(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 591 589 A1**

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **92402731.1**

(51) Int. Cl.5: **B21D 1/02**

(22) Date of filing: **07.10.92**

(43) Date of publication of application:
13.04.94 Bulletin 94/15

(84) Designated Contracting States:
DE FR GB

(71) Applicant: **SUMITOMO METAL INDUSTRIES, LTD.**
5-33, Kitahama 4-chome
Chuo-ku
Osaka-Shi Osaka 541(JP)

(72) Inventor: **Isaka, Kazumi**
6-9-9-204, Minami-Tsukaguchi-cho
Amagasaki-shi, Hyogo-ken(JP)

(74) Representative: **Schrimpf, Robert et al**
Cabinet Regimbeau
26, Avenue Kléber
F-75116 Paris (FR)

(54) **Metal plate levelling method and apparatus.**

(57) A method and apparatus for levelling a metal plate (5), in which levelling or levelling and heat treatment before and after levelling is performed while directly supplying an electric current to the metal plate through a work roller and/or pinch roller provided on the downstream or upstream side of the work roller, which are connected to an electric source (3) and used as an electrode.

EP 0 591 589 A1

The present invention relates to a metal plate levelling and apparatus in which a metal plate, such as a hot-rolled or cold-rolled steel plate, sheet, or strip having a relatively large thickness, is heated to a predetermined temperature by directly applying an electric current to the metal plate, sheet, or strip so as to perform levelling or levelling + heat treatment. Metal plate, metal sheet, and metal strip are collectively referred to as metal plate hereunder.

As a metal plate levelling apparatus, a roller leveler and tension leveler are widely used. A roller leveler comprises upper and lower rollers which are arranged in staggered form. A metal plate is passed through the rollers and is bent repeatedly upward and downward so as to perform correction of shape. A tension leveler is a machine in which a metal plate is repeatedly bent upward and downward under application of tension to the metal plate. They are referred to merely as "levelers" hereunder.

When defects in the shape of a metal plate such as a camber, edge wave, and middle waviness are corrected by using a leveler, levelling can be performed by way of applying a large amount of tension or reduction to the metal plate. However, such a method requires a leveler of a large scale which also requires a large space for the machine, resulting in an increase in initial and running costs.

Another approach to increase the levelling effect is to heat the metal plate So as to decrease the deformation resistance of a metal plate. An article titled "Development of New Type Leveler for Thick Plate" in "Plasticity and Working" vol.29, No.333, pp.1010-1015 discloses a method of effecting levelling of a metal plate after heating it. According to this article, elongation of a metal plate increases as the temperature thereof increases even when a small amount of tension is applied to the metal plate. This means that it is possible to provide a leveler which can be operated under small tension, i.e., a small-sized and economical leveler, if the levelling is carried out on a metal plate kept at a high temperature.

For the purpose of effecting levelling of a metal plate under hot conditions, many approaches have been conceived, including levelling before coiling a hot-rolled metal plate or levelling after re-heating a metal plate in an off-line furnace of the batch-type.

However, there are temperature differences between central and edge portions in the widthwise direction of a metal plate just after hot rolling. Though the surface of the metal plate after levelling might appear to have become flat, a relatively large amount of stresses remain within the plate. Such residual stresses are released when the metal plate is cut with a shearing machine or punched by a press, resulting in formation of cambers. On the other hand, when a metal plate is heated off-line, there is a need to provide an additional heating furnace, and sometimes the temperature of a metal plate drops to some extent until levelling is carried out, so that sufficient levelling is not achieved. On-line heating with an induction heating means is also possible. However, induction heating requires a complicated control system and is expensive, and the heating efficiency is not high. In this case, a temperature drop before levelling is inevitable, and it is rather difficult to maintain a temperature suitable for levelling.

Today not only a complete apparent flatness but also a minimum residual stress are required for metal plates from the viewpoint of achieving labor savings and manufacturing automation. If a substantial amount of stress remains within a metal plate, the stress is released to produce a camber during cutting or punching of the plate. When metal plates having cambers are used, troubles during travel, weld defects due to the occurrence of a large gap between welding pieces, and an increase in man-hours are inevitable.

An object of the present invention is to provide a method and apparatus for efficiently carrying out levelling by heating a metal plate to be treated to a temperature suitable for effecting levelling in a levelling line.

