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Okamoto et al.

[11] **3,719,066**

[45] **March 6, 1973**

[54] **PIERCING ROLLING APPARATUS FOR PRODUCING ROLLED MATERIAL FREE FROM SURFACE TORSION**

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[73] Assignee: **Sumitomo Metal Industries, Ltd.,** Osaka, Japan

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[21] Appl. No.: **84,663**

[30] **Foreign Application Priority Data**

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Jan. 16, 1970 Japan 45/4729

[52] **U.S. Cl.** **72/97,** 72/209
[51] **Int. Cl.** **B21b 19/04,** B21b 17/10
[58] **Field of Search** 72/35, 97, 209

[56] **References Cited**

UNITED STATES PATENTS

1,141,426 6/1915 Simpkins 72/97
1,587,112 6/1926 Gassen 72/97
3,512,403 5/1970 Kato 72/97
3,550,415 12/1970 Tarenskeen 72/97

FOREIGN PATENTS OR APPLICATIONS

160,498 6/1964 U.S.S.R. 72/209

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Assistant Examiner—E. M. Combs
Attorney—Kurt Kelman

[57] **ABSTRACT**

A piercing rolling apparatus utilizing the principle of the Stiefel Mannesmann type piercing mill and having two main rolls axes of which incline with each other vertically at the feed angle β with respect to the longitudinal axis of the material to be rolled and cross with each other horizontally at the cross angle γ with respect to the longitudinal axis of the material. A seamless steel pipe free from surface torsion is obtained by adjusting these angles β and γ.

