(54) PIPE AND MOLDING EQUIPMENT ARRAY AND PIPE MOLDING METHOD

A pipe forming line that has breakdown and cluster forming sections and have rolls having flexible forming capability and compatibility with steel pipes of various sizes and is capable of conducting forming by continuous roll forming is provided together with a pipe production method.

A pipe forming line comprising breakdown stands, cluster stands or cage roll stands, and fin-pass stands and a pipe forming method, the pipe forming line being characterized in that, in order to bend-form to a substantially semicircular shape or a substantially final product shape by upper and lower rolls of at least multiple stages of the break down stands, it uses as the roll caliber a curve whose curvature varies continuously or stepwise, and is directly installed with a fin-pass mill without installation of cage rolls.

![Diagram of pipe forming line](image)
Description

TECHNICAL FIELD

[0001] This invention relates to a new pipe forming line and pipe forming method for, in the production of steel pipe, particularly electric welding steel pipe, by continuous roll forming, conducting steel pipe forming by forming rolls capable of flexible forming and compatible with steel pipes of multiple sizes without the use of cage rolls.

BACKGROUND TECHNOLOGY

[0002] In the production of electric welded steel pipe, the mainstream technology widely considered ideal for large-lot production of limited types is that of utilizing forming rolls suitable for forming the desired bore and wall thickness, laying out a line of forming rolls matched to the bore, and conducting continuous roll forming for continuously forming a steel strip. This production process, which precedes the welding of the electric welded steel pipe, is generally divided into the three process of initial forming (breakdown forming), intermediate forming (cluster forming or cage forming) and finish forming (fin-pass forming). The product is obtained following a final squeeze process in which welding is conducted. Although the initial forming and intermediate forming are sometimes called “breakdown forming,” they will be distinguished in this explanation. In combined forming, particularly at the start thereof, the steel strip constituting the raw material has the basic shape of an open plate. To apply bending, upper and lower (concave and convex) rolls are used to form the steel strip by simultaneously restraining its inner and outer surfaces. During the intermediate forming, corresponding to the latter half of the combined forming process, the steel strip gradually approaches pipe shape. Use of convex rolls (inner rolls), even if possible, is extremely difficult from the aspect of equipment design. The current practice is therefore to restrain the steel strip from the outer surface using ordinary concave rolls.

[0003] With supply and demand for small-variety, big-lot production recently on the decline, in order to achieve lower cost and enhanced competitiveness through use of rolls with flexible forming capability, proposals have been made regarding improvement of the cage roll forming method, with particular emphasis on enabling flexible forming in the intermediate forming process, and regarding flexible forming not only in the intermediate forming process but also at the breakdown forming section where the focus is on edge bending. Typical of these is the method taught by JP-B(examined published Japanese patent application)-3-129777, commonly called the “FF mill” method, which uses forming rolls of such sectional shape that part or all of the sectional curve of the roll surface of each forming roll is a curve whose curvature is preset to vary continuously or stepwise to include the curves of the steel strip edge portions at the roll flower (roll-designed profile) of various steel pipes for forming steel pipes of the various outer diameters, wall-thickness, materials envisioned, and which forms both edge portions of the steel strip by paired upper and lower rolls having the sectional configuration of this curve.

[0004] However, a number of problems have arisen in connection with the aforesaid flexible forming. The problems that have emerged in the ordinary mill designed for flexible forming include, for example, that 1) the need for greater adjustment freedom and adjustment space complicates the mechanical structure, canceling the cost-reduction effect of flexible forming and making the mill relatively low in robustness, and that 2) expansion of the range of good quality flexible forming becomes increasingly difficult and constitutes a cause of welding instability and product quality degradation.

[0005] Between the breakdown step and the beginning of the fin-pass step, a particular problem in the method that disposes a large number, ordinarily 10-30 pairs, of small-diameter rolls in the forming direction, i.e., the so-called cage method, is that the desired bent shape cannot be obtained owing to the weak forming capability of the cage rolls and that, therefore, the actual bent shape frequently differs greatly from the roll flower shape of the design. In other words, this kind of flexible forming is a compromise that sacrifices the forming capability of the overall mill.