According to the present invention, work rollers of a roller leveler, tension leveler, and the like, i.e., leveler rollers are used as electrodes, and an electric current is directly supplied to the metal plate to be treated. Pinch rollers provided outside the leveler may also be used as electrodes. It is easy to carry out efficient heating and precise temperature control when such a direct application of electric current to the metal plate is employed.

Thus, in one aspect, the present invention is a method of levelling a metal plate characterized in that levelling or levelling and heat treatment before and after levelling is performed while directly supplying an electric current to the metal plate through a work roller and/or pinch roller provided on the downstream or upstream side of the work roller, which are connected to an electric source.

In another aspect, the present invention is a metal plate levelling apparatus comprising at least two work rollers and an electric source which is connected to the work rollers to directly supply an electric current to a metal plate.

In still another aspect, the present invention is a metal plate levelling apparatus comprising at least one work roller, at least one pair of pinch rollers provided on the inlet or outlet side of the work roller, and an electric source which is connected to the work roller or pinch rollers, or both to directly apply an electric current to a metal plate.

Figure 1 is a schematic side view of a levelling apparatus of the present invention in which two work rollers are used as electrodes.

Figure 2 is a schematic side view of a levelling apparatus of the present invention in which one pair of pinch rollers and a work roller are used as electrodes.

Figure 3 is a schematic side view of a levelling apparatus of the present invention in which two pairs of pinch rollers are provided on the upstream side of a work roller and are used as electrodes.

Figure 4 is a schematic side view of a levelling apparatus of the present invention in which one work roller and one pair of pinch rollers provided on the downstream side of a work roller are used as electrodes.

Figure 5 is a schematic side view of a levelling apparatus of the present invention in which two pairs of pinch rollers are provided on the downstream side of a work roller and are used as electrodes.

Figure 6 is a schematic side view of a levelling apparatus of the present invention in which a pair of pinch rollers is provided on both the upstream side and downstream side of a work roller, respectively, and each pair is used as electrodes.

Figure 7 is a schematic side view of a levelling apparatus of the present invention in which a pair of pinch rollers is provided on both the upstream side and downstream side of a work roller, respectively, and each pair is used as electrodes together with the corresponding work rollers.

Figure 8 is a schematic side view of a levelling apparatus which is used in a working example of the present invention.

Figure 9 is an illustration of shape defects such as edge waviness.

Figure 1 shows a levelling apparatus which comprises at least two work rollers used as electrodes.

In Figure 1 a steel plate S is travelling in the direction shown by the arrow through a leveler 1 in which it is subjected to levelling. The leveler comprises a plurality of work rollers 2-1, 2-2, 2-4, - - - -, 2-n. The steel plate S is bent upward and downward repeatedly to flatten it. Additional tension rollers (not shown) may be provided before or after the leveler 1 so as to apply tension to the metal plate.

Work roller 2-1 and work roller 2-4 serve as electrodes and are connected to an electric source 3. In this case it is necessary to electrically insulate intermediate work rollers 2-2 and 2-3 from the roller stand. The electric current may be an alternating or direct current. When the electric current is directly supplied to the metal plate S, Joule heat is generated in the metal sheet between the work rollers 2-1 and 2-4 to heat it. Any two of the work rollers may be used as a pair of electrodes.

Figure 2 shows another levelling apparatus which comprises a pair of pinch rollers provided upstream of the leveller and at least one work roller used as electrodes.

In Figure 2, a pair of pinch rollers 4 and a work roller 2-4 are used as electrodes. Needless to say, a work roller other than work roller 2-4 may be used as an electrode. In order to further increase the temperature of the metal sheet, additional work rollers 2-8 and 2-n may be used as supplementary electrodes, as illustrated by dashed lines.

Figure 3 shows still another levelling apparatus which comprises at least two pair of pinch rollers used as electrodes, the pinch rollers being provided on the inlet side of the leveller 1.