4 Claims, 15 Drawing Figures

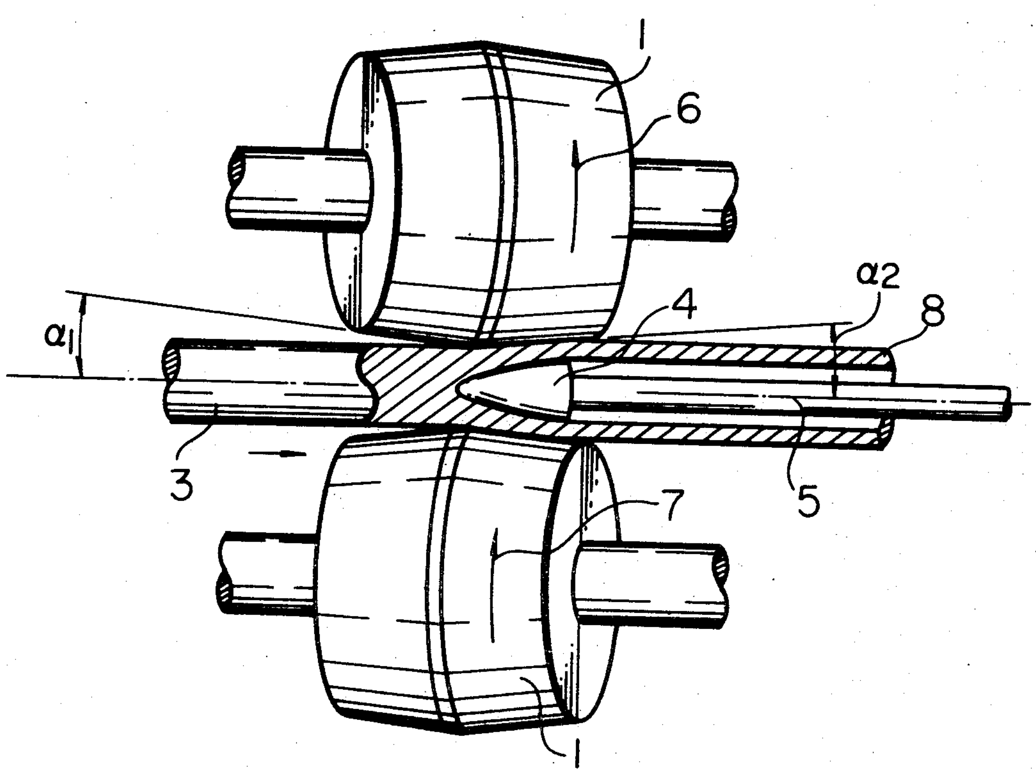


Fig. 1

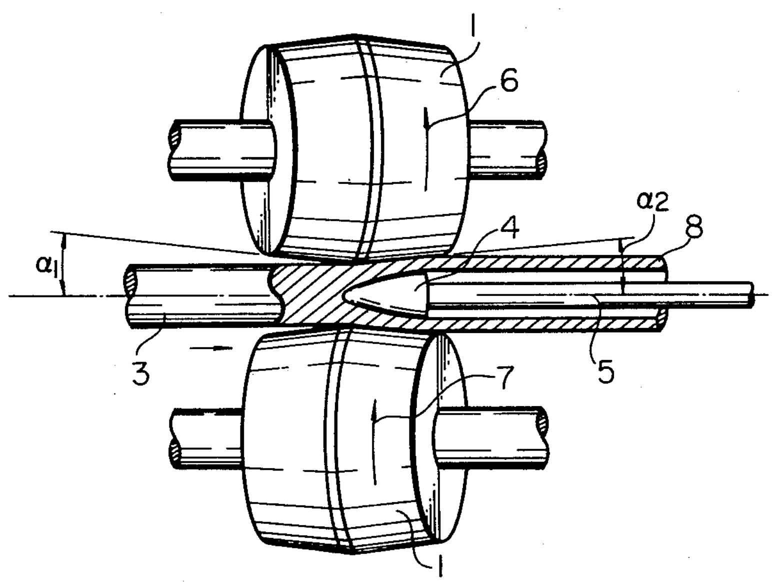


Fig. 2

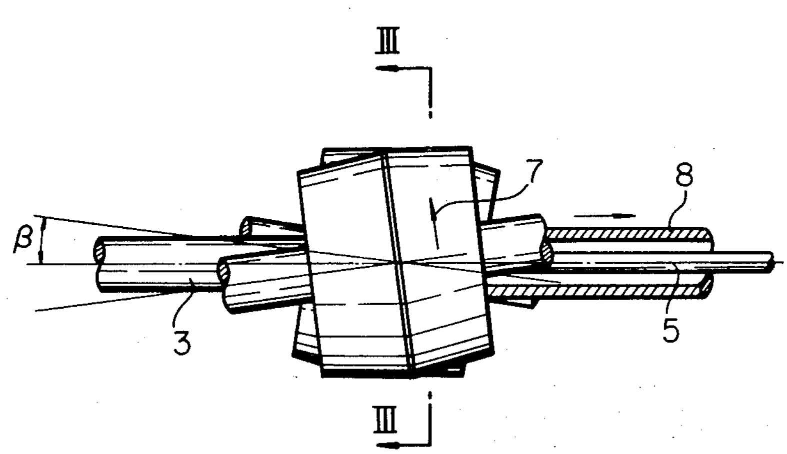
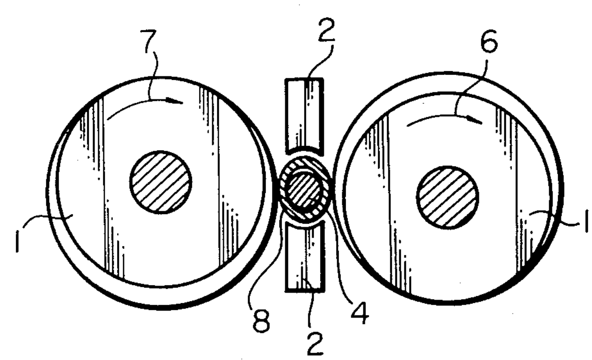


