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[54] **APPARATUS FOR MANUFACTURING STRETCH-FORMED PRODUCTS OF HIGH-MELTING METALS**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 586,494, Oct. 13, 1966, Pat. No. 3,491,823, and a continuation-in-part of Ser. No. 632,001, Apr. 13, 1967, abandoned.

[52] **U.S. Cl.** **164/270,** 164/282
[51] **Int. Cl.** **B22d 11/12**
[58] **Field of Search** 164/76, 82, 270, 282

[56] **References Cited**

UNITED STATES PATENTS

395,684	1/1889	Baker	164/76
494,659	4/1893	Very	164/283 X
3,157,920	11/1964	Hess	164/282 X
3,393,727	7/1968	Rys	164/282
3,358,358	12/1967	Jenks et al.	164/76

FOREIGN PATENTS OR APPLICATIONS

517,838	3/1955	Italy	164/82
392,785	10/1965	Switzerland	164/282

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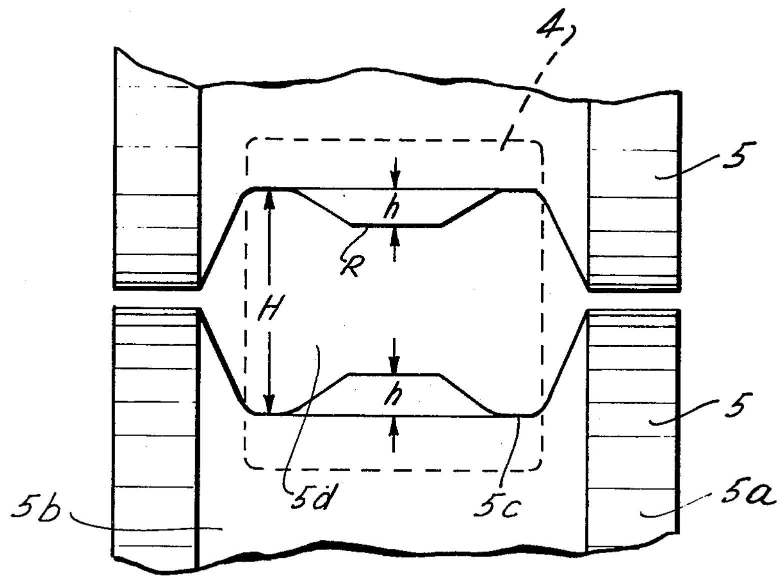
[57] **ABSTRACT**

An apparatus for the manufacture of strands of molten metal, in particular nonalloyed and alloyed steels, by continuous casting, comprising a mold for continuously casting a strand and means for simultaneously withdrawing the cast strand from the mold. The cast strand which exits from the mold is in a partially solidified state and has a molten core. The withdrawing means comprise a pair of spaced grooved rollers which define a box-pass therebetween. The bottom of the groove of each roller includes a convexedly curved portion, the camber of convexity of which amounts to 10–25 percent of the height of the box-pass. Pressure producing means are operatively connected to the pair of grooved rollers. This pressure producing means being selectively variable in applying pressure at ratios ranging from 1:4 to 1:8.

