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(54) **Rolling process for clad steel.**

(57) A process for rolling a clad steel satisfactorily reduces the adverse influence of the difference of the deformation resistance of the metal layers composing the clad steel and thereby improves the yield of the rolling process. The rolling process for clad steel includes a step pre-form rolling for a length of 20% to 80% of the overall length of the clad steel. After pre-forming rolling, reduction rolling is performed at a draft substantially equal to or greater than the draft of the pre-form rolling. According to the invention, pre-form rolling process and reduction rolling process are performed for at least two passes.

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Description

ROLLING PROCESS FOR CLAD STEEL

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to a process for rolling a clad steel which combines iron base plate and stainless steel plate, cupronickel plate, monel metal plate, titanium plate, aluminium plate or the like. More specifically, the present invention relates to a hot rolling process for the clad steel which successfully avoids influence of difference of draft of the different materials of the clad steel.

Description of the Background Art

Generally, the different material metal plates composed into the clad steel have different deformation resistance in hot rolling. This causes a difference in drafts which redults in difference of rolling reductions. Therefore, thickness ratio of the different material plates is differentiated at the entrance of a rolling mill and at the exit thereof. Namely, the plate made of the material having smaller deformation resistance relative to the other, is reduced at greater magnitude than that of the other. This natually causes difference of expansion length of composed plates to lowering the yield of the hot rolling process. This is because the material having the smaller deformation resistance tends to flow toward the material having greater deformation resistance to form the single layer longitudinal ends where only the smaller deformation resistance material exists.

In order to eliminate influence of the difference in expansion rates between the material metal plates forming the clad steel, Japanese Patent First (unexamined) Publication (Tokkai) Showa 61-232003, published on October 16, 1986, discloses a process for rolling of clad steel, in which pre-form rolling is performed at least one of longitudinal ends. After pre-forming rolling, reduction rolling is performed for overall length of the clad steel. The publication further discloses that the preferred length of the end portion of the clad steel, for which pre-forming rolling is to be performed, is equal to the thickness of the clad steel at the maximum. When the shown process is practically applied to a clad slab, the section on which the perform pre-form rolling is performed, becomes less than 10% of the overall length of the slab. Furthermore, the above-mentioned prior proposal suggests the process of pre-fom rolling to reduce the thickness of the corresponding to the thickness of the final product. Therefore, in many case, substantial reduction is performed one pass of pre-form rolling. This conventional process including pre-form rolling for the longitudinal end did not satisfactorily avoid the adverse influence of the expansion rates of the difference deformation resistance of the materials from which the clad steel was formed.

Furthermore, when hot rolling was experimentarily performed according to the process proposed in the aforementioned publication, the portion where the thickness ratios of the layers forming the clad metal fluctuates and is not maintained constant. The thickness ratio of the layers will be hereafter referred to as "clad ratio" are formed at the longitudinal ends. The portion where the clad ratio fluctuates, will be hereafter referred to as "uneven clad ratio portion". By the presence of this uneven clad ratio portions, yield of the hot rolling of the clad steel is degraded even though attempt is made for improving yield.

SUMMARY OF THE INVENTION

Therefore, it is an object of the present invention to provide a process for rolling a clad steel which satisfactorily reduces the influence of the difference between the deformation resistances of the material metals composing the layers in the clad steel and can improve yield of rolling.

In order to accomplish aforementioned and other objects, in a rolling prcess for a clad steel, according to the present invention, pre-form rolling is performed over 20% to 80% of the overall length of the clad steel. After pre-form rolling, main reduction rolling is performed at a draft substantially equal to or greater than a draft of the pre-forming rolling. According to the invention, pre-form rolling process and reduction rolling process are performed for at least two passes.

According to one aspect of the invention, a process for rolling an elongate clad steel composed of a first layer of a first material and a second layer of a second material which has lower malleability than that of the first material, comprises the steps of:
performing pre-form rolling at a first given draft from one longitudinal end of the elongated clad steel for 20% to 80% of the overall length of clad steel;
performing reduction rolling for a second given draft which is greater than or equal to the first given draft from the other longitudinal end of the elongated clad steel for rolling; and
repeating the cycle of the pre-form rolling and reduction rolling at least for two cycles.

The reduction rolling is performed on the portion of the clad steel maintained unrolled or, alternatively, for over entire length of the clad steel.

According to another aspect of the invention, a process for rolling an elongate clad steel composed of a first layer of a first material and a second layer of a second material which has lower mallerability than that of the first material, comprises the steps of:
defining a path of the elongated clad steel between a first and second rolls to pass the clad steel therethrough during rolling;
driving the second roll mating with the second layer of the clad steel at higher speed than that of the first

roll which mates the first layer of the clad steel;
performing pre-form rolling at a first given draft from one longitudinal end of the elongated clad steel 20% to 80% of the overall length of clad steel;
performing reduction rolling at a second given draft which is greater than or equal to the first given draft from the other longitudinal end of the elongated clad steel; and
repeating the cycle of the pre-form rolling and reduction rolling at least for two cycles.

The reduction rolling is performed on the portion of the clad steel maintained unrolled or, alternatively, for over entire length of the clad steel.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given herebelow and from the accompanying drawings of the preferred embodiment of the invention, which, however, should not be taken to limit the invention to the specific embodiment but are for explanation and understanding only.