Fig. 3



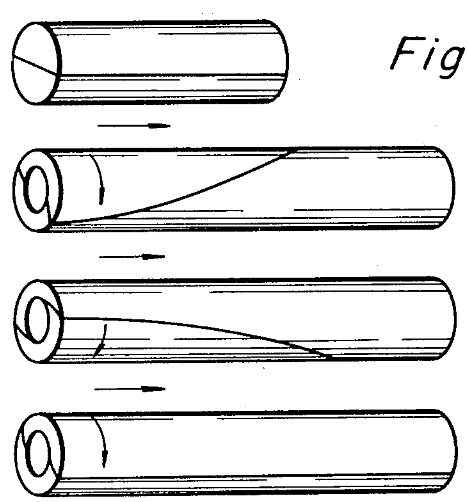


Fig. 4A

Fig. 4B

Fig. 4C

Fig. 4D

Fig. 5

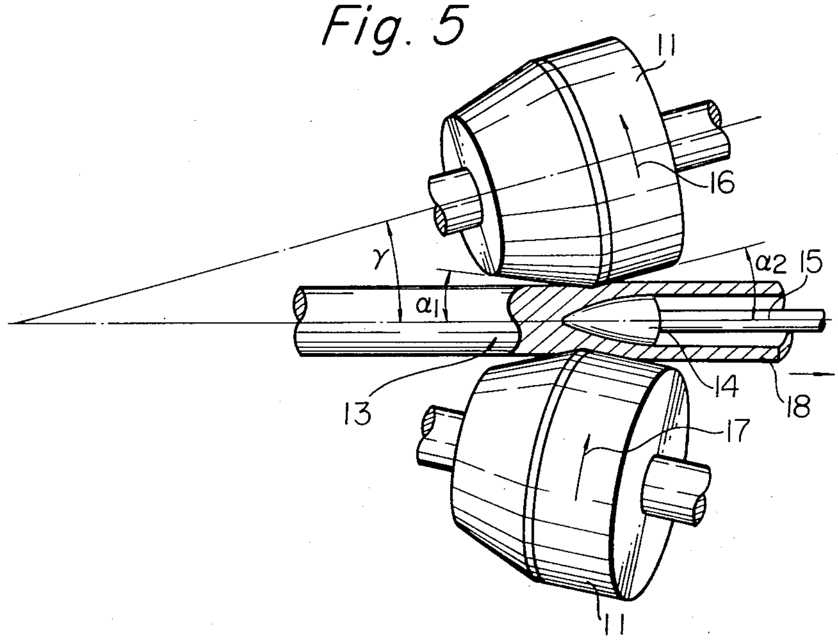


Fig. 6

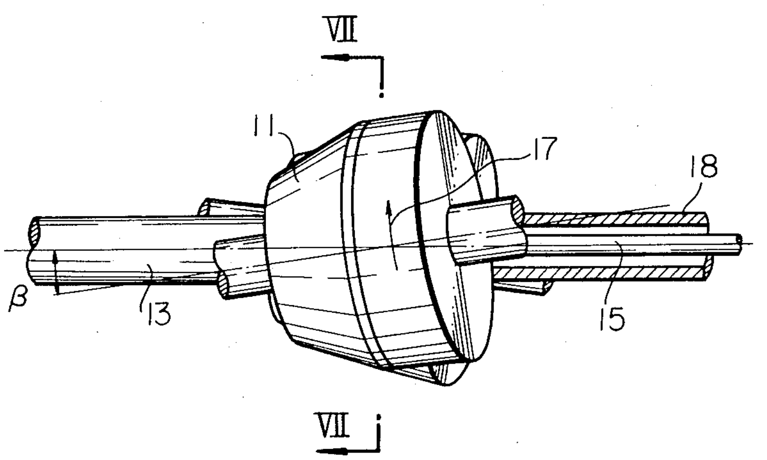


Fig. 7

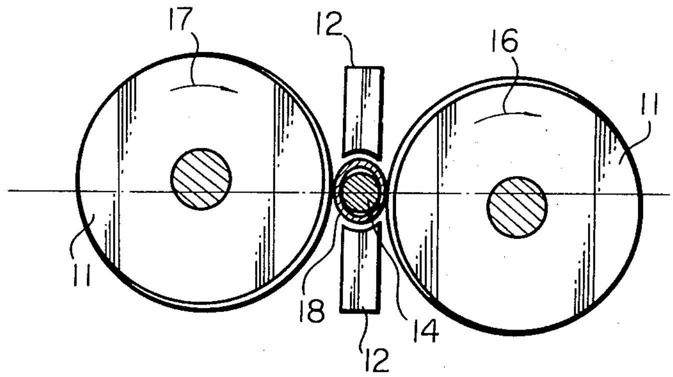

17
12
16
11
11
18
14
12

Fig. 8

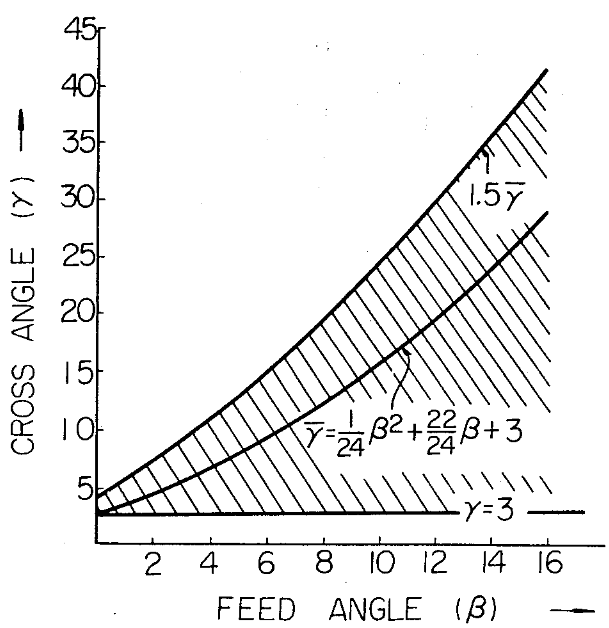
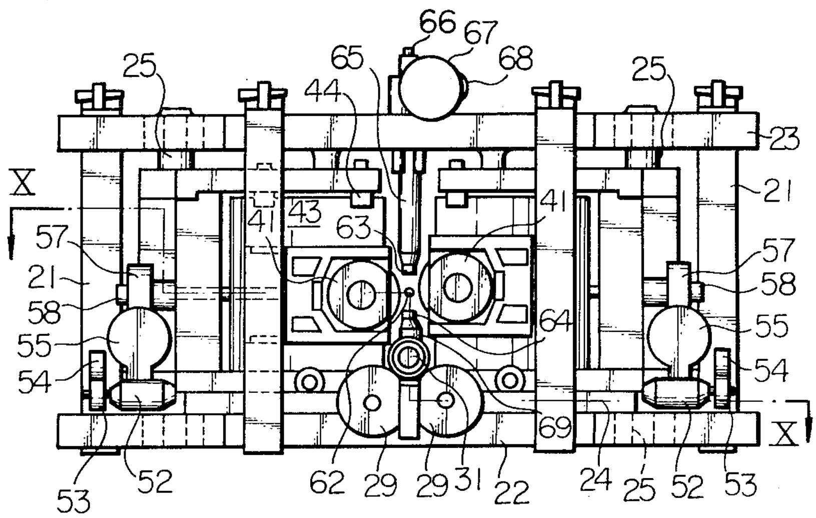

45
40
35
30
25
20
15
10
5
CROSS ANGLE (γ)
1.5$\bar{\gamma}$
$\bar{\gamma}=\frac{1}{24}\beta^2+\frac{22}{24}\beta+3$