7 Claims, 4 Drawing Figures



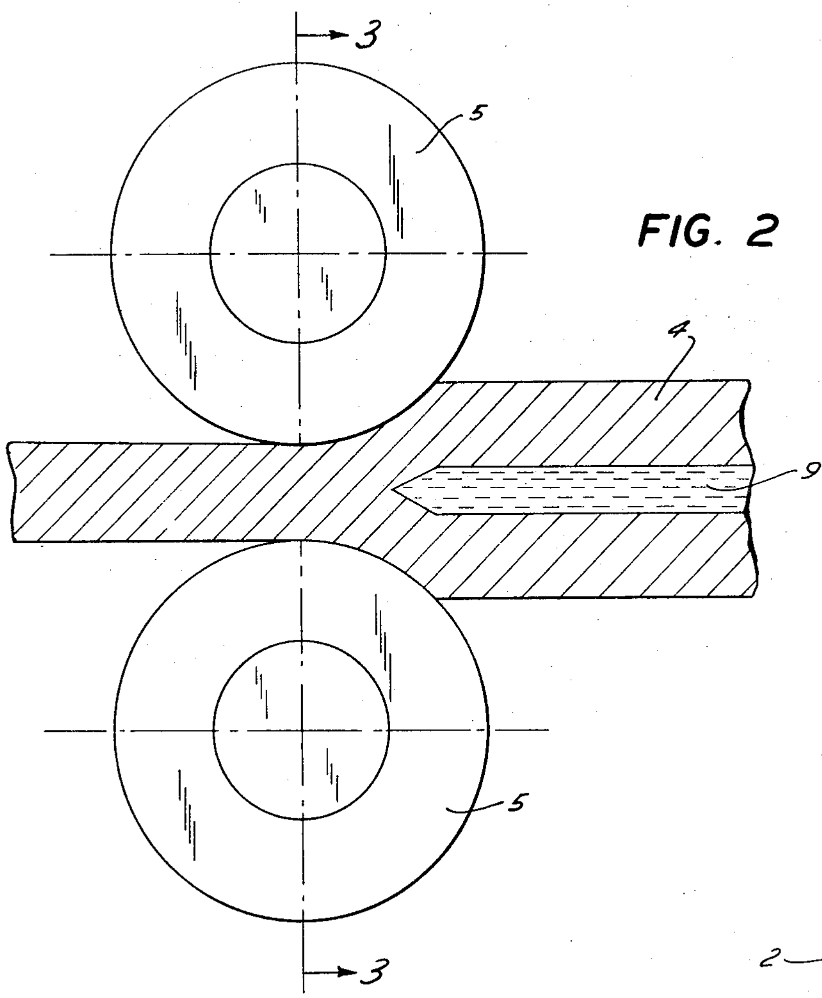


FIG. 2

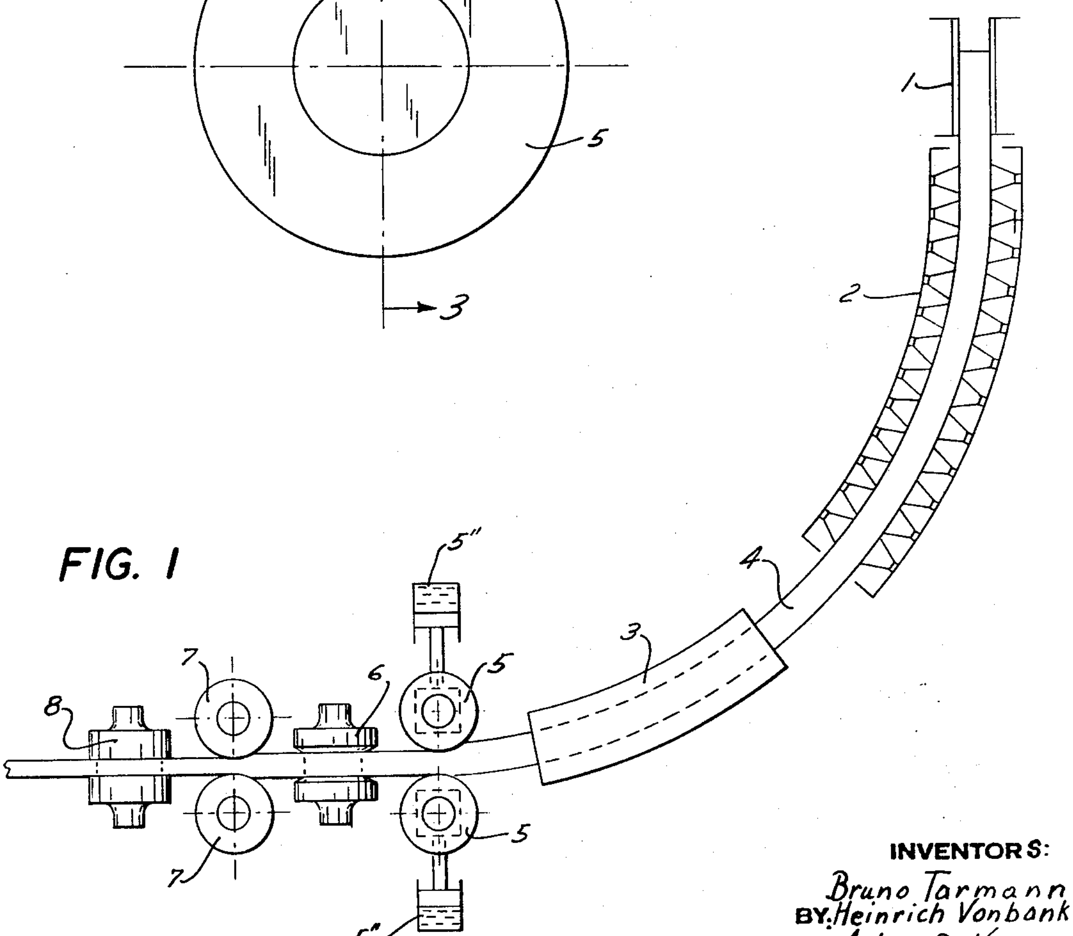


FIG. 1

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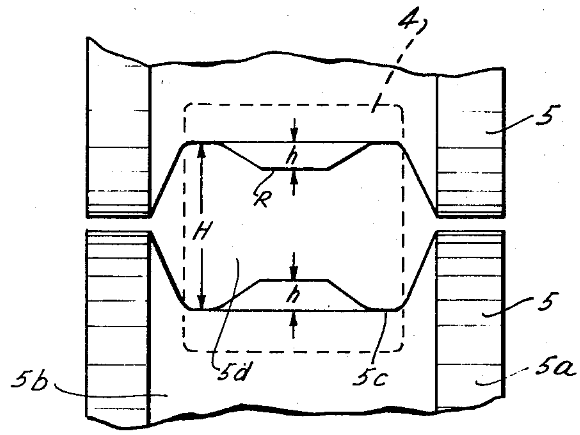

FIG. 3

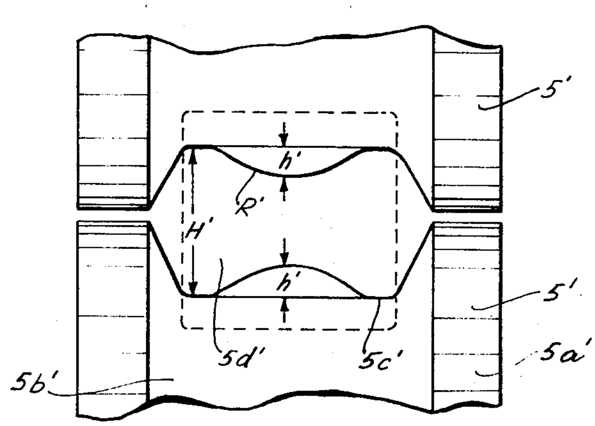

FIG. 4

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APPARATUS FOR MANUFACTURING STRETCH-FORMED PRODUCTS OF HIGH-MELTING METALS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of copending applications Ser. No. 586,494 filed on Oct. 13, 1966, now U.S. Pat. No. 3,491,823, and Ser. No. 632,001 filed on Apr. 13, 1967, now abandoned.

BACKGROUND OF THE INVENTION shrinkages,

This invention relates generally to an apparatus for continuous casting of molten metals, and in particular of nonalloyed and alloyed steels.

It is known that during the continuous casting of steel only the external peripheral zone of the strand is brought to a hardened condition in the ingot mold. The liquid interior, that is to say, the so-called liquid pool or core, attains, with today's rapid continuous casting techniques, a depth i.e., length of about 5 to 15 meters. It is, furthermore, known that convection currents take place in the liquid core which initially prevent the formation of strong liquations and segregations. However, as soon as the diameter of the liquid core is decreased to a thickness of 5 to 30 mm., due to a concomitant increase of the external hardened zone, the convection currents lose their effectiveness, which manifests itself by the formation in the core of the strand of soft spots, shriknages, cavities and liquations. These formed liquations and segregations cannot be removed by subsequent processing of the continuously cast strands. This limits, in some instances, the usability of the continuously cast strands.