In the drawings:

Figs. 1(A), 1(B), 1(C), 1(D), 1(E), 1(F) and **1(G)** are illustration showing the preferred process of rolling for a clad steel, according to the present invention;

Figs. 2(A), 2(B), 2(C), 2(D) and **2(E)** and **Figs, 3(A), 3(B), 3(C)** and **3(D)** are illustrations showing coventional rolling processes for clad steels, in which **Figs. 2(A), 2(B), 2(C), 2(D)** and **2(E)** illustrate the process disclosed in the aforementioned Tokkai Showa **61-232003** and **Figs. 3(A), 3(B), 3(C)** and **3(D)** illustrate the conventional reverse rolling process;

Fig. 4 is a sectional view of the clad steel rolled through the process of **Figs. 2(A), 2(B), 2(C), 2(D)** and **2(E)**;

Fig. 5 is a graph showing the relationship between pre-form rolling length, uneven clad ratio portion of the longitudinal ends formed due to difference of the expansion of the material metal plates, and clad rate;

Fig. 6 is a graph showing relationship between pre-form rolling length, uneven clad raio portion, and rolling temperature;

Fig. 7 is a graph showing relationship between pre-form rolling length, uneven clad ratio portion, and draft;

Fig. 8 is a graph showing relationship between uneven clad ratio portion and number of passes in rolling process;

Fig. 9 is a graph showing relationship between pre-form rolling length and uneven clad ratio portion;

Fig. 10 is a graph showing relationship between rolling speed ratio and uneven clad ratio portion;

Fig. 11 is a graph showing relationship between pre-form rolling length and uneven clad ratio portion;

Fig. 12 is a graph showing relationship between pre-form rolling length and uneven clad ratio portion; and

Fig. 13 is a graph showing relationship between number of passes in rolling and uneven clad ratio portion.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, **Figs. 1(A), 1(B), 1(C), 1(D), 1(E), 1(F)** and **1(G)** illustrates the preferred rolling process according to the present invention. Rolling is performed by upper and lower rolls **1a** and **1b** by passing a clad steel **4** in the form of a plate, slab or so forth. The clad steel **4** is composed of a pair of layer of different material metals 2 and 3. A portion of the clad steel **4** is subject pre-form rolling by being passed through the clearance between the upper and lower rolls **1a** and **1b**. The pre-form rolling is performed from one longitudinal end of the clad steel **4**, for a length $\mathbf{L_0}$ that is in the range of 20% to 80% of the overall length **L** of the clad steel **4**.

After the pre-form rolling process set forth above, reduction rolling is performed from the the opposite longitudinal end of the clad steel **4** over the portion nopt rolled in the pre-form rolling process. The draft in the reduction rolling is greater than or equal to the draft in the pre-form rolling.

In the preferred rolling process, the pre-form rolling and reduction rolling processes are performed in one rolling pass cycle. The rolling process is performed at least for two cycles.

In order to compare the performance of the preferred rolling process according to the invention to those of the prior art, comparative rolling processes are performed through the processes shown in **Figs. 2(A), 2(B), 2(C), 2(D)** and **2(E)** and **Figs. 3(A), 3(B), 3(C)** and **3(D)**, in which **Figs. 2(A), 2(B), 2(C), 2(D)** and **2(E)** illustrate the process disclosed in the aforementioned Tokkai Showa **61-232003** and **Figs. 3(A), 3(B), 3(C)** and **3(D)** illustrate the conventional reverse rolling process.

In the process of **Figs. 2(A), 2(B), 2(C), 2(D)** and **2(E)**, pre-form rolling is performed on both longitudinal ends of the clad steel **4**. According to the disclosure of Tokkai Showa **61-232003**, pre-form rolling was performed over a distance corresponding to the thickness of the clad steel. On the other hand, in the process of **Figs. 3(A), 3(B), 3(C)** and **3(D)**, the clad steel **4** passes, at first, from one end thereof and then from the other end.

As observed from Fig. **1(E)**, the clad steel **4** rolled by the preferred process has a substantially even clad ratio over the entire length. On the other hand, as seen from **Fig. 2(E)**, the clad steel rolled by the process shown in Tokkai Showa **61-232003** had portions at both ends where no layer of the metal **2** is formed. The single layer portions extend for lengths ℓ_1 and ℓ_2, as seen from **Fig. 4**. Furthermore, as shown in more detail in **Fig. 4**, at the regions $\mathbf{C_1}$ and $\mathbf{C_2}$ adjacent both end portion, the clad ratio becomes uneven. The rigion where single layer is formed, and uneven clad ratio region are hereafter referred to as "inferior quality region". On the other hand, the clad steel **4** processed by the process of reverse rolling of **Figs. 3(A), 3(B), 3(C)** and **3(D)** had metal layers **2** and **3** where difference in length corresponded to the difference between the expansion ratios of the respective layers.

Figs. 5 to 7 show results of experimentally performed rolling utilising the preferred processes. In the experiments, clad steel slab composed of a layer of stainless steel and a layer of soft steel was used. The slab was 200 mm thick and 5 m length. The clad slab was a total draft of 50% in total including the reduction in the pre-form rolling and reduction rolling stages. In rolling according to the preferred process, rolling was performed in two rolling pass cycles.