[0006] The object of the present invention is to provide a new pipe forming line and pipe forming method that, in the production of steel pipe, particularly electric welded steel pipe, by continuous roll forming, enables stable steel pipe forming by forming rolls having flexible forming capability and compatibility with steel pipes of multiple sizes without use of cage rolls.

DISCLOSURE OF THE INVENTION

[0007] The present invention is for overcoming the foregoing problems and, specifically, provides a pipe forming line, making no use whatsoever of the aforesaid cage rolls, that is installed with the aforesaid FF mill edge portion bending stands at least the initial few stages, preferably 2-3 stages, of the upper and lower rolls installed in multiple stages of the aforesaid breakdown (BD) process, forms a substantially semicircular or substantially final product shape by combinations of the upper and lower rolls of these multiple stages, and directly conducts fin-pass forming in the fin-pass process that follows, or is disposed with multiple stages, preferably 2-3 stages, of conventional side roll stands for connection with the fin-pass process, thereby imparting a flexible forming size range over a ratio of steel pipe outside diameters of 1 : 3 at higher accuracy than the conventional cage-type mill, and also provides a pipe forming method.

[0008] The gist thereof is (1) a pipe forming line
comprising breakdown forming stands, cluster forming stands or cage forming stands, and fin-pass stands, which pipe forming line is characterized in that it successively conducts bend-forming from both edge portions toward the center of a steel strip in at least multiple stages of the breakdown forming stands by use of one set of common-use forming rolls of such sectional shapes that part or all of the sectional curve of the roll surface of each forming roll is a curve whose curvature is preset to vary continuously or stepwise to include the curves of the steel strip cross-section at the roll flowers of various steel pipes for forming steel pipes of the various outer diameters, wall-thickness, materials envisioned, and is directly installed on the upstream side of a fin-pass section without being installed with cluster rolls or cage rolls, and (2), in the foregoing (1), a pipe forming line characterized in being installed with one stage or multiple stages of stands having cluster rolls or side rolls for connection between the breakdown forming process and the fin-pass process.

[0009] The present invention also provides a pipe forming method comprising a breakdown process, a cluster process or an intermediate forming process, and a fin-pass process, which pipe forming method is characterized in carrying out pipe forming by conducting breakdown forming with multiple stands equipped with a set of upper and lower rolls having flexible forming capability of such a sectional shape that part or all of the sectional curve of the roll surface of each forming roll is a curve whose curvature is preset to vary continuously or stepwise to include the curvatures of the deformed shapes at the roll flowers of various steel pipes for forming steel pipes of the various outer diameters, wall-thickness, material envisioned, thereby enabling bend-forming in the breakdown process of pipes of multiple sizes having different outer diameters, wall-thickness, material to a substantially semicircular shape of the final product or a substantially final product shape, and conducting fin-pass forming in a fin-pass process either after intermediate forming with the side rolls of multiple stands or directly without conducting intermediate forming.

BRIEF DESCRIPTION OF DRAWINGS

[0010]

FIG. 1 is a schematic view of a conventional cage-forming mill.
FIG. 2 is a cross-sectional view of the A-A region of FIG. 1.
FIG. 3 is a cross-sectional view of the B-B region of FIG. 1.
FIG. 4 is a schematic view of the pipe forming line of a conventional FF mill.
FIG. 5 is a schematic view of a pipe forming line according to present invention.
FIG. 6 is a schematic view of another example of a pipe forming line according to present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0011] As a result of the various studies conducted regarding the aforesaid flexible forming, the present inventors acquired the following knowledge. First, they discovered that, from the viewpoint of the caliber and the roll layout of the forming rolls used in the different forming processes of electric welded steel pipe, flexible forming is most difficult in the fin-pass forming and is the sticking point of flexible forming throughout the mill. The only way to overcome this is to eliminate the conventional fin-pass forming. This fin-pass forming has a number of functions, however, and cannot be completely done away with until these functions are transferred to other forming stages. Nevertheless, the load on the fin-pass forming can be markedly reduced.