In order to eliminate the aforerecited disadvantages, there has for example, been proposed in the prior art to press together the travelling strand by means of rollers at a point upstream from the natural terminating point of the liquid core until the interior wall surfaces of the already hardened external shell are welded together. This is being accomplished without creating a change of the wall thickness or a stretching of the shell zone. In this manner, the formation of a slim liquid core can be avoided and the terminating point of the liquid core extends to the axial plane of the rollers of the roller press. It has been found that with this known process the aforerecited disadvantages can be eliminated but a new undesirable side effect takes place, namely cracks and fissures appear in the interior of the strand, which cannot be welded together during the further processing of the strand. (The aforedescribed known process of the prior art is disclosed in Austrian Pat. No. 187,251 and English Pat. No. 766,584).

SUMMARY OF THE INVENTION

It is therefore a general object of this invention to provide a novel apparatus for continuous casting of molten metals in which all of the aforerecited disadvantages have been eliminated.

Experiments have indicated that during the working over of a strand which has not completely hardened, the formation of cracks and fissures cannot be absolutely avoided. It has, however, also been noted that these formed fissures and cracks are again subsequently welded together during this same working process, if the working takes place in a region of the strand, in which the liquid core thickness during hardening without working amounts to 5 to 30 mm., and if the working results in a substantial reduction in the cross-sectional area of the hardened portion of the strand. In other words, if the liquid core head terminates at a point which, due to the working of the strand, is positioned upstream from the place in which the strand reaches its final cross-sectional configuration due to the working thereof.

The working process according to this invention can be carried out with the existing working installations for working strands, which are suitable for reduction of the cross section of materials. It is preferred that the working is effected by means of rollers. The rollers of the driving installation in a continuous casting processing machine have been found suitable for carrying out the process step of this invention. The rollers of the driving installation may have the usual diameter that is prevalent in rolling mills of the described character. It has been found to be particularly advantageous to use grooved rollers in the fabrication of square and round strands.

The apparatus of the invention comprises at least one pair of grooved rollers the bottoms of the grooves of which are spaced at a distance H from each other. The rollers are mounted downstream from the exit end of the ingot mold. The bottom surface of the groove of each roller of the pair of grooved rollers includes a convexedly curved portion which projects a maximum distance H from the bottom surface proper. The pair of grooved rollers not only deform the cast strand but also serve to withdraw the strand from the ingot mold. It has been found that a pair of grooved rollers shaped as described hereinabove exert a particularly strong and effective pressure on that portion of the cast strand where the molten core is situated and cause the leading point of the molten core to be shifted to a position upstream from the pair of grooved rollers. It has been noted that the distances h must be 10–25 percent of the distance H in order to achieve this effect satisfactorily. Furthermore, the diameter of the rollers of the pair of grooved rollers should be **3.5-5** times as large as the distance H.

The apparatus of the invention operates as follows:

Initially a dummy strand leaves the mold and passes between the pair of grooved rollers which engage it and withdraw it from the mold. The dummy strand has substantially the same cross section as the continuously cast strand before the latter has been deformed. Since the dummy strand is not to be deformed, the pair of grooved rollers are provided with means (preferably hydraulic means) for varying the pressure applied by the pair of grooved rollers and the distance between the pair of grooved rollers. These means adjust the pair of grooved rollers so that it bears against the surface of the dummy strand with a relatively small pressure so as to not damage it. By withdrawing the dummy strand, the continuously cast strand is also withdrawn, and when the latter has reached the region between the pair of grooved rollers, the pressure exerted on it by the pair of rollers is increased four to eight times. This causes the pair of grooved rollers to gradually move together as the cast strand passes therebetween until the edges of the grooved rollers engage each other.

The continuously cast strand which has been worked in accordance with the process of this invention has, after working, still a sufficiently high temperature so that, if necessary, it can by means of the usual known steps be further deformed into the desired shapes and dimensions as will be described hereinbelow.

The conditions which must prevail during the operation of the apparatus of this invention can be maintained without difficulties.

The prevailing thickness of the strand shell, i.e., of the liquid core, can be easily calculated on the basis of known formulas, so that the required distance between the ingot mold and the working installation for a certain strand cross section can also be easily determined. Preferably, the deformation by the pair of grooved rollers according to this invention should be effected with steels having a large solidification period with a liquid core having a thickness near the upper limit of the thickness range, whereas with steels having a small solidification period the deformation should be effected near the lower limit of the thickness range of 5 to 30 mm. of the liquid core.