In the first experiments, rolling temperature was fixed at 1000 °C. In the sample slabs wherein the layer thickness were 10%, 20%, 30% and 40%, the ratio of the length of single layer regions ($\ell_1 + \ell_2$) to the length L_0 of the portion of clad slab, ocer which pre-form rolling was performed, was checked. The result is shown in **Fig. 5**. As will be seen from **Fig. 5**, the length of the single layer region could be maintained at a minimum value when pre-form rolling was performed over of 20% to 80% of the overall length of the slab. In the secondary experiments, clad ratio was fixed at 30%. Experimental rollings were performed respectively at 900 °C, 1000 °C and 1200 °C. In the second set of experiments, the relationship between the length of the single layer regions and the rolling temperature was checked. The result of the experiments is shown in **Fig. 6**. In the third experiments, experimental rollings were performed of 5%, 10% and 20% drafts. Relationship between the length of the single layer regions and the draft was checked. The results of the experiments is shown in **Fig. 7**. The second and third sets of experiments confirm that the pre-form rolling length is preferred in a range of 20% to 80%.

The relationship between number of pass cycles and the length of the single layer regions was observed. The result is shown in **Fig. 8**. As seen from **Fig. 8**, by performing of rolling two pass cycles or more, the length of the single layer regionsas significantly reduced.

Further experimentation was performed to determine the relationship between the layer thickness ratio and length ($C_1 + C_2$) of the uneven clad ratio region. Clad ratios were respectively 30% and 40%. The results of these tests are shown in Fig. 9. From the results of experiments shown in Fig. 9, it can be confirmed that the preferred range of length of portion of the clad slab, for which the pre-form rolling is to be performed is 20% to 80% of the overall length. Furthermore, similarly to the length of the single layer region, the length of the uneven clad ratio region can be significantly reduced by performing rolling for two pass cycles of rolling or more.

In another experiment, rotation speeds of the upper and lower rolls **1a** and **1b** were differentiated relative to each other. In the experiments performed, upper roll **1a** was rotated at higher speed than the lower roll **1b**. The higher speed upper roll **1a** mated the material **2** which has higher deformation resistance. Naturally, the other material **3** having higher malleability mates with the lower roll **1b** which rotates at lower speed. The roll speed ratio was varied. Result of experiments is shown in **Fig. 10**. As seen from **Fig. 10**, when the roll speed ratio, i.e. roll speed of the upper roll1a versus roll speed of the lower roll **1b** is greater than or equal to 1.1, the length of inferior quality regions can be substantially reduced in comparison with that obtained from rolling utilizing the rolls of equal roll speed.

Example

In order to further comfirm the improved performance of the preferred process according to the present invention, further experiments were performed for clad steel composed of a layer of stainless steel and a layer of soft steel. The clad steel was in the form of a slab having length of 5m and thickness of 200 mm. Rolling was performed in two pass cycles, each of which pass cycles included pre-form rolling from one longitudinal end of the clad slab and reduction rolling from the other longitudinal end. The draft was 50%. In order to compare this, comparative experiments were performed utilizing the conventional process. In the conventional rolling process, pre-form rolling was performed on one longitudinal end portion of the clad slab. Then, reduction rolling was performed from the other end. After one pass cycle, normal rolling was performed for another pass cycle.

Additional experiments were perfromed in which the roll speeds of the upper and lower rolls were different. In the experiments, ratio of the roll speed of the upper roll versus the roll speed of the lower roll is set at 1.1.

Results of the experiments are shown in **Figs. 11** and **13**. In **Figs. 11** and **12**, the result of the comparative example is shown by solid line, the result of the preferred process with equal roll speed is shown by the broken line, and the result of the preferred process with different roll speed is shown by the one-dot chain line. As will be seen from **Figs. 11** and **12**, by setting the pre-form rolling length within the range of 20% to 80% of the overall length of the slab, substantial reduction of the single layer region ($\ell_1 + \ell_2$) and the uneven clad ratio region ($C_1 + C_2$) can be obtained. Furthermore, the length of single layer region ($\ell_1 + \ell_2$) and the uneven clad ratio region ($C_1 + C_2$) in the slab rolled by the preferred process of the present invention is much smaller than that of the slab rolled by the conventional process.

In addition, the length of the inferior quality region in relation to the number of pass cycles performed for obtaining the desired draft versus the original thickness was observed and the results are shown in **Fig. 13**. As will be seen from **Fig. 13**, the rolling processes were performed for obtaining the desired draft, i.e. 50% by two pass cycles or more substantially reduces the length of the inferior quality region.

As will be appreciated herefrom, the preferred process for rolling of clad steel provides a substantially increased yield when pre-form rolling is performed from one end on a portion, the length of which is 20% to 80% of the overall length of the clad steel, and the reduction rolling is performed subsequently from the other end with a draft that is greater than or equal to the draft used in the pre-forming. A still greater increase in yield can be obtained by repeating the foregoing rolling process at least two passes. Differentiating of the roll speed to mate the higher speed roll to the layer having lower malleability, further assist for improvement of the yield by reducing length of inferior quality portions.

Therefore, the present invention fulfills all of the objects and advantages sought therefor.

While the present invention has been disclosed in terms of the preferred embodiment in order to facilitate better understanding of the invention, it should be appreciated that the invention can be embodied in various ways without departing from the principle of the invention. Therefore, the invention should be understood to include all possible embodiments and modifications to the shown embodiments which can be embodied without departing from the principle of the invention set out in the appended claims.