γ=3
2 4 6 8 10 12 14 16
FEED ANGLE (β)

Fig. 9


66
67
65
68
25
44
25
23
X
43
41
63
41
21
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57
21
58
58
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64
55
54
54
69
X
62
29
29
31
22
24
25
52
53
53
52

Fig. 10

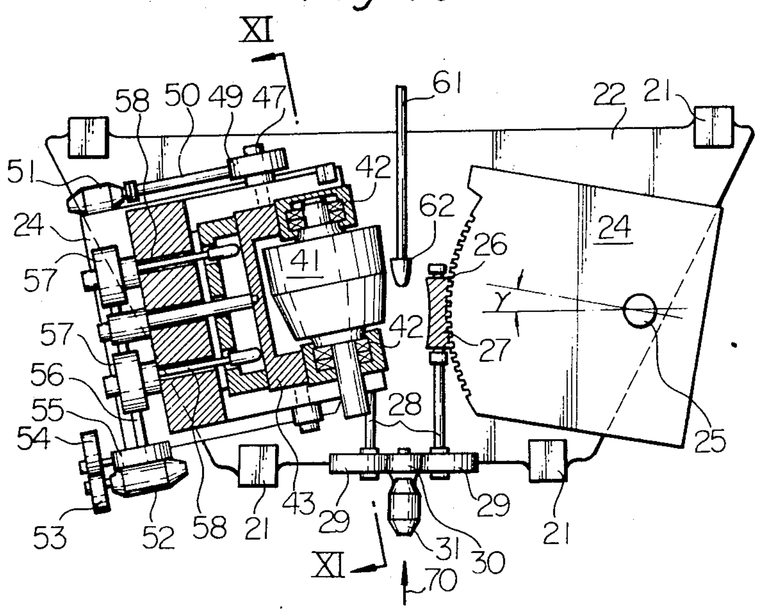

XI
61
58
50
49
47
22
21
51
42
24
62
41
24
26
57
γ
57
42
27
56
55
28
25
54
53
52
58
21
43
29
29
21
31
30
XI
70