[0012] As a measure for reducing the load on the fin-pass forming, the sectional shape can be corrected with small reduction by making the sectional shape of the steel strip as close as possible to circular or the shape of the fin-pass roll caliber before entering the fin-pass forming section. Although this can be achieved by upgrading the forming capability of the breakdown forming or the cluster forming (cage roll forming) to which the fin-pass functions are to be transferred, up to now flexible forming has mainly been implemented only with respect to the aforesaid intermediate forming. In the case of using cage rolls, while flexible intermediate forming would seem easy to conduct, the practice has been to leave the deformation properties of the steel strip, the raw material, out of consideration and, focusing only on the geometry, to rely solely on empirical roll design based on the roll flower. Particularly in the case of flexible forming, since caliber rolls are not used and only a portion of the steel strip width is restrained, the result of the actual formation often differs greatly from the original design due to the fact that the roll flower is not the actual deformed shape of the steel strip cross-section and the fact that, owing to the successive nature of the roll forming, differences occurring between the two on the upstream side tend to accrue and affect the downstream side.

[0013] In cage forming using the aforesaid cage rolls, although the basis for flexible forming is the geometric similarity of the different sized roll flowers of the intermediate forming section, these roll flowers are not the actual deformed shape. Of particular note is that the difference between the roll flower and the actual sectionally deformed shape is already great following breakdown forming before entering the intermediate forming section. Further, since the plastic deformation behavior includes a high degree of nonlinearity (material nonlinearity, geometric nonlinearity), it is clearly not possible to obtain deformation similarity with the ordinary method of constituting the cage rolls. As cage roll forming is by the air-bend method, moreover, the mag-
nitude of the bending moment received at different portions of the steel strip cross-section varies with the arm length (the location of the individual sectional portions). Since the amount of forming at the individual sectional locations naturally differs accordingly, folding occurs with particularly high frequency at the pipe bottom portion where the arm is longest. While inner rolls are used as means for preventing this, in such case the bending moment changes abruptly at the steel strip portion contacted by the inner rolls, which has the contrary effect of making folding more likely to occur. From the aspect of flexible forming, moreover, use of inner rolls is by no means easy in terms of equipment structure.

The foregoing problems are present not only in cage roll forming but also in other types of intermediate forming. The cause is rooted in a shortcoming peculiar to the air bend method, namely, that the magnitude of the bending moment is hard to control. Therefore, owing to the uncertainty of the formation, the strip sectional shape of the formed steel strip is sensitively affected by the material and t/D (thickness/diameter) and the like, so that control thereof is difficult and determining the caliber of the fin-pass rolls becomes difficult. As a result, the number of fin-pass forming stands increases. Thus, the approach up to now of focusing on the intermediate forming section as the center of flexible forming leads to unstable forming and, as such, remains unresolved. In view of the foregoing circumstances, the present invention was accomplished based on the notion that implementation of flexible forming should be centered on the breakdown forming section.