Claims

1. A process of rolling an elongated clad steel composed of a first layer of a first material and a second layer of a second material which has lower malleability than that of said first material, comprising the steps of:
performing pre-form rolling at a first given draft from one longitudinal end of said elongated clad steel for rolling the clad steel in a length of 20% to 80% of the overall length of clad steel;
performing reduction rolling at a second given draft which is greater than or equal to said first given draft from the other longitudinal end of said elongated clad steel for rolling; and
repeating the cycle of said pre-form rolling and reduction rolling at least for two cycles.

2. A rolling process for an elongated clad steel as set forth in claim 1, in which said reduction rolling is performed for the portion of the clad steel left in pre-form rolling.

3. A rolling process for an elongated clad steel as set forth in claim 1, in which said reduction rolling is performed for the overall length of said clad steel.

4. A process of rolling an elongate clad steel composed of a first layer of a first material and a second layer of a second material which has lower malleability than that of said first material, comprising the steps of:
defining a path between a first and second rolls to pass said clad steel therethrough during rolling;
driving said second roll mating with said second layer at higher speed than that of said first roll which mates said first layer;
performing pre-form rolling for a first given draft from one longitudinal end of said elongated clad steel for rolling the clad steel in a length of 20% to 80% of the overall length of clad steel;
performing reduction rolling for a second given draft which is greater than or equal to said first given draft from the other longitudinal end of said elongated clad steel for rolling; and
repeating the cycle of said pre-form rolling and reduction rolling at least for two cycles.

5. A process for rolling an elongate clad steel composed of a first layer of a first material and a second layer of a second material which has lower mallerability than that of said first material, comprising the steps of:
performing pre-form rolling at a first given draft from one longitudinal end of said elongated clad steel for rolling the clad steel in a length of 20% to 80% of the overall length of clad steel;
performing reduction rolling at a second given draft which is greater than said first given draft from the other longitudinal end of said elongated clad steel for rolling; and
repeating the cycle of said pre-form rolling and reduction rolling at least for two cycles.

6. A rolling process for an elongated clad steel as set forth in claim 5, in which said reduction rolling is performed for the portion of the clad steel left in pre-form rolling.

7. A rolling process for an elongated clad steel as set forth in claim 5, in which said reduction rolling is performed for the overall length of said clad steel.

8. A process for rolling an elongate clad steel composed of a first layer of a first material and a second layer of a second material which has lower malleability than that of said first material, comprising the steps of:
performing pre-form rolling at a first given draft from one longitudinal end of said elongated clad steel for rolling the clad steel in a length of 20% to 80% of the overall length of clad steel;
performing reduction rolling at a second given draft which is equal to said first given draft from the other longitudinal end of said elongated clad steel for rolling; and
repeating the cycle of said pre-form rolling and reduction rolling at least for two cycles.

9. A rolling process for an elongated clad steel as set forth in claim 8, in which said reduction rolling is performed for the portion of the clad steel left in pre-form rolling.

10. A rolling process for an elongated clad steel as set forth in claim 8, in which said reduction rolling is performed for the overall length of said clad steel.

FIG.1

(A)

(B)

(C)

(D)

(E)

(F)

(G)

