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[54] **ARRANGEMENT FOR BENDING STEEL PLATES**

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[51] **Int. Cl.** **B21d 5/14**

[58] **Field of Search** 72/168, 171, 177; 29/124, 29/125, 130

[56] **References Cited**

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[57] **ABSTRACT**

A method of bending a steel plate to form a pressure outside plating for a spherical holder or the like which comprises arranging in the center a pair of pinch-type bending rolls of mating configurations, one of which being barrel-shaped and the other hourglass-shaped, either roll being adjustable in position toward and away from the other roll, disposing two hourglass-shaped pressure bending rolls at appropriate distances away from the both ends of the said bending rolls in such a manner as to be adjustable at least in the same direction as the said bending rolls, and feeding the steel plate through the center pair of bending rolls and then along the hourglass-shaped pressure bending rolls.

1 Claim, 3 Drawing Figures

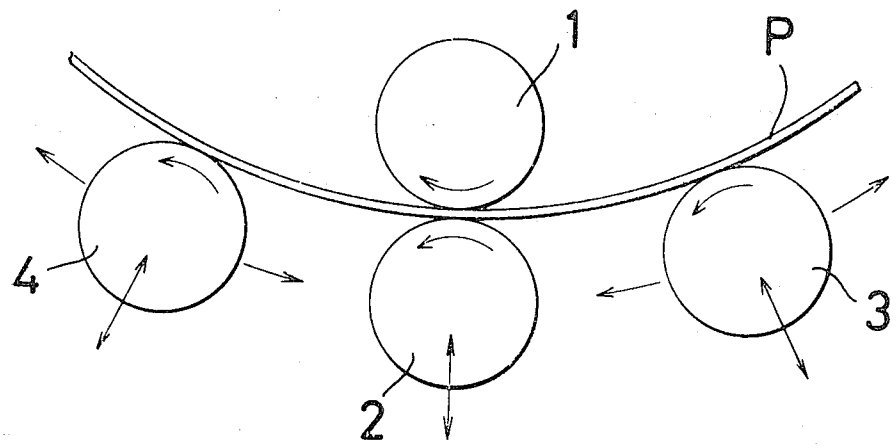


FIG. 1

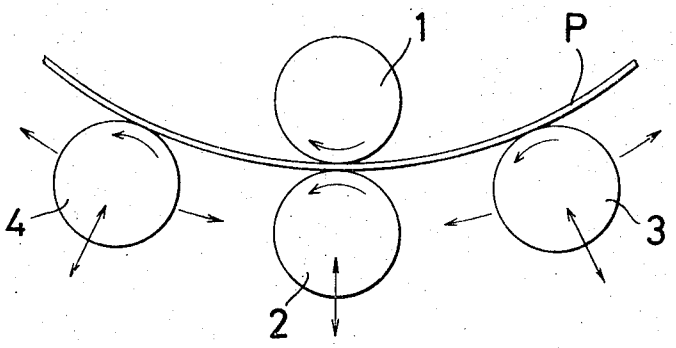


FIG. 2

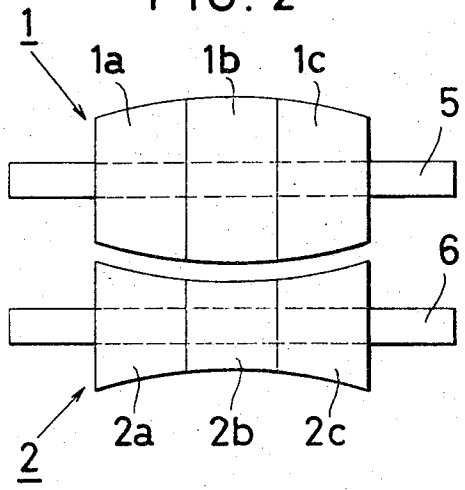
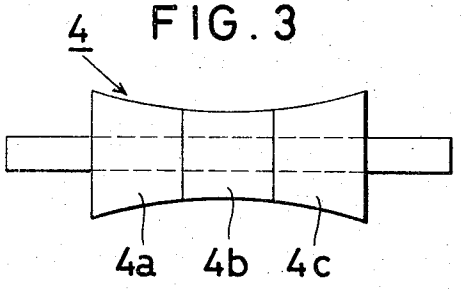


FIG. 3



ARRANGEMENT FOR BENDING STEEL PLATES

This invention relates to a method and apparatus for bending steel plates for use in the construction of large-size pressure vessels, such as spherical holders, and more specifically to a method and apparatus for forming by bending part of the outside plating of such vessels.