FIG. 1 is a schematic view of a cage roll forming mill, which is typical of conventional flexible forming mills. In FIG. 1, an unrolled steel strip 1 is fed to the breakdown process of a pipe forming line and formed into a steel pipe. A pair of laterally spaced edge bend rolls 2 are disposed on the inlet side of the line to contact the steel strip edge portions and bend-form both steel strip edges. The steel strip with the formed edge portions then enters the intermediate forming section, where bend-forming of the middle portion of the steel strip is conducted by a center bend roll group 3a-3d and a cage roll group 4a-4x. The steel strip after intermediate forming further enters the fin-pass process, in which circumferential compression is applied to the steel strip by a fin-pass roll group F1, F2, F3 to correct its sectional shape and put it in a condition enabling appropriate electric seam welding, and is finally sent to the squeezer process, in which the whole pipe is restrained by squeezer rolls 5 and electric seam welded by a welding apparatus (not shown) to afford an electric welded steel pipe product. FIGs. 2 and 3 show the structure of a different type of cage mill in the intermediate forming process. Taking FIG. 1 as an example, there are shown cross-sections of the mill at the A-A region of FIG. 1 (in FIG. 2) and at the B-B region (in FIG. 3). A large number of inner roll groups 6 are disposed on the inside of the formed portion in addition to the cage rolls shown in FIG. 1, in order to restrain the inner portion of the steel strip so that folding of the pipe bottom portion does not occur. FIG. 4 is a perspective view of the pipe forming line, called an FF mill, taught by the aforementioned JP-B-3-12977. In FIG. 4, the line is constituted of a breakdown forming section composed of a BD1 stand for conducting edge bending, a BD2 stand for conducting reverse bending and a BD3 stand for forming the middle region of the sheet width; a cluster roll stand for producing a circular cross-section composed of a roll group made up of C1-Cm, ordinarily six sets, installed on the same table to conduct intermediate forming; a fin-pass roll section composed of F1, F2 for conducting finish forming; and a squeeze roll stand for establishing a weldable condition. In the FF mill pipe forming line shown in FIG. 4, the BD1 stand for the edge bending of the breakdown forming is designed to have as its roll caliber a curve whose curvature varies continuously or stepwise and, further, is combined with a roll positioning system capable of moving and rotating the forming rolls so that roll surface regions having appropriate curvature can be brought into contact with the required steel strip region to enable effective forming of steel pipes differing in size and material with the same rolls.

On the other hand, at the cluster roll stand, ordinarily six sets of rolls, is adopted but a problem arises regarding forming performance because the purpose of the forming by these rolls is the same as the purpose of forming by conventional cage rolls. Specifically, the designed deformed shape is hard to obtain owing to the uncertainty of the forming.

In addition, the mechanical structure at the conventional cluster forming section mentioned earlier also involves a number of problems. Specifically, even though the number of rolls of the cluster forming section is not as great as in cage roll forming, a problem again arises regarding the complexity of the mechanical structure because, in consideration of size flexible forming and the like, it is not sufficient only to effect parallel translation of the rolls in the different directions but is also necessary to rotate the rolls within a certain range.

Thus, notwithstanding that flexible breakdown forming is achieved, the forming load and the stress in flexible forming still remains in the cluster forming section. The present invention completely overcomes these problems. As shown in FIG. 5, in the present invention, breakdown forming is conducted within a range of about 50% of the sheet width by a BD1 stand for edge bending the outermost edge portion, a BD2 stand for edge bending a region inward and adjacent to the outermost edge portion, a BD3 stand for forming a region further inward from said inward region and, further, reverse bending, and a side roll group composed of multiple stages, preferably three stages S1-S3, is installed, with no use whatsoever of the cluster rolls or cage rolls conventionally used in intermediate forming.

As the side roll group in this invention there
are installed side roll stands comprising side roll groups having commonly used roll forming surfaces. It should be noted, however, that, as with the breakdown rolls, there can be used as the caliber of the side rolls a curve whose curvature varies continuously or stepwise. Since such side rolls do not make contact with the formed steel pipe edge portions, edge elongation at the steel pipe edge portions is small and the steel pipe edge portions form neat straight lines. Connection with the next process, i.e., the fin-pass forming process, is therefore possible. Moreover, by adopting the foregoing configuration, the present invention enables production of products with a low t/D (thickness/diameter ratio).

Moreover, if sufficient edge bending and forming of the middle region of the sheet width can be achieved in the breakdown process, it is possible to provide a pipe forming line that, as shown in FIG. 6, establishes a direct connection from the breakdown process to the fin-pass forming section and, further, to provide a pipe forming line that has only a retaining roll or the like interposed to connect the breakdown process with the fin-pass forming section.

In addition, there can be provided a pipe forming line that is imparted with a flexible forming size range over a ratio of steel pipe outside diameters of about 1:3.