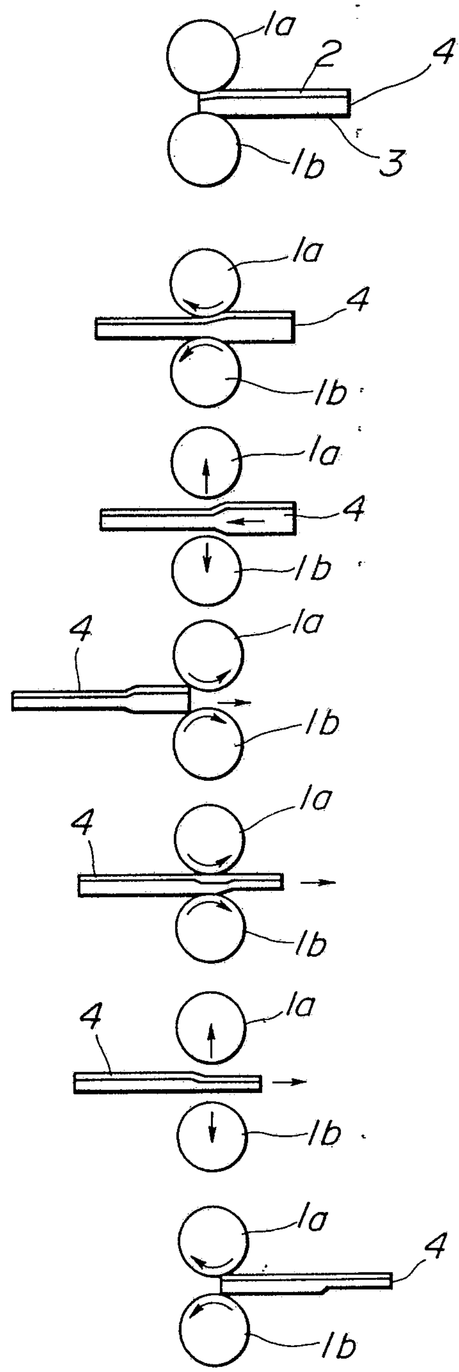


FIG.2

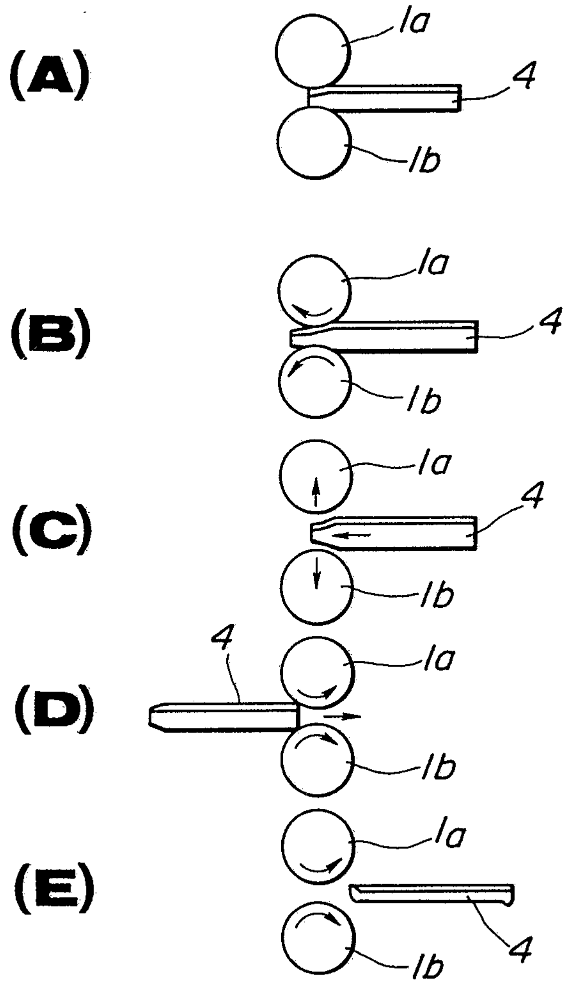
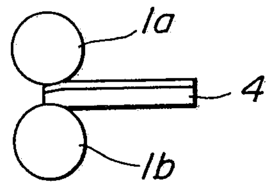
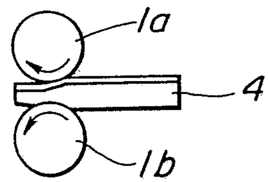


FIG. 3

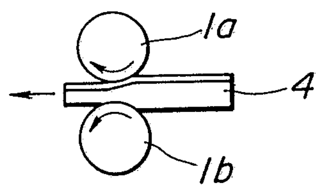
(A)



(B)



(C)



(D)

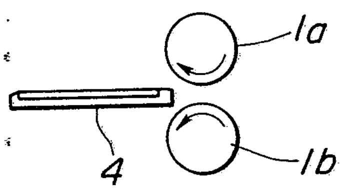


FIG.4

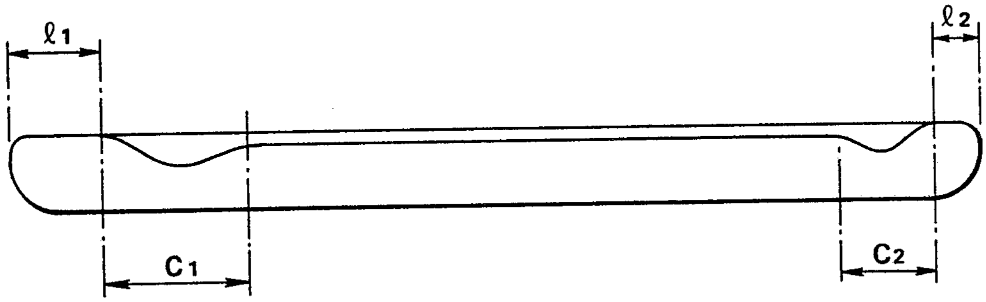

ℓ1
ℓ2
C1
C2

FIG.5

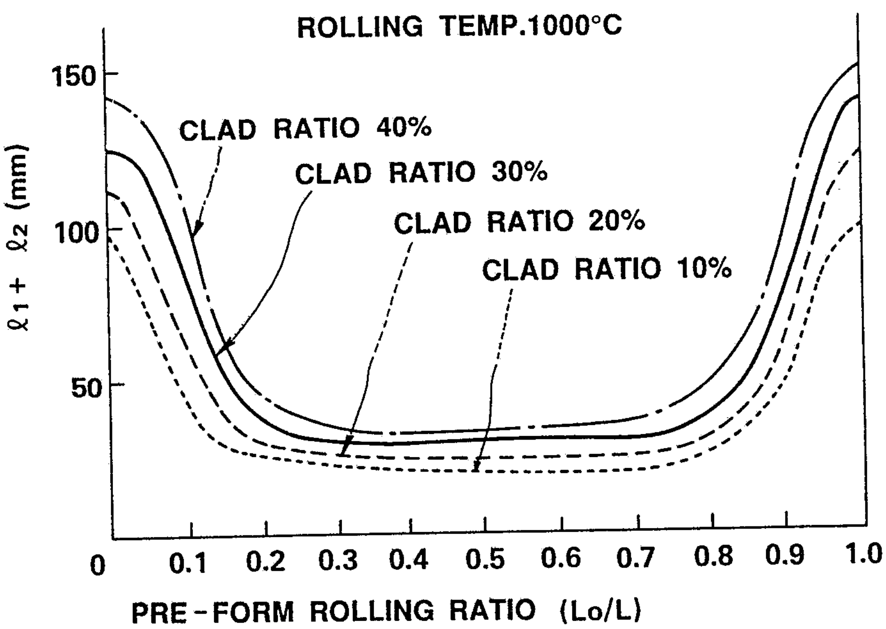

ROLLING TEMP.1000°C
150
100
50
0
CLAD RATIO 40%
CLAD RATIO 30%
CLAD RATIO 20%
CLAD RATIO 10%
ℓ1 + ℓ2 (mm)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
PRE-FORM ROLLING RATIO (Lo/L)