In Figure 3, two pairs of pinch rollers 4-1 and 4-2 provided on the inlet side, i.e., upstream of the leveller are used as electrodes. A metal plate S is heated by supplying an electric current between these pairs of pinch rollers. It is advisable to set up the pinch rollers 4-2 as close as possible to the leveller 1. If the metal plate S is heated thoroughly before going into the leveler, levelling can be done at a relatively high temperature. Since the temperature of the metal plate is decreased when it contacts the work roller within the leveller, it is also advisable to re-heat the metal plate by supplying an electric current between work rollers 2-4 and 2-8, for example, as illustrated by dashed lines.

Figure 4 shows still another levelling apparatus which comprises at least one work roller and a pair of pinch rollers used as electrodes.

In Figure 4, a pair of pinch rollers 4 which are positioned on the outlet side, i.e., downstream of a leveller 1 is used as electrodes, and a work roller 2-n which is positioned closest to the outlet of the leveller 1 is used as an electrode. If necessary, any other of the work rollers may instead be used as an electrode.

In this embodiment levelling itself is carried out under usual conditions without heating the metal plate S, but the metal plate is subjected to heat treatment after levelling. The heat treatment includes heating, for example, to release residual stresses and improve the metallurgical properties of the plate.

When a work roller positioned upstream of the work roller 2-n is used as an electrode in place of work roller 2-n, the levelling can be achieved under hot conditions. Alternatively, if necessary, any two other work rollers, e.g., work rollers 2-4 and 2-8, may be used as additional electrodes as shown by the dashed line in Figure 4 in order to heat the metal plate while it is passing through the leveller 1.

Figure 5 shows a levelling apparatus which comprises at least two pairs of pinch rollers used as electrodes and positioned on the outlet side of a leveller.

In Figure 5 two pair of pinch rollers 4-1 and 4-2 are used as electrodes and are disposed so as to heat a metal plate S for effecting heat treatment of the metal plate S after levelling thereof. In this case, too, any two other work rollers, e.g., work rollers 2-4 and 2-8, may be used as additional electrodes as shown by the dashed line in Figure 4 in order to carry out levelling of the metal plate under hot conditions.

Figure 6 shows a levelling apparatus using, as electrodes, two pairs of pinch rollers. One pair is positioned on the inlet side and the other one is on the outlet side of the leveller.

In Figure 6 two pairs of pinch rollers 4-1 and 4-2 are used as electrodes. Since a metal plate S is heated while it is passing between the pinch rollers 4-1 and 4-2, the entire levelling process of the metal plate S can be carried out under hot conditions. However, in this arrangement it is necessary to electrically insulate all of the work rollers of the leveler 1 from the roller stands, requiring some additional costs.

Figure 7 shows a levelling apparatus which uses, as electrodes, a pair of pinch rollers positioned on the inlet side of a leveler, another pair of pinch rollers positioned on the outlet side of the leveller 1, and at least two work rollers each corresponding to the pairs of pinch rollers, respectively.

In Figure 7 two pairs of pinch rollers 4-1 and 4-2 as well as corresponding work rollers 2-1 and 2-n, for example, are used as electrodes. It is possible to efficiently carry out levelling and heat treatment before and after levelling using a levelling apparatus of this type.

As is apparent from the embodiments shown in Figures 1 - 7, according to the levelling method of the present invention an electric current is directly supplied to a metal plate through rollers which contact the metal plate in order to heat it. When a work roller is used as one of the electrodes, there is no need of a space for a heating apparatus. On the other hand, when a pinch roller provided outside of the leveller is used as one of the electrodes, the pinch roller is just required to contact a metal plate uniformly in the widthwise direction. Therefore, a small diameter roller, such as rollers of 100 - 200 mm in diameter, can be used, making the levelling apparatus simple and small. Compared with the costs required to set up an off-line heating furnace or to provide the levelling line with an induction heating apparatus, the initial costs of the levelling apparatus of the present invention are much smaller and the process does not need any additional space. Furthermore, in an embodiment in which a work roller is used as an electrode, a metal sheet is heated to a maximum temperature just before it reaches the work roller, and excess heating of a metal plate to compensate for a temperature reduction, which is inevitable during travel to a work roller in a heating furnace method, is not necessary.

In general, it is rather difficult to electrically insulate rotating members such as rollers. In the apparatus shown in Figure 7, for example, it is possible to electrically insulate pinch rollers 4-1 and 4-2 and to use work rollers without insulation. Insulation of the pinch rollers is very easy since the pinch rollers are simple and of the non-driven type. Supply of an electric current to rollers can be achieved by means of a copper brush.