Fig. 11

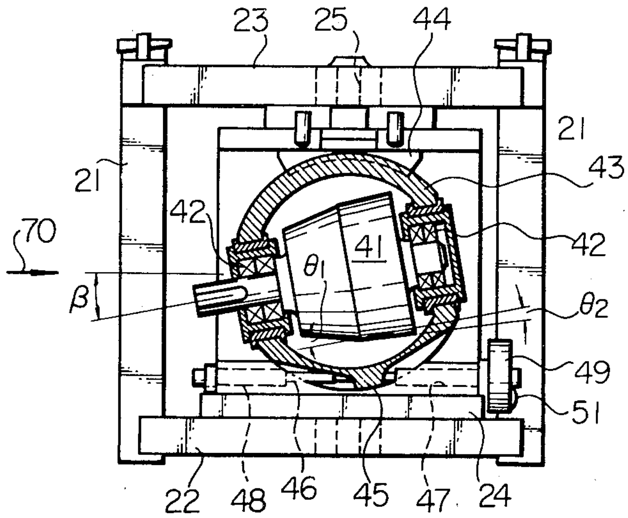
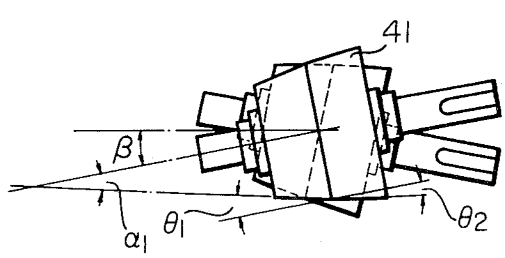

23
25
44
21
21
43
42
42
70
41
θ1
β
θ2
49
51
22
48
46
45
47
24

Fig. 12


41
β
α1
θ1
θ2

PIERCING ROLLING APPARATUS FOR PRODUCING ROLLED MATERIAL FREE FROM SURFACE TORSION

The present invention relates to an improved piercing mill to prevent surface torsion of the rolled material in mass production of seamless steel pipe, particularly in a Stiefel Mannesmann type piercing mill.

Among various conventional processes for producing seamless steel pipes, the most widely employed is the Stiefel Mannesmann type continuous process comprising in sequential arrangement a piercing mill, plug mill, reeling mill, reducing mill and sizing mill. In this process, a round billet previously heated to a hot rolling temperature by a heating furnace is pierced by the shaping rolls of the piercing mill. Since the hollow piece obtained in this way is short and very thick, it is subsequently reduced in thickness and elongated in length by the plug mill, reeled on the inner and outer surfaces by the reeling mill to the specified thickness, and then reduced to the specified diameter by the succeeding sizing mill into the desired. Alternately, it may be further heated in a reheating furnace, reduced to a tube of small diameter and then cut to the prescribed length of the product.

In the conventional type piercing mill, it is inevitable that torsional forces create a twisting or turning in the surface of the billet rolled during the piercing. If such surface torsion is large, it leads to the inclusion of non-metallic impurities in nearly all of the surface causing rough surface defects, such as seams or small cracks. Such defects or roughness on the surface produced through the piercing are aggravated and enlarged by the succeeding plug mill and reeling mill operations. As a result, the quality of the resulting products is poor and a gross decline in products yield is experienced.

An object of this invention is to prevent surface twisting of the rolled material caused by torsional forces, to improve the surface condition of the produced pipe or tube and thus to promote products yield in the Stiefel Mannesmann type piercing mill employed in production of seamless steel pipe.

Another object of the present invention is to provide a mill construction having a piercing mill providing the foregoing object.

These objects are attained by arranging the two main rolls of the piercing mill so that their axes may incline with respect to each other vertically at a feed angle β with respect to the longitudinal axis of the material to be rolled and may cross with respect to each other horizontally at a cross angle γ with respect to the longitudinal axis of the material. obtaining An appropriate relationship between β and γ is obtained wherein no surface torsion is caused by changing these two angles β and γ, and defining their range applicable to the industrial production of hollow steel pipes. Particularly, the objects of the present invention are attained by mounting the rolls to have a cross angle γ, adjusting the base of the main rolls on a fixed base of the piercing mill rotatably with respect to the longitudinal axis of the material to be rolled, mounting a supporting frame of the main rolls on the cross angle γ, adjusting the base rotatably with respect to the longitudinal axis of the material and mounting a roll opening adjusting device on the cross angle adjusting base.

FIG. 1 is a top view showing an arrangement of main rolls of a conventional piercing mill.

FIG. 2 is a side view of the arrangement shown in FIG. 1.

FIG. 3 is a partial sectional view taken along the line III—III of FIG. 2.

FIGS. 4A to D are perspective views each showing a model billet comprising plasticine in two colors and model hollow pieces formed out of the model billets by various model piercing mills.