FIG.6

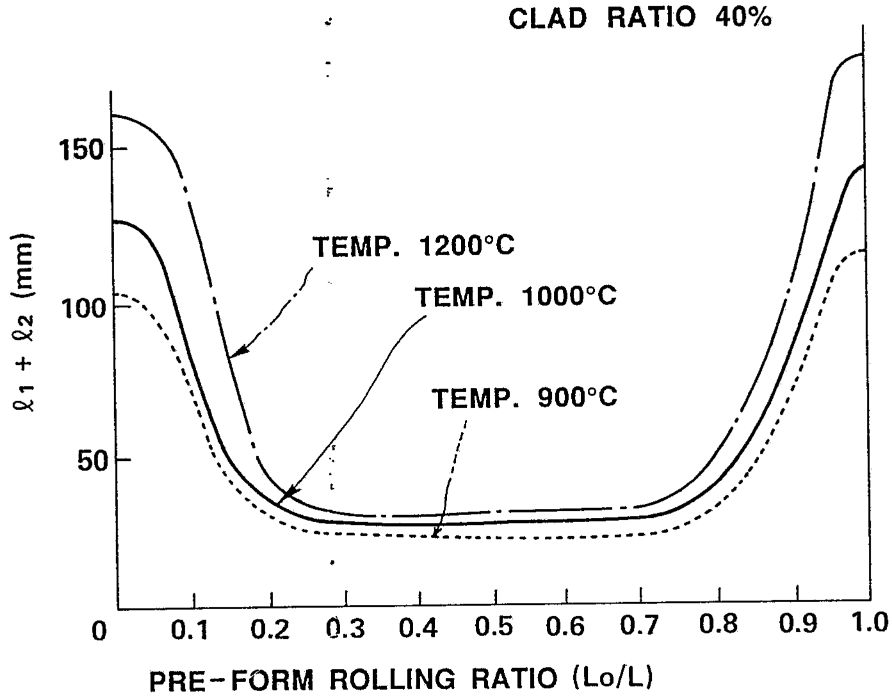

CLAD RATIO 40%
150
100
50
0
ℓ1 + ℓ2 (mm)
TEMP. 1200°C
TEMP. 1000°C
TEMP. 900°C
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
PRE-FORM ROLLING RATIO (Lo/L)

FIG.7

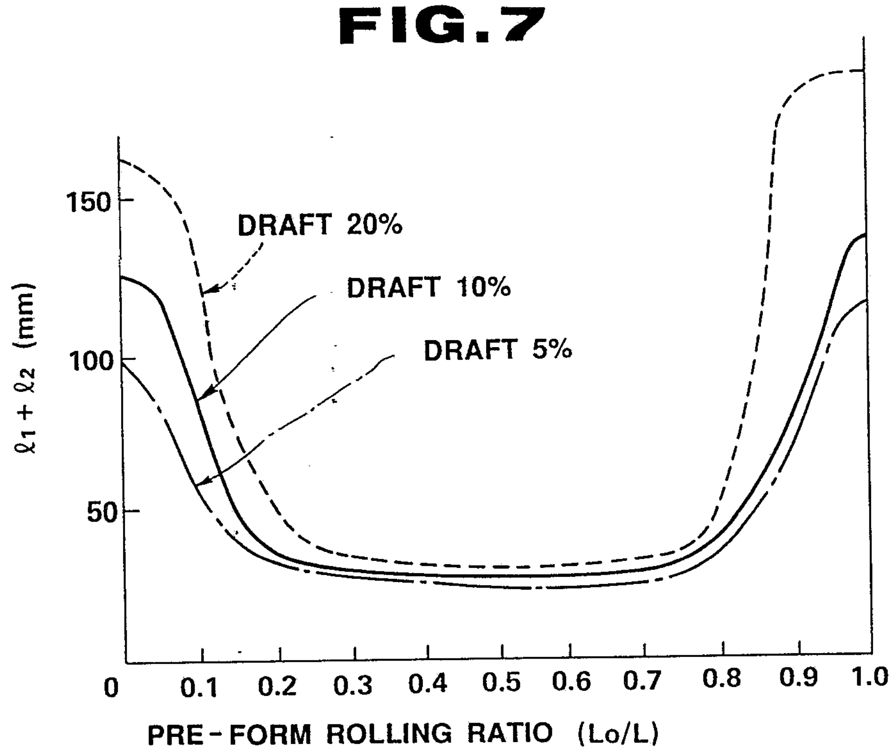

150
100
50
0
ℓ1 + ℓ2 (mm)
DRAFT 20%
DRAFT 10%
DRAFT 5%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
PRE-FORM ROLLING RATIO (Lo/L)