When an electric current is passed through a metal plate between roller electrodes, Joule heat in an amount proportional to the product of I^2 (I: electric current) X R (R: resistance of a metal plate between the roller electrodes) is generated. Due to the generation of Joule heat, the metal plate is heated rapidly to a high temperature which can be controlled easily and precisely by varying the electric current. Thus, according to the present invention levelling and heat treatment can be done at a temperature most suitable for a metal plate to be treated. A temperature difference in the widthwise direction does not occur at all.

Furthermore, according to the present invention a residual stress which appears in the metal plate after levelling is suppressed thoroughly. With a levelling apparatus such as shown in Figures 4 - 7, a metal plate is heated after levelling and is substantially totally free from residual stress.

The method of the present invention is applicable to any metal plates of the type which can be heated when an electric current is supplied. Examples of such metal plates are steel plates, such as carbon steel plates, low-alloy steel plate, stainless steel plates, titanium plates, and titanium alloy plates.

The present invention will be further described in conjunction with working examples which are presented merely for illustrative purposes and are not intended to limit the present invention in any way.

Example 1

A levelling apparatus having five work rollers like that shown in Figure 8 was used to carry out a levelling method of the present invention.

In Figure 8 a pair of pinch rollers 5 on the inlet side and a pair of pinch roller 6 on the outlet side are of the driven type, and a metal plate S is passed through the first pair of pinch rollers 5 into a leveler installed in a housing 7, in which the metal plate S subjected to levelling, preferably in an inert atmosphere, while it passes through work rollers 2-1, 2-2, 2-3, 2-4, and 2-5, of which the work rollers 2-1 and 2-5 are used as electrodes and are connected to an electric source 3. Work rollers 2-1 through 2-4 are electrically insulated

from the housing 7. The outermost work roller 2-5 is not insulated. When an electric current is supplied to a metal plate while it is travelling along a series of work rollers, an electric current passing in the metal plate generates Joule heat to increase the temperature thereof. In Figure 8 insulated work rollers are hatched.

Figure 9 shows shape defects appearing on a metal plate before levelling. Levelling effects are determined in terms of the height (H) of an edge wave of the metal plate S.

The dimensions and specifications of the levelling apparatus and revelling conditions employed are summarized below.

A. Leveler:

Number of work rollers:	five
Work roller diameter (D):	30 mm
Work roller pitch:	40 mm
Driving means:	pinch rollers

B. Metal Plate to be treated:

Material:	JIS SUS 304
Dimensions:	1 mm (thickness)X 150 mm (width)
Shape before levelling:	Height (H) of 5 mm (edge wave) (on average)

C. Levelling and Heating Conditions:

Heating system:	Heating between the work rollers
Distance between Electrode rollers (L):	120 mm
Electric Source:	60 Hz, 5 V, 2000 A
Temperature before Work Roller 2-5:	650 °C
Travelling Rate:	0.5 m/min
Intermesh between neighboring work rollers:	1 mm, the same as the thickness of metal plate

For comparison, the following two comparative examples were performed.

Comparative Example 1: A metal plate was supplied to the same levelling apparatus without heating.

Comparative Example 2: A metal plate was heated to 700 °C in an off-line furnace and then was supplied to the levelling apparatus.

Test results are summarized in Table 1.

Table 1

	Temperature of Metal Plate (℃)		Height (H) of Edge Wave (mm)	
	After Heating	After Levelling	Before Levelling	After Levelling
Invention	650	600	5	0.2
Comparative 1	20	20	5	4.5
Comparative 2	700	280	5	2.0

Note 1): A temperature after heating is determined by: the temperature just before the inlet of the leveler --- Present invention, room temperature --- Comparative Example 1, and the temperature in an off-line furnace --- Comparative Example 2.

2): The height (H) of an edge wave is an average of the heights on both edges of the metal plate.

As is apparent from Table 1, according to the present invention, since the levelling was carried out under hot conditions at a temperature of 650 - 620 °C under a low deformation resistance, the metal plate was flattened satisfactorily.

On the other hand, when the levelling was carried out at room temperature (Comparative Example 1), the metal plate was not flattened at all due to a strong deformation resistance.