In the event there are produced strands having different cross-sectional configurations and sizes, which generally would result in varying liquid core lengths, the correct liquid core length can always be obtained by adjusting the rate of pouring of the molten metals or by adjusting the cooling rate of the strand.

Furthermore, the determination of the required size of the worked over area of the hardened strand cross section can be obtained without difficulty, because the cross-sectional portion of the liquid core can be calculated as well as the prevailing thickness of the liquid core. In order to shorten the liquid core length, in accordance with the process of this invention, to an extent that the leading point of the liquid core point is positioned upstream from that plane in which the strand attains, due to the working thereof, its final cross-sectional configuration, it is only necessary to select such a large degree of deformation that it exceeds the cross-sectional portion of the liquid core. It has been found that strands of pronouncedly improved qualities can be obtained when the total cross-sectional area reduction during the working process of this invention is at least 20 percent.

BRIEF DESCRIPTION OF DRAWING

Two embodiments of the apparatus of this invention are now described with reference to the accompanying drawing, in which

FIG. 1 is a schematic elevational view of an installation in accordance with this invention;

FIG. 2 is a cross-sectional elevational view on a larger scale illustrating the continuously cast strand passing through the pair of grooved rollers;

FIG. 3 is a view along line 3—3 of FIG. 2 illustrating a first embodiment of the pair of grooved rollers; and

FIG. 4 is a view along line 3—3 of FIG. 2 illustrating a second embodiment of the pair of grooved rollers.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is illustrated an open ended reciprocating mold 1 in which a continuously cast strand 4 partially solidifies. The partially solidified strand which emerges from the mold 1 passes through the curved cooling installation 2 which comprises a plurality of water sprays. The partially solidified strand 4 then passes through a curved insulated chamber 3 in which the temperature gradient of the solidified portion of the strand 4 is reduced. The apparatus of the invention further includes a working installation of four contiguous pairs of rollers 5, 6, 7 and 8 between each of which the strand 4 passes.

There is set forth hereinbelow an example of a working installation of this invention and an example of steel worked by the installation:

Steel: 0.35 percent C, 0.60 percent Mn, 0.20 percent Si, the balance consisting substantially of Fe.

Mold:	
Cross section of mold	140 mm. square
radius of curved path of the strand	6.5 m.
length of curved path of the strand	10.0 m.
length of cooling device	5.0 m.
length of insulated chamber	2.0 m.
diameter of all rollers	0.4 m.

When the strand is withdrawn from the mold at a velocity of 1.8 m. per minute, the partially solidified strand 4 which enters between the first pair or rollers will have a liquid core of 22 mm. in thickness. As the strand 4 passes between the four pair of rollers 5, 6, 7 and 8, the cross section of the strand 4 is first reduced to 150 × 70 respectively 100mm. (the strand is no longer truly rectangular after passing between the first pair of rollers as can be noted in FIGS. 3 and 4) between the pair of rollers 5, then to 100 × 107 mm. between the pair of rollers 6, then 110 × 72 mm. between the pair of rollers 7, and then 80 mm square between the pair of rollers 8.

The main step of effecting a welding together of the solidified wall portions of the cast thread 4, and thereby the shifting upstreamwards of the leading edge of the molten core 9 (see FIG. 2) is performed by the first pair of grooved rollers 5. This first pair of rollers 5 causes a 36 percent reduction of the cross-sectional area of the cast strand 4 whereby the cross-sectional area of the solidified portion of the cast strand is reduced by 34 percent.

Referring now to FIGS. 3 and 4, there are illustrated in these figures two embodiments of the pair of rollers 5, respectively 5'. In FIG. 3, the pair of rollers 5, each of which has a symmetrical outer configuration, comprises outer portions *5a* which are of substantial cylindrical shape. Adjacent to these outer portions, there are respectively arranged frustoconical portions *5b*. Adjacent to the portions *5b* extends the bottom surface *5c* of the groove *5d* defined by the roller 5. In this embodiment, the portion R projecting from the bottom surface *5c* at a distance h is not curved but is flat.