FIG. 8

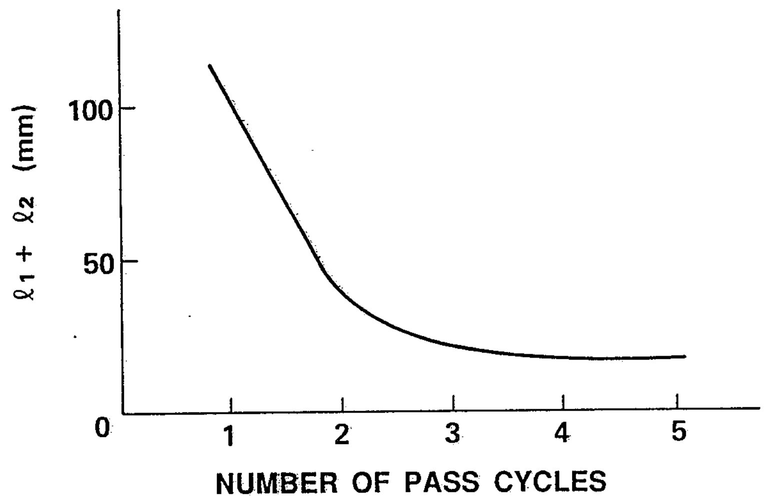

100
50
0
$\ell_1 + \ell_2$ (mm)
1
2
3
4
5
NUMBER OF PASS CYCLES

FIG. 9

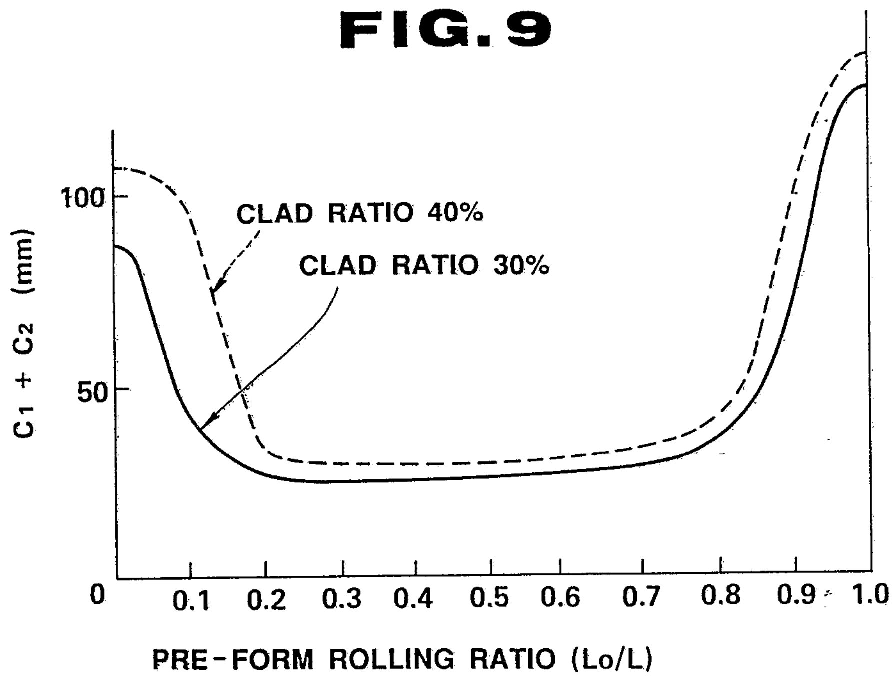
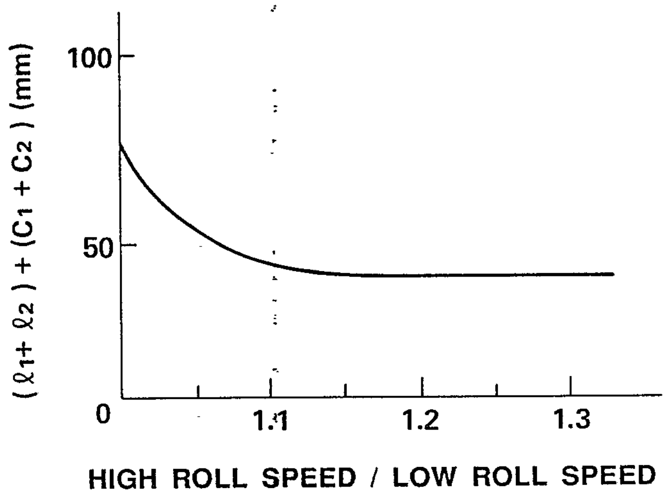
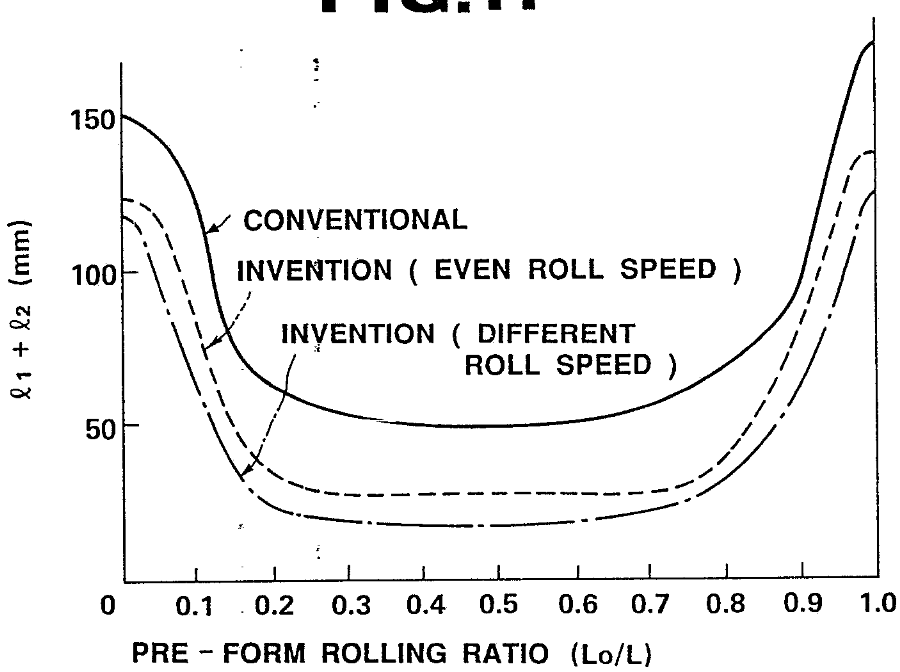