In the case of Comparative Example 2 as well, a sufficient degree of levelling did not occur. Though the metal plate was heated to 700 °C in a heating furnace, due to the contact with transfer rollers and work rollers the temperature of the metal plate before levelling decreased, and a sufficient degree of levelling did not occur.

The temperature difference between the central area and edges of the metal plate was less than 7 °C in accordance with the present invention.

It was also experimentally determined that there were no sparks between the metal plate and rollers.

Thus, according to the present invention, the following advantages can be obtained:

1) It is possible to rapidly heat a metal plate just before levelling or during levelling in an optimum heating pattern, so that heat loss due to the contact with transferring rollers and work rollers can be minimized. Thus, deformation resistance during levelling can also be reduced efficiently, and an extremely high degree of levelling can be achieved.

2) Heat treatment, if necessary, can be carried out simultaneously, and when the heat treatment is done, the amount of residual stress in the metal plate after levelling can be decreased significantly.

3) In contrast to off-line furnace heating, it is easy to control the heating temperature precisely and heat loss can be reduced, resulting in a decrease in energy costs.

4) Levelling can be done smoothly and efficiently with an improvement in the flatness of metal plates.

5) The levelling apparatus of the present invention is compact and small-sized, and it does not need any additional space when the levelling apparatus is to be set up in a conventional levelling line.

Claims

1. A method of levelling a metal plate characterized in that levelling or levelling and heat treatment before and after levelling is performed while directly supplying an electric current to the metal plate through a work roller and/or pinch roller provided on the downstream or upstream side of the work roller, which are connected to an electric source and used as an electrode.

2. A method of levelling a metal plate as set forth in Claim 1 wherein at least two work rollers are provided and the work rollers are connected to the electric source to directly supply an electric current to the metal plate through the two work rollers which are used as electrodes.

3. A method of levelling a metal plate as set forth in Claim 1 wherein at least two work rollers and at least one pair of pinch rollers are provided and at least one work roller and the pinch roller are connected to the electric source to directly supply an electric current to the metal plate through the work roller and pinch roller used as electrodes.

4. A method of levelling a metal plate as set forth in claim 1 wherein at least two work rollers and at least two pairs of pinch rollers are provided and the pinch rollers are connected to the electric source to directly supply an electric current to the metal plate through the two pinch rollers used as electrodes.

5. A metal plate levelling apparatus comprising at least two work rollers and an electric source which is connected to said work rollers to directly supply an electric current to a metal plate.

6. A metal plate levelling apparatus comprising at least two work rollers, at least one pair of pinch rollers provided on the inlet or outlet side of the work roller, and an electric source which is connected to at least one of the work rollers, or the pinch roller, or both to directly supply an electric current to a metal plate.

7. A metal plate levelling apparatus comprising at least two work rollers, at least two pairs of pinch rollers, and an electric source which is connected to said two pairs of pinch rollers to directly supply an electric current to a metal plate.

8. A metal plate levelling apparatus as set forth in Claim 7 wherein said two pairs of pinch rollers are provided on the upstream side or downstream side of said work rollers.

9. A metal plate levelling apparatus as set forth in claim 7 wherein each pair of said two pairs of pinch rollers is provided on both the upstream side and downstream side, respectively.