The large curved steel plates for the manufacture of pressure vessels are usually fabricated by one of the four methods as classified below:

1. Forming by cold double action press
2. Forming by hot single action press
3. Spinning
4. Explosive forming

The cold double action press is used where the plates to be bent are less than 25 to 30 mm in thickness, for example for the fabrication of outer plates of tank trucks, and where a relatively large number of such plates are to be handled at a time. The hot single action press, which does not put any limitation to the thickness of the plate to be formed, is suited for the bending of outside plating of thick-walled spherical holders for transportation of natural gas or the like. In any case, however, the forming by a press requires a male die as large as the workpiece and also a ring-shaped female die of the corresponding size, usually ranging in diameter from 2,000 to 3,000 mm. Therefore, the high die cost often makes the process economically infeasible. Moreover, the heavy weight of the die and stay intervals of the press are limiting factors in many cases.

Spinning is a process which has sometimes been resorted to in the forming of tank heads but not in the fabrication of curved plating for spherical holders.

As a unique method of plate bending, explosive process has been studied. However, the amount of explosive that can be safely used has rendered it difficult to apply the process to the fabrication of large curved plates.

Thus the conventional methods are being confronted with growing difficulties in the forming of bent plates for the construction of pressure vessels, such as spherical holders, which have in recent years been demanded to be larger and larger in size with the ability to withstand higher internal pressures.

In view of the foregoing, the present invention has for its object to provide a method and apparatus by which the aforedescribed problems are all settled.

The present invention resides, in essence, in a method and apparatus for bending steel plates by feeding a plate through a combination of rolls consisting of a pair of pinch-type bending rolls in the center, both with a smaller diameter than that of the cylinder to be formed by the bent plates, one of the rolls being barrel-shaped to mate with the other roll which is substantially hourglass-shaped, either of the rolls being movable toward and away from the other, and two hourglass-shaped pressure bending rolls arranged in the front and rear of one of the pair of bending rolls, said pressure bending rolls being adjustable in position, if necessary, in the direction where the workpiece is being fed, said steel plate being driven forward by the center pair of bending rolls while being bent under pressure by the front and rear hourglass-shaped rolls.

This invention will be better understood from the following detailed description taken in conjunction with the accompanying drawing showing an embodiment thereof, in which:

FIG. 1 is a schematic side view showing an arrangement of rolls embodying the method of bending heavy steel plates in accordance with the invention;

FIG. 2 is a front view of the center pair of pinch-type bending rolls; and

FIG. 3 is a front view of one of the pressure bending rolls located adjacent the both sides of the center pair of rolls.

Referring now to FIG. 1, the reference character P indicates a thick plate being bent by a combination of bending rolls, i.e., a barrel-shaped upper roll **1**, an hourglass-shaped lower roll **2** which is movable upward and downward as indicated by arrows, said rolls **1** and **2** constituting a pair of pinch-type bending rolls, at least one of the rolls being adapted to be coupled to a conventional drive, and hourglass-shaped pressure bending rolls **3, 4** which are also movable upward and downward and further back and forth in the plate feeding direction as indicated by arrows. The hourglass-shaped rolls **3, 4** are held a suitable distance in either direction from the center bending rolls **1, 2,** the distance being governed by the radius of curvature desired of the plate.

The adjustments of the rolls **1, 2, 3** and **4** in the vertical and horizontal directions are made in the usual manner, for example by hydraulic means (not shown).