In FIG. 4 a curved portion having a chamber *h'* projects from the bottom surface *5c'*. The configuration of the cast strand 4 prior to being deformed by the pair of rollers 5', is illustrated by a dotted line. The distance between the bottom surface *5c'* of the pair of rollers 5' is indicated by reference letter H'.

The pairs of rollers 5, respectively 5' will deform the cast strand 4 so that it will substantially correspond in shape to the passage defined between the pair of rollers 5, respectively 5' when the cylindrical portions *5a*, respectively *5a'* come into contact with each other. Such a contacting between these cylindrical portions comes about after a short run-in stage of the cast strand.

The pairs of rollers 5, respectively 5' not only shape the cast strand but also effect its withdrawal from the mold 1. The withdrawal of the cast strand is performed with the aid of a dummy strand (not illustrated). This dummy strand should, of course, not be deformed, and therefore, the pressure applied to the dummy strand should not be excessive in order to avoid damaging it. The pair of grooved rollers 5, respectively 5' are provided with pressure application means 5'' which preferably are in form of a hydraulic piston and cylinder arrangement. Similar means may be provided for the pair of rollers 6, 7 and 8.

The dummy strand has substantially the same cross section as the continuous cast strand 4 before its deformation. Experiments have indicated that the distance *h* in the pair of rollers 5, 5' should be 10 to 25 percent of the distances H. Furthermore, the diameter of the rollers of the pair of rollers 5, 5' should be 3.5 to 5 times as large as the distance H. It has been found advantageous to provide variable pressure application means 5'' which have a range of variability ranging from 1:4 to 1:8.

It is also advantageous for a proper functioning of the apparatuses that at least one additional pair of rollers be provided adjacent to the pair of grooved rollers 5, 5''. This additional pair of rollers 6 should have its axes in a plane perpendicular to the plane defined by the axes of the pair of rollers 5, 5'. Such an arrangement can be supplemented with additional pairs of rollers 7 and 8. The pair of rollers 6 should preferably also have a groove which has, however, a flat bottom, that is, no projecting portion.

It has been found that the pair of rollers 5, 5' each shaped as set forth hereinabove, will effect the welding together of the solidified portions of the cast strand and the shifting upstreamward of the leading edge of the molten core 9.

Although the invention is illustrated and described with reference to a plurality of preferred embodiments thereof, it is to be expressly understood that it is in no way limited to the disclosure of such preferred embodiments, but is capable of numerous modifications within the scope of the appended claims.

We claim:

1. Apparatus for manufacturing stretch-formed high-melting metal products, comprising in combination,
  - mold means for continuously casting a rectangular metal strand;
  - combination withdrawing and shaping means for withdrawing said metal strand in a partially solidified state in which the metal strand has solid exterior and a liquid core and for stretch-forming it so that the solid exterior and a liquid core and for stretch-forming it so that the solid exterior is welded together and substantially reduced in cross section and the leading edge of said liquid core is displaced to a position upstream from said combination withdrawing and shaping means,

said combination withdrawing and shaping means comprising a first pair of oppositely mounted rollers being spaced a predetermined first distance from each other and defining a box-pass therebetween, each roller of said first pair of rollers having a bottom surface,

a portion projecting a predetermined second distance from the central area of said bottom surface, the second distance being equal to 10–25 percent of said first distance,

the diameter of each roller of said first pair of rollers being about 3.5 to 5 times said first distance, and

pressure application means being operatively connected to said first pair of rollers for applying a withdrawal pressure and subsequently applying a shaping pressure 4–8 times greater than said withdrawal pressure.

2. The apparatus as set forth in claim **1**, wherein said pressure application means have a degree of variability ranging from 1:4 to 1:8.

3. The apparatus as set forth in claim **2**, wherein said projecting portion is substantially curved.

4. The apparatus as set forth in claim **2**, wherein said projecting portion is substantially flat.

5. The apparatus as set forth in claim **2**, including at least one second pair of oppositely mounted rollers which is mounted downstream from said first pair of rollers.

6. The apparatus as set forth in claim **5**, wherein the axes of the rollers of said first pair and of said second are perpendicular with respect to each other.

7. The apparatus as set forth in claim **6**, wherein said second pair of rollers define a second box-pass therebetween, the bottom of each roller of said second pair being substantially flat over its entire surface.

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