100
50
0
$C_1 + C_2$ (mm)
CLAD RATIO 40%
CLAD RATIO 30%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
PRE-FORM ROLLING RATIO (Lo/L)

FIG. 10



100
50
0
1.1
1.2
1.3
(ℓ1 + ℓ2) + (C1 + C2) (mm)
HIGH ROLL SPEED / LOW ROLL SPEED

FIG. 11



150
100
50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ℓ1 + ℓ2 (mm)
CONVENTIONAL
INVENTION (EVEN ROLL SPEED)
INVENTION (DIFFERENT ROLL SPEED)
PRE - FORM ROLLING RATIO (Lo/L)

FIG.12

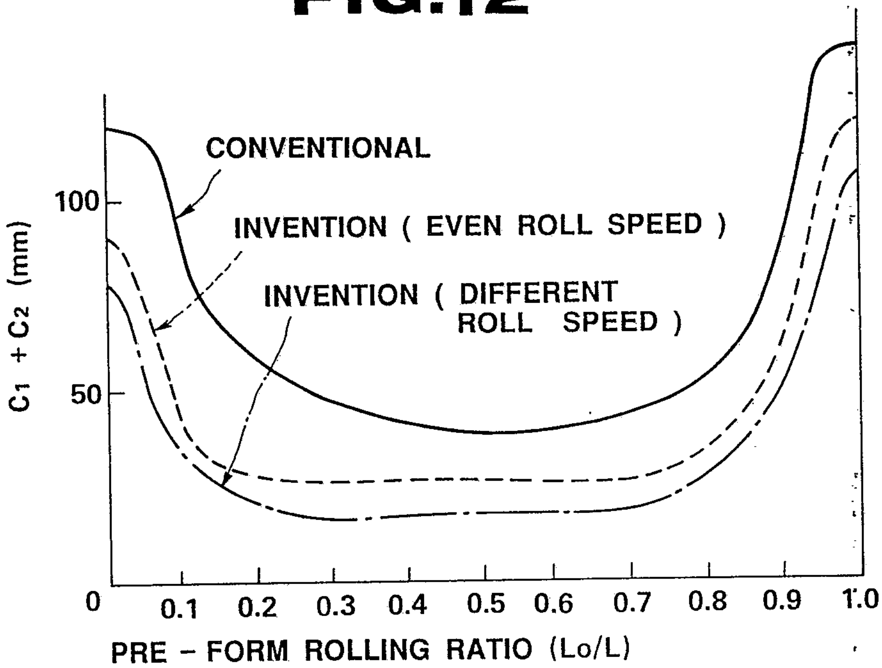
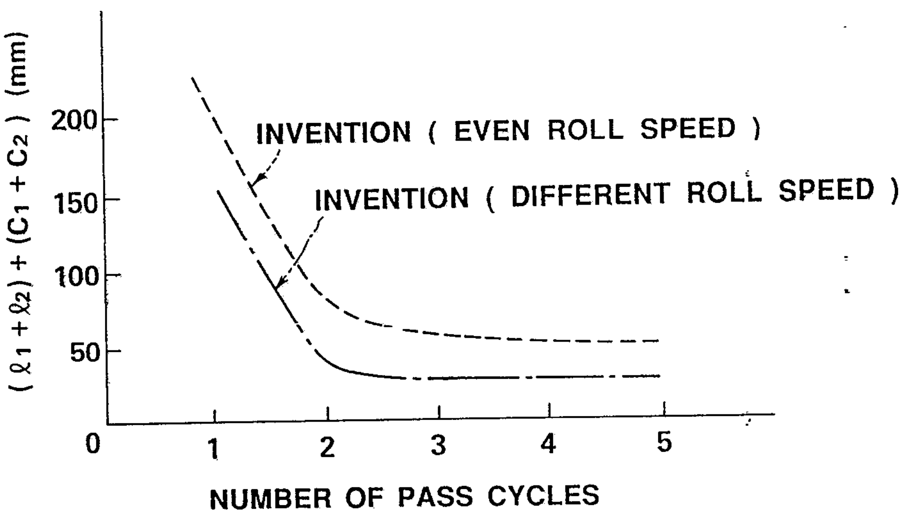

CONVENTIONAL
INVENTION (EVEN ROLL SPEED)
INVENTION (DIFFERENT ROLL SPEED)
100
50
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
C1 + C2 (mm)
PRE - FORM ROLLING RATIO (Lo/L)

FIG.13


INVENTION (EVEN ROLL SPEED)
INVENTION (DIFFERENT ROLL SPEED)
200
150
100
50
0
1 2 3 4 5
(ℓ1 + ℓ2) + (C1 + C2) (mm)
NUMBER OF PASS CYCLES