learned after many grinding experiments.

The results of measurement by a contact pyrometer of the grinding wheel temperature 1 min after and about 6 min after stopping the rotation of a wheel which continuously ground a coil of about 400 m, are shown in **Fig. 7**.

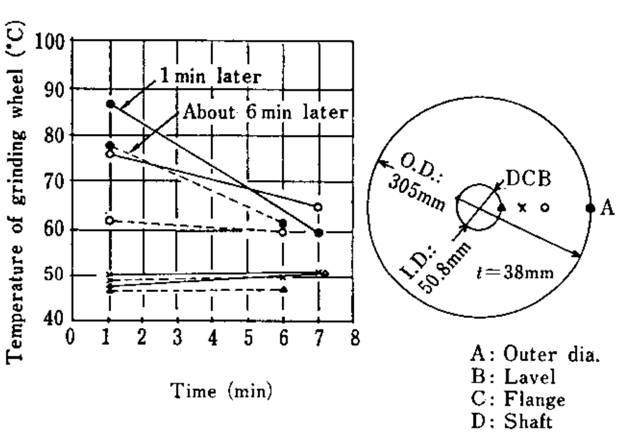

Fig. 7 Temperature change of grinding wheel surface

It is known that the grinding wheel breaks on account of thermal stress when the temperature difference is more than 90°C. In the above experiments, the wheel broke at temperature differences ranging from 30° to 35°C. This was attributable to the centrifugal force in addition to the thermal stress applied to the wheel.

Taking account of the view that breaking of the wheel ascribable to thermal stress could be prevented when the rapid cooling of the wheel's peripheral surface was avoided, wheel rotation was stopped when grinding was suspended, and this solved the problem. The damage described above has never occurred on almina grinding wheels either.

4 Auxiliary Equipment for the Coil Edge Grinder

4.1 Grinding Wheel Diameter Detector

Since the grinding wheel diameter is reduced because of abrasion when the wheel grinds coil edges, a wheel diameter detector has been provided in order to calculate the wheel life in advance and maintain the wheel's peripheral speed. The outline is shown in **Fig. 8**.

The detector consists of a touch roll, which comes into contact with the ground strip edge, a sliding rod and a differential transformer, which measures the reduction of wheel diameter. The touch roll is lightly pushed toward the strip edge by a coil spring so that the roller always touches the strip edge. Further, since the detector and the bearing of the wheel spindle are mounted together on a common, movable stock and thus the detector can continuously measure the wheel diameter as it is abrased.

4.2 Edge Shape Detector

The operation of the coil edge grinder has possibilities of a grinding wheel breakage resulting from serious defects in strip edge, such as the cracks and

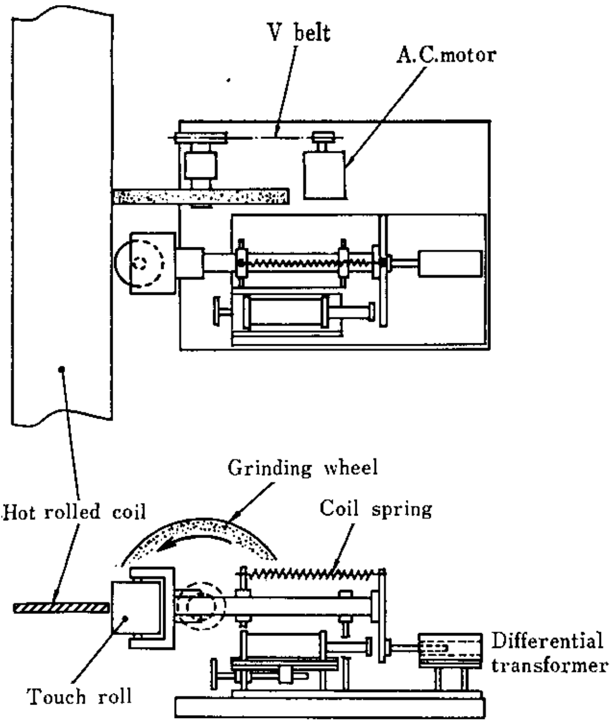

Fig. 8 Grinding wheel diameter detector

edge bands, which is peculiar to hot rolled coils. This might lead to operational danger, an increase in unit consumption, and a decrease in productivity.