FIG. 5 is a top view of a main rolls arrangement of a piercing mill according to the present invention.

FIG. 6 is a side view of the arrangement shown in FIG. 5.

FIG. 7 is a partial sectional view taken along the line VII—VII of FIG. 6.

FIG. 8 is a graphical illustration of the relationship between the feed angle β and the cross angle γ of the main rolls according to the present invention.

FIG. 9 is a front view showing a construction of a piercing apparatus embodying the present invention.

FIG. 10 is a sectional view taken along the line X—X of FIG. 9.

FIG. 11 is a sectional view taken along the line XI—XI of FIG. 10.

FIG. 12 is a partial side view showing the inclining relationship between the two main rolls.

In order to afford a better understanding of the present invention, a piercing mill of the most widely used Stiefel Mannesmann type is outlined immediately below.

As shown in FIGS. 1 – 3, main rolls 1, 1 have the largest diameters at their longitudinal centers and are in a bisymmetric barrel shape with a surface angle α selected in the range 3° – 5°. The aforementioned largest diameters of the rolls are larger than the length thereof. The axes of the main rolls are in parallel with each other when seen from the top but incline with respect to each other as seen from the side. The the axes are provided with a feed angle β selected in the range 5° – 13° vertically with respect to the longitudinal axis of the material to be rolled or the billet 3 (FIG. 2). In the upper and lower spaces between the main rolls are provided guide shoes 2, 2 for supporting the rotating hollow piece 8 during rolling. The portion where the diameters of the main rolls 1, 1 are largest and the interval between them is the smallest is named a gorge. A piercing plug 4 is positioned by a mandrel 5 a prescribed distance from the gorge toward the entrance side of the mill.

The main rolls rotate in the same direction, as shown by arrows 6 and 7. When the billet 3, heated up to the rolling temperature, is introduced from the roll entrance, it is fed toward the gorge by the function of the feed angle β and rapidly rotates in to the direction contrary to that of the main rolls. Since the gap between the main rolls 1, 1 becomes narrower as it comes close to the gorge, the billet 3 is rotatingly pressed repeatedly by the surfaces of the main rolls and grows into a condition tending to form a hole at the center. As a result, it is easily pierced by the pointed head of the plug 4. Since the plug 4 is so maintained that it will rotate freely together with the mandrel 5 in accordance with the rotation of the work piece but will not move backward, the hollow piece 8 is reduced in thickness, and being subject to the radial plastic deformation due to the interaction between the main rolls and the plug, it increases its inner diameter. The outer diameter of the piece 8 is increased a little according to the surface angle α_2 at the exit side of the rolls. Thus this billet 3 becomes a hollow piece 8 with a thick wall and short size.

The arrangement of the main rolls according to the present invention is described as follows with reference to the FIGS. 5 – 7. The main rolls 11, 11 to be used in the present invention are basically of the barrel type and it is preferably that their cutting angles θ_1 and θ_2 with the roll axes toward the entrance θ_1 and the exit θ_2 should satisfy the relation $|\theta_1|>|\theta_2|$ (see FIG. 12). The axes of the main rolls 11, 11 incline towards each other vertically at the feed angle β with respect to the longitudinal axis of the material to be rolled or the billet 13 (see FIG. 6) and intersect each other horizontally at the cross angle γ with respect to said axis (see FIG. 5). The main rolls 11, 11 are rotated in the same direction, as shown by the arrows 16 and 17. Guide shoes 12, 12 are provided between the rolls 11, 11 for supporting the hollow piece 18 from the upper and lower sides during rolling (see FIG. 7). A plug 14 for piercing the billet is positioned by a mandrel 15 at a distance toward the entrance from the gorge.

As aforesaid, the two main rolls in the conventional Stiefel Mannesmann piercing method have the surface angle α and the feed angle β but not cross angle corresponding to the angle γ in FIG. 5 of the present invention. In the present invention, it is possible to obtain a hollow piece completely or substantially free from surface twisting or torsion by selecting the feed angle and the cross angle properly. Metal flow of the billet is experimentally visualized in FIG. 4 which shows the effect on model hollow pieces made of model billets of plasticine (a trade name of a kind of clay) of two colors pierced by a model piercing mil. The optimum feed angle β and cross angle γ may be experimentally obtained using the model billets.

As shown in FIG. 4A, a model starting billet of 47 mm in diameter and 120 mm in length is made by adhering two semi-cylindrical sections of plasticine of two colors respectively.