Fig. 1

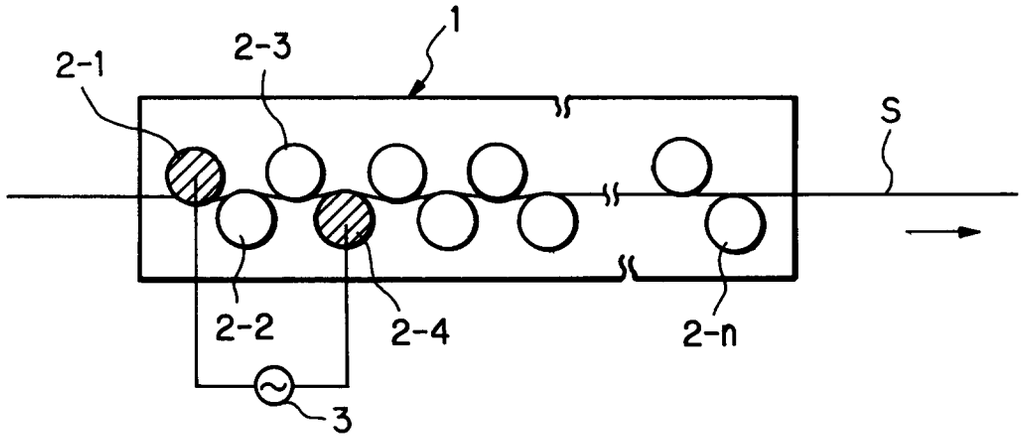


Fig. 2

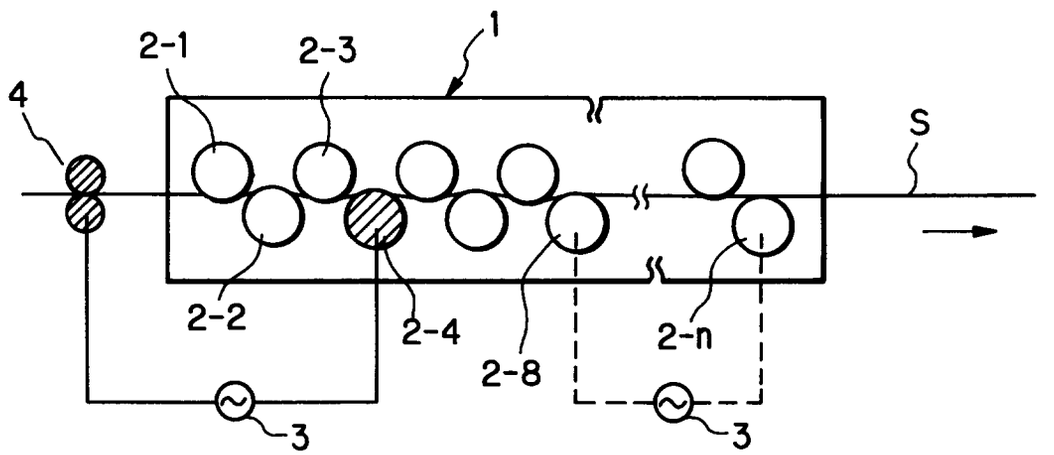


Fig. 3

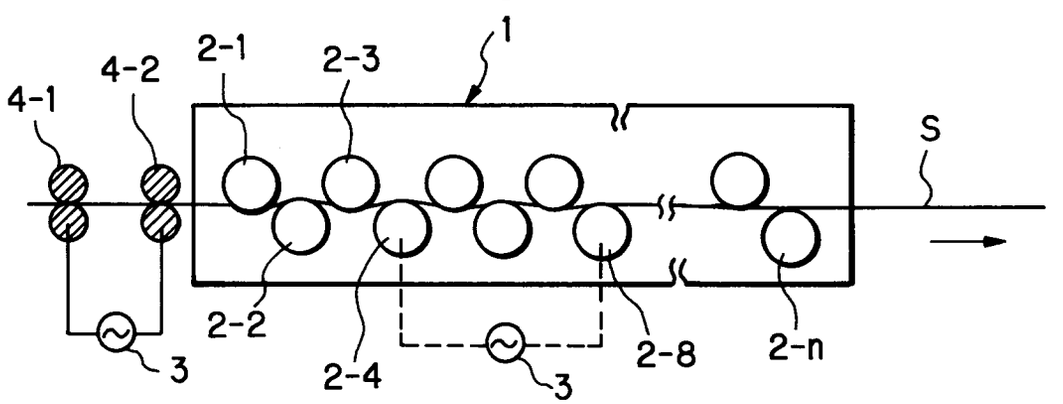


Fig. 4

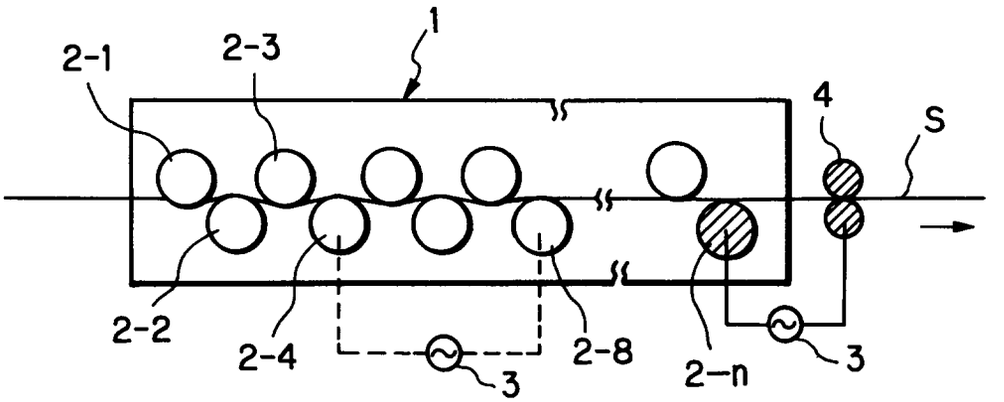


Fig. 5

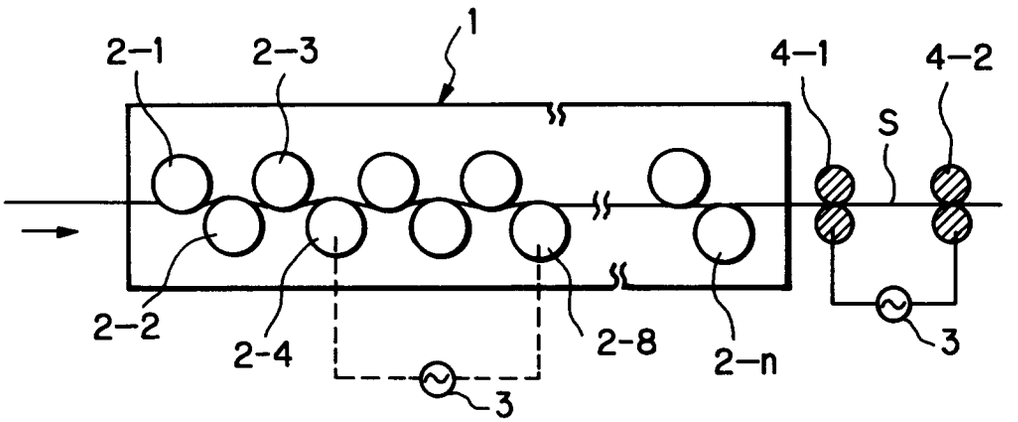


Fig. 6

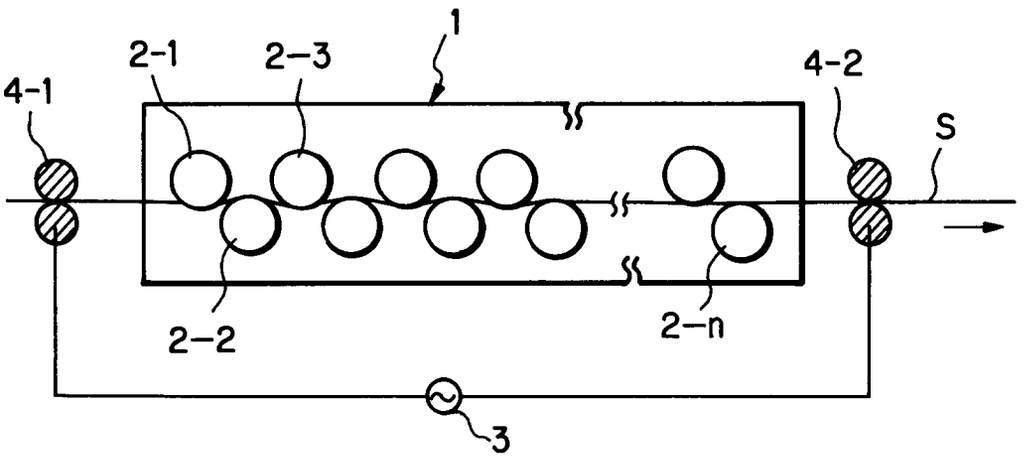


Fig. 7

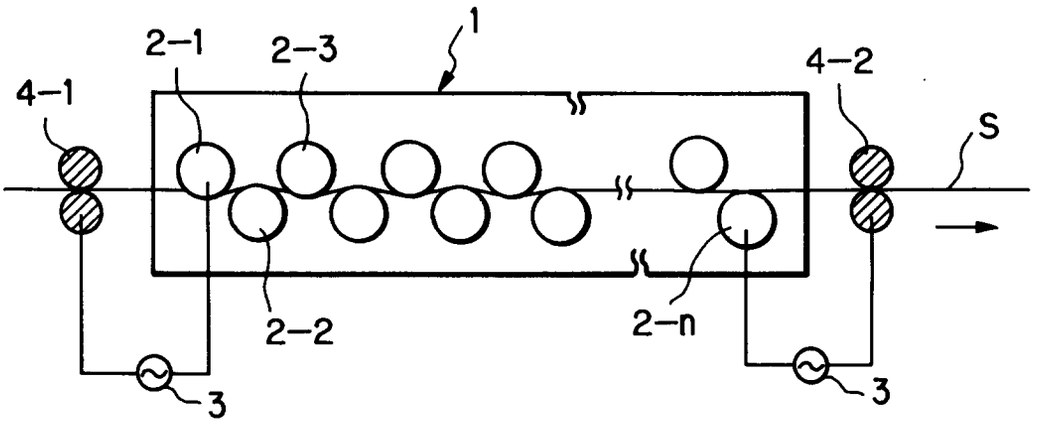