It is, therefore, important to detect beforehand the state of the edge of the hot rolled coil (concavities and notches) to avoid the above problems.

The edge shape detector adopted for the coil edge grinder can detect any concavity in a strip edge measuring more than 3 mm in depth and more than 20 mm in width. These dimensions have been determined with a view to preventing a grinding wheel of 38 mm in width from dipping into a concavity in a strip. The outline of the edge shape detector is shown in **Fig. 9**.

5 Operation results

The production of edge ground coils of AISI 430 (ferrite series stainless steel) in Hanshin Works has been increased through the adoption of the coil edge grinder. As a result of the introduction of the coil edge grinder, the yield of the cold rolling production at the skin pass process stage has been improved by 3 %. Further experiments and investigations are being conducted to widen the applicability of edge grinding to other steels.

A patent and a utility model on the application of this coil edge grinder have been published in Japan and in eight other countries.

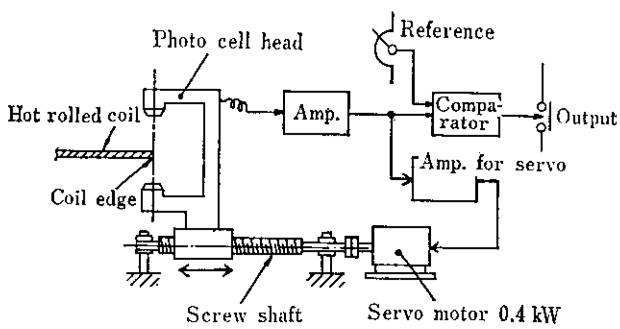

Fig. 9 Edge shape detector

6 Summary

The task of eliminating microcracks at the edges of a hot rolled coil travelling at a speed of 40 m/min began with a study of the best way to use the grinding wheel. As a result, the vertical weight on the sliding bars was reduced and coil springs were adopted to give cushioning and the necessary pressure for the grinding wheel. The coil edge grinder was developed for the practical use after solving such problems as grinding wheel breakage due to thermal strain and the discovery of an edge shape detection method.

In concluding this report, the authors wish to express their thanks to the members of Kurenorton Co., Ltd. for their kind cooperation in the development of the coil edge grinder.

References

1) T. Yamamoto, et al.: *Mitsubishi Denki Giho*, **46** (1972) 11, pp. 1 340–1 346
2) A. Isozaki, et al.: Grinder Handbook, Safety Section, Industrial Safety and Health Dept., Ministry of Labour of Japan, (1972), pp. 1–183 (Japan Industrial Safety and Health Association)
3) G. Stetiu, G.K. Lal: *Wear of Grinding Wheel*, **30** (1974), pp. 229–236
4) S.K. Bhattacharyya, V.L. Moffatt: "Characteristics of Micro Wheel Wear in Grinding", *Int. J. Mach. Tool. Des. Res.*, **16** (1976), p. 325
5) K. Kishi: "Grinding of non-machinability material", *Journal of the Japan Society of Precision Engineering*, **39** (1973) 2, pp. 178–185
6) S. Okada: "Characteristics and Selection of Grinding Wheel", *Science of Machine*, **27** (1975) 12, pp. 1 475–1 479
7) T. Matsuo, "Recent Tendency of Heavy Grinding", *Machine and Tool*, **20** (1976) 5, pp. 61–68
8) Milton C. Shaw: "How to Estimate Grinding Forces and Power", *Machinery*, (1968) 3, pp. 85–87
9) T. Takazawa: "Present and Future Processing Technique by Abrasive", *Journal of The Japan Society of Mechanical Engineers*, **80** (1977) 704, pp. 31–34
10) Kawasaki Steel Corp.: Japan Patent Laid Open Application No. 113 396-'78
11) Kawasaki Steel Corp.: Japan Utility Model Laid Open Application No. 162 996-'79