For the comparison of the present invention with the prior art technique, a hollow piece formed by a model piercing mill of the conventional Stiefel Mannesmann type is shown in FIG. 4B. On the surface of the model hollow piece appears a spiral surface twists, as seen in the drawing. Another hollow piece formed by a model piercing mill using the conventional cone type rolls is shown in FIG. 4C wherein a spiral surface twist appears, twisted to the direction contrary to that of the FIG. 4B. It is absolutely impossible to prevent torsion on the surface of the billets by the prior art techniques, no matter in what manner the surface angle α or feed angle β are changed.

In a model mill structured according to the present invention, a series of piercing tests were carried out under various conditions covering the ranges, wherein the feed angle $\beta = 0° - 16°$ and the cross angle $\gamma = 5° - 30°$. The appropriate relationship between these two angles produces a hollow piece without surface twist, as shown in FIG. 4D. The ranges of the two angles wherein an absence of torsional effects appeared on the surface of the model billet were found by changing the angles gradually, i.e., by stepping up the cross angle γ from 5° to 30° by 5° increments and by stepping up the feed angle β from 0° to 16°. The inlet surface angle α_1 was kept equalized to the outlet surface angle α_2, at a constant 3.5°. As a result, it was found that the relation between the two angles β and γ wherein no surface torsion appeared may be expressed by the following equation as shown in FIG. 8:

$$\gamma=\frac{1}{24}\beta^2+\frac{22}{24}\beta+3 \qquad (1)$$

(Unit: degree)

In the region above the curve, the torsion causes a twisting spiral to the direction of rotation and in the region below the curve, the torsion causes a twisting spiral contrary to the direction of rotation. The feed angle 62 may be determined arbitrarily. However, in the range smaller than 2°, it is not practical since the feeding of the billet, namely through productivity, is too low, and in the range larger than 16°, it is not practical as well since the opposing cross angle γ approaches 45°.

As is evident from the foregoing, it can be confirmed that there exists an optimum condition which produces an ideal hollow piece 18 free from any surface torsion by adequately combining the feed angle β and the cross angle γ.

In the equation (1), the surface angle α_1 of the rolls is kept constant at 3.5°. However, in actual operations, the suitable range of the surface angle α_1 of the rolls is between 2°–6°. if the angle α_1 is larger than 6°, advancement of the billet becomes difficult, and if it is smaller than 2°, initial feeding of the material is obstructed. From the aforementioned reason, the optimum range of the cross angle γ of the rolls is between the lower limit of 3° and the upper limit corresponding to 150 percent of γ of the equation (1), in other words, the angle γ may be selected arbitrarily within the obliquely lined region in FIG. 8.

$$1.5\left(\frac{1}{24}\beta^2+\frac{22}{24}\beta+3\right)>\gamma>3 \qquad (2)$$

(Unit: degree)

provided:

$\alpha = 2° - 6°$

$\beta = 2° - 16°$

$\gamma = 3° - 30°$

In FIGS. 9 – 12, apparatus for carrying out present invention is shown. The apparatus is provided with a fixed base 22 secured to the foundation by four columns 21 and a removable base plate 23. A cross angle adjusting base 24 of C-shaped section is mounted on the fixed base 22 by a shaft column 25 so as to be able to rotate on a horizontal plane. The side of the cross angle adjusting base 24 facing the main roll is formed in a circular arc provided with gear teeth 26. A worm gear 27 is adapted to intermesh with the gear teeth 26. The worm gear 27 is mounted on an elongated shaft 28, whose gear 29, meshes with a common pinion 30 driven by an electric motor 31 The cross angle adjusting base 24 may thus be rotated with the cross angle within 30°. The cross angle adjusting base 24 is provided with a roll housing 43 on which both ends of the main rolls 41, 41 are journaled on bearings 42, 42 so as to be adjustable with the roll opening adjustment device and the cross angle adjustment device, as described below. The roll housing **43** has a cross section of C-shape and a vertical section of partially notched cylindrical shape, as shown in FIG. **11**. The upper part of the housing is slidably supported by the sliding guide **44** of circular arc shape. The lower part of the housing forms a boss **45** against both sides of which cylinder rods **46** press and the tip of a rotary driver **47** contacts. The cylinder rods **46** are supported by an oil pressure cylinder **48**, whereas the rotary driving shaft **47** is connected to a series of transmission gears consisting of a gear **49**, a pinion (not shown) to intermesh with the gear, a shaft **50** connected to the pinion and a driving motor **51** fixed to the cross angle adjusting base **24**. Operation of the driving shaft **47** adjusts the feed angle β of the main roll by pushing the lower boss **45** of the roll housing in response to the rotary driving of the electric motor **51**. The adjustment range of the shaft is 0° - 16°.