It is now assumed that a strip of steel plate enters and goes through the pair of pinch-type bending rolls **1, 2** which are being driven in the directions of arrows by a motor (not shown), and the lower hourglass-shaped roll **2** presses the plate with an appropriate pressure against the upper barrel-shaped roll. Then, as viewed in FIG. **1,** the steel plate P moves leftward while being pressed by the rolls **1, 2.** When the plate has arrived at a certain point, the hourglass-shaped roll **4** at the left is raised to deflect the workpiece upward, thus producing a curve. Because the single pressure application performed in this way is not sufficient for forming a curved plate for the construction of spherical holders or the like, the mating rolls **1, 2** are driven in the opposite direction by the motor, so that the plate is fed backward, or in this case rightward. Upon arrival of the plate at a given point, the other hourglass-shaped roll **3** is raised for additional bending. In the manner described, the procedure of passing the plate along the center hourglass-shaped roll **2** and the adjacent roll **4** or **3** while raising the latter for pressure application is repeated several times for gradual curving of the plate until the plate attains the desired radius of curvature for the outside plating of a spherical holder, when the plate is taken out leftwardly of the roll arrangement.

Since the rolls are fairly largely crowned, there is a tendency of relative slipping widthwise between the plate P and the pair of bending rolls **1, 2.** This is precluded, in accordance with this invention, by dividing the rolls into subrolls as illustrated in FIG. **2,** i.e., by dividing the upper barrel-shaped roll into roll members **1***a*, **1***b* and **1***c*, and the lower hourglass-shaped roll into **2***a*, **2***b* and **2***c*. The roll members are mounted on roll shafts **5** and **6,** respectively, and the central member **1***b* of the upper barrel-shaped roll **1** is fastened from the both ends (not shown) in such a manner that it can freely run in combination with the both end members **2***a*, **2***c* of the lower hourglass-shaped roll **2.** Of course,

the other roll members may be allowed to run freely instead to achieve the same bending efficiency.

By reducing the length of the roll portions secured to the shafts **5, 6** in the manner described and, if necessary, covering the roll surfaces with hard rubber or the like, it will be possible to eliminate practically all of the problems in plate forming which are attributable to the slipping.

The lower hourglass-shaped rolls **3** and **4** mounted adjacent the both ends of the pinch-type bending rolls **1, 2** are also divided into a plurality of roll members, for example into members **4***a*, **4***b* and **4***c* as shown in FIG. **3,** so that either the middle member **4***b* or the both end members **4***a*, **4***c* can freely run on a shaft **7.**

In this way a flat strip of steel plate is bent to an upwardly curved outside plate which is also curved in cross section with both edges bent upwardly.

It is not in the least objectionable, of course, to adopt a roll arrangement contrary to that of FIG. **1** so that the workpiece can be curved downwardly at both ends and both edges.

What is claimed is:

1. An apparatus for bending a steel plate in three dimensions to form a pressure outside plating for a spherical holder or the like comprising in combination: an upper and lower roll arrangement including a center pair of pinch-type bending rolls of mating configurations, one of which being barrel-shaped and the other hourglass-shaped, said pair of rolls being divided across their longitudinal axes into the same numbers of members, some of which are firedly mounted while the remaining members are rotatably mounted as followers, said center pair of bending rolls being adjustable in position toward and away from each other, and two other hourglass-shaped pressure bending rolls disposed at appropriate distances away from the pair of bending rolls in such a matter as to be adjustable in the same direction as the said bending rolls and also to be adjustable toward and away from the said pair of bending rolls, said two hourglass rolls being also divided in the same manner across their longitudinal axes; whereby, desired bending is accomplished by forcing a plate through the center pair of bending rolls and along the hourglass rolls disposed on both sides of the pair, driving the two rolls of the center pair together in alternate directions; moving the two other hourglass-shaped pressure bending rolls on both sides of the center pair alternately toward the plate until they, by turns, reach preset positions in pressure contact with the plate; and repeating the afore-said procedure until the plate attains the desired curvature along the rolls.

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