Fig. 8

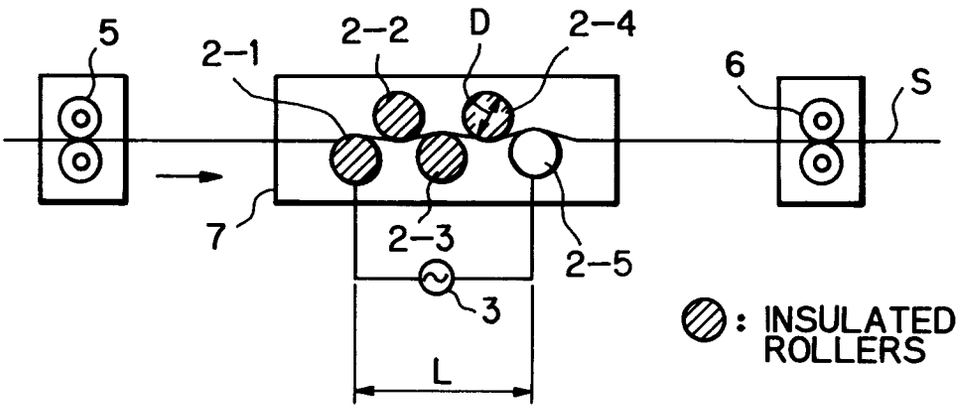
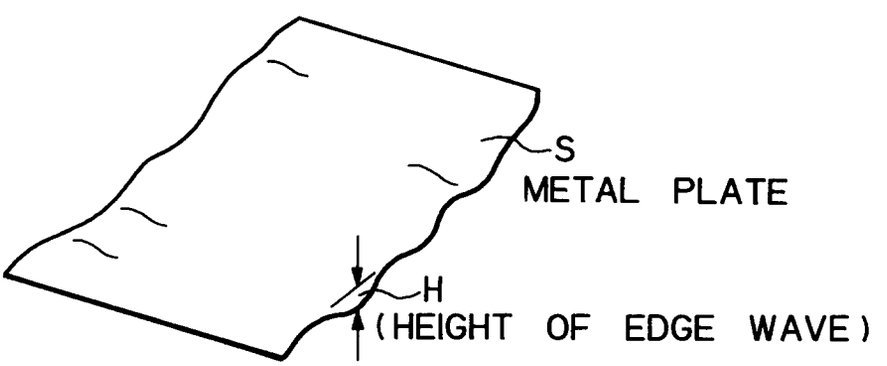


Fig. 9



European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 40 2731

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	US-A-1 347 917 (SHEPERDSON) * the whole document *	1-9	B21D1/02
Y	GB-A-882 756 (THE ARMCO INTERNATIONAL CORPORATION) * the whole document *	1-9	
A	DE-C-702 241 (VITS)		
A	FR-A-1 232 687 (WESTINGHOUSE ELECTRIC CORPORATION)		
A	GB-A-951 749 (ARMCO STEEL CORPORATION)		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B21D
B21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	07 JUNE 1993	PEETERS L.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P0401)