It is necessary to provide an apparatus for adjusting the gorge in response to the relationship between the diameter of the billet and the outer diameter of the hollow piece. For this purpose, two supporting shafts **58** adjust the roll opening of the main rolls by forward and backward movements when rotatably driven by two gears **57** rotated by a power transmission comprising an electric motor **52**, a gear **53** rotated by said motor **52**, a gear **54** intermeshed by the gear **53**, a worm gear **55** intermeshed by the gear **54** and a shaft **56** connected directly to the gear **55**. The piercing plug **62** is supported by a mandrel **61** between rolls **41** at the gorge. The billet is introduced in the direction denoted by an arrow **70** and rotatingly pierced by the interaction of the main rolls and the plug. During rolling, the hollow piece is supported by the upper and lower guide shoes **63** and **64**. The vertical position of the upper guide shoe is adjusted by a shaft **66** which is connected to a guide shoe holder **65** and is driven by a worm gear **67** and a driving motor therefor. The lower guide shoe is adjusted by conventional methods such by replacing the shoe **64** with one of a different size or, insertion of a liner Rotation of the main rolls is obtained through a drive and a conventional transmission gear such as universal coupling provided on the roll shaft at the entrance side of the billet to be rolled.

As shown in FIGS. **11** and **12**, the main rolls **41**, **41** are mounted with the feed angle β and the cross angle γ with each other. Moreover, in order to provide the entrance and exit sides of the rolls to the material to be rolled with the surface angle of 2° - 6°, it is preferable that the main rolls be provided with the entrance and exit sides cutting angles θ_1 and θ_2 which will satisfy the following angular condition:

$$\theta_1=\alpha_1+\gamma, \quad \theta_2=\alpha_1-\gamma \qquad (3)$$

In the range wherein the cross angle γ is larger than the surface angles α_1 or α_2, the diameters of the rolls become larger as they proceed from the entrance side to the exit side.

Although the foregoing description is made for a construction wherein the main rolls are arranged horizontally, the rolls may be arranged vertically one over the other. When arranged vertically, it should be noted that the directions with respect to the feed angle β and the cross angle γ are reversed.

We claim:

1. A piercing rolling mill of the Stiefel Mannesmann type for producing hollow seamless pieces, said mill comprising in combination: a pair of rolls between which a billet is fed, rolled and advanced to a hollow piece substantially free of surface torsion, means for driving said rolls, and means for adjustably mounting said rolls between a feed angle β and a cross angle γ, said angle β being taken in the horizontal plane and defining the angle between the axis of the rolls and the billet axis, said angle γ being taken in the vertical plane and defining the angle between the axis of the rolls and the billet axis, the angles β and γ being variable in the range satisfying the condition expressed by the following equation:

$$1.5\left(\frac{1}{24}\beta^2+\frac{22}{24}\beta+3\right)>\gamma>3$$

provided:

β=2° - 16°

γ=3° 30°

2. The mill of claim **1** wherein each of said rolls has entrance surface angle α_1 and exit surface angle α_2 taken in the vertical plane, said angles α_1 and α_2 defining the angle of the said surface to the billet axis and selected in the range between 2° and 6°; and wherein each of said rolls has entrance cutting angle θ_1 and exit cutting angle θ_2, said angles θ_1 and θ_2 defining the angle of the said surface to the billet when taken in the horizontal plane and satisfying the conditions expressed by the following equations:

$$\theta_1=\alpha_1+\gamma$$

$$\theta_2=\alpha_2-\gamma$$

3. The mill of claim **1** wherein the adjustable mounting means includes a pair of opposed bases, each of said bases being mounted for rotation about a fixed axis vertical to the billet, axis, a housing mounted on each of said bases, said housings being pivotal about an axis parallel to said associated vertical axis, said rolls being journaled respectively in said housings, means for rotating said base to adjust the angle α and means for pivoting said housing to adjust the angle β.

4. The mill of claim **3**, including means for limiting the rotation of said bases about the vertical axis to maintain said angle γ between 3° and 30° and means to limit the pivoting of said housings to maintain the feed angle β between 2° to 16°.

* * * * *