The configuration adopted by the present invention enables (1) stable formation minimally affected by material properties and t/D to be conducted in a breakdown forming section with strong forming capability and, as a result, (2) reduction of the load on the cluster forming section, whereby the number of cluster forming rolls can be markedly reduced to substantially simplify the equipment structure and lower the cost.

INDUSTRIAL APPLICABILITY

As explained in the foregoing, the present invention provides a new pipe forming line that is high in forming accuracy and low in cost, which, in the production of steel pipe, particularly electric welded steel pipe, by continuous roll forming, enables steel pipe forming by forming rolls having flexible forming capability and compatibility with steel pipes of multiple sizes without the use of cage rolls.

Claims

1. A pipe forming line comprising breakdown forming stands, cluster forming stands or cage forming stands, and fin-pass stands, which pipe forming line is characterized in that it successively conducts bend-forming from both edge portions toward the center of a steel strip in at least multiple stages of the breakdown forming stands by use of one set of common-use forming rolls having flexible forming capability that are of such a sectional shape that

2. A pipe forming line according to claim 1, characterized in that one stage or multiple stages of stands having cluster rolls or side rolls are installed for connection between the breakdown forming stands and the fin-pass forming stands of the next process.

3. A pipe forming method comprising a breakdown process, a cluster process or an intermediate forming process, and a fin-pass process, which pipe forming method is characterized in carrying out pipe forming by conducting breakdown forming with multiple stands equipped with a set of common-use upper and lower rolls having flexible forming capability that are of such sectional shape that part or all of the sectional curve of the roll surface of each forming roll is a curve whose curvature is preset to vary continuously or stepwise to include the curves of deformed shapes at roll flowers of various steel pipes for forming steel pipes of the various outer diameters envisioned, and is directly installed on the downstream side with fin-pass forming stands without being installed with cage rolls.
Fig. 4

Fin-pass forming section

Cluster forming section

Breakdown forming section

Cn
C1
Z
X
Fig. 6

Fin-pass forming section

Breakdown forming section
## INTERNATIONAL SEARCH REPORT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>JP, 9-10829, A (Sumitomo Metal Industries, Ltd.), 14 January, 1998 (14. 01. 98), Par. No. [0061]; Fig. 9 (Family: none)</td>
<td>1-3</td>
</tr>
<tr>
<td>X</td>
<td>JP, 6-15351, A (NKK Corp.), 25 January, 1994 (25. 01. 94), Par. Nos. [0016] to [0018]; Figs. 1, 2 (Family: none)</td>
<td>1-3</td>
</tr>
<tr>
<td>X</td>
<td>JP, 6-134525, A (Sumitomo Metal Industries, Ltd.), 17 May, 1994 (17. 05. 94), Par. No. [0011]; Figs. 4, 9 (Family: none)</td>
<td>1-3</td>
</tr>
<tr>
<td>A</td>
<td>JP, 6-126337, A (Sumitomo Metal Industries, Ltd.), 10 May, 1994 (10. 05. 94), Fig. 8 (Family: none)</td>
<td>1-3</td>
</tr>
</tbody>
</table>

- **Special categories of cited documents:**
  - "A" document defining the general state of the art which is not considered to be of particular relevance.
  - "E" earlier document but published as or after the international filing date of the claimed invention.
  - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason.
  - "O" document referring to an oral disclosure, use, exhibition or other means.
  - "P" document published prior to the international filing date but later than the priority date claimed.

- **Documents published after the international filing date or priority date:**
  - "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention.
  - "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone.
  - "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
  - "A" document member of the same patent family.

**Date of the actual completion of the international search:**
12 January, 1999 (12. 01. 99)

**Date of mailing of the international search report:**
19 January, 1999 (19. 01. 99)

**Name and mailing address of the ISA/JPEN/ Japanese Patent Office**

**Authorized officer**

**Telephone No.**

Form PCT/ISA/210 (second sheet) (July 1992)