An incremental metal folding apparatus may include a crank arm driving a folding mechanism in continuous reciprocating motion. The folding mechanism may be mechanically linked to a clamp arrangement such that motion of the folding mechanism causes movement of the clamp arrangement. The apparatus may be arranged to perform tangential folding operations.
METAL FOLDING APPARATUS

FIELD OF THE INVENTION

[0001] The invention relates to incremental metal folding, particularly but not exclusively to incremental folding of sheet metal.

BACKGROUND TO THE INVENTION

[0002] Metal folding operations are an essential part of many fabrication processes. Folding operations are applied to a number of different metal materials, including sheet metal, metal tubes or pipes, metal rods etc.

[0003] Existing folding methods include wipe bending, in which a fold wing slides over the material being folded, while pressing it against a fold die. This process tends to damage the metal surface because of the sliding action and also causes distortion in the metal thickness around the fold. This process also requires a specific die for each type of fold.

[0004] Incremental folding methods are known, in which a series of closely spaced folding operations are performed in order to “build up” a large fold from a number of smaller folds. However, existing incremental folding methods suffer from slow speed and/or overly complex control systems.

[0005] It is an object of the invention to provide an improved incremental metal folding apparatus, or at least to provide the public with a useful choice.

SUMMARY OF THE INVENTION

[0006] In a first aspect the invention provides an incremental metal folding apparatus including:

[0007] a folding mechanism configured to move so as to fold metal stock;

[0008] a feed arrangement configured to move metal stock through the folding mechanism; and

[0009] a clamp arrangement configured to hold metal stock while it is being folded;

[0010] wherein the folding mechanism, feed arrangement and clamp arrangement are arranged to work together to perform a plurality of spaced incremental folding operations so as to build up a fold from a plurality of incremental folds; and wherein the folding mechanism and the clamp arrangement are mechanically linked, such that movement of the folding mechanism causes movement of the clamp arrangement.

[0011] In a second aspect the invention provides an incremental metal folding apparatus including:

[0012] a folding mechanism configured to move so as to fold metal stock;

[0013] a crank mechanism arranged to convert circular drive motion into reciprocating motion of the folding mechanism;

[0014] a feed arrangement configured to move metal stock through the folding mechanism; and

[0015] a clamp arrangement configured to hold metal stock while it is being folded;

[0016] wherein the folding mechanism, feed arrangement and clamp arrangement are arranged to work together to perform a plurality of spaced incremental folding operations so as to build up a fold from a plurality of incremental folds.

[0017] In a third aspect the invention provides an incremental metal folding apparatus including:

[0018] i. a folding mechanism configured to move so as to fold metal stock;

[0019] ii. a feed arrangement configured to move metal stock through the folding mechanism; and

[0020] iii. a clamp arrangement configured to hold metal stock while it is being folded;

[0021] wherein the folding mechanism, feed arrangement and clamp arrangement are arranged to work together to perform a plurality of spaced incremental tangential folding operations so as to build up a fold from a plurality of incremental folds.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The invention will now be described by way of example only, with reference to the accompanying drawings, in which:

[0023] FIG. 1 is a perspective view of a folding apparatus according to one embodiment;

[0024] FIG. 2 is a side view of the folding apparatus of FIG. 1;

[0025] FIG. 3 is a cross-section along the line 3-3 in FIG. 2, with the folding mechanism in a first position;

[0026] FIG. 4 is a detailed view of part of the cross-section of FIG. 3;

[0027] FIG. 5 is a similar view to that of FIG. 3, with the folding mechanism in a second position;

[0028] FIG. 6 is a detailed view of part of the cross-section of FIG. 5;

[0029] FIG. 7 is a cross-section along the line 7-7 in FIG. 2;

[0030] FIG. 8 is a cross-section along the line 8-8 in FIG. 2;

[0031] FIG. 9 is a cross-section along the line 9-9 in FIG. 7;

[0032] FIG. 10 is a perspective view of a folding system according to a further embodiment;

[0033] FIG. 11 is a side view of the folding system of FIG. 10; and

[0034] FIG. 12 is a top plan view of the folding system of FIG. 10.

DETAILED DESCRIPTION

[0035] FIG. 1 is a perspective view and FIG. 2 is a side view of a metal forming apparatus 10 according to one embodiment. The apparatus 10 may include a supporting framework 12. A drive arrangement 13 is connected at one end of the folding apparatus 10. The workings of the apparatus will be described with reference to a number of cross-sections through the apparatus 10.

[0036] FIG. 3 is a cross-section along the line 3-3 in FIG. 2. The apparatus 10 includes a folding mechanism 20 and a clamp arrangement 21. In use, a feed mechanism (not shown in FIG. 3) feeds sheet metal material (not shown in the drawings) into the apparatus 10.

[0037] A leaf spring 22 may be provided below the clamp arrangement 21, and the sheet metal material is fed through the apparatus 10 between the leaf spring 22 and the clamp arrangement 21. The leaf spring 22 is flexible so as to bend with the material being folded and functions to protect the material surface from damage by the folding mechanism 20.

[0038] The clamp arrangement 21 holds the sheet metal material in place, while the folding mechanism 20 moves to create a fold in the sheet metal material. The folding mechanism 20 rotates about an axis 23 (obscured in FIG. 3).

[0039] The clamp arrangement 21 may be biased towards a clamped position by a spring, hydraulic or pneumatic cylinder or other biasing means.
As will become clear below, the folding mechanism 20 and clamp arrangement 21 are arranged to perform a series of spaced incremental folding operations. The spaced incremental folds together build up an overall fold.

The incremental folds have some finite radius and for the best smoothness the incremental folds will overlap. For best results, the overlap between adjacent folds may be in the range 0 to 1 mm. The spacing between adjacent folds may be around 4 to 5 mm for some applications. These values are examples only, as different spacings and overlaps may be suitable for different applications.

Where the folds do not overlap, the overall smoothness will be less since there will be flat regions in between the incremental folds.

FIG. 4 is a detailed view of a part (marked 4 in FIG. 3) of the cross-section of FIG. 3, more clearly showing the folding mechanism 20. The folding mechanism 20 includes a beam 24, which preferably runs substantially along the length of the apparatus 10. One or more attachments 25 may be provided at the top of the beam 24, in order to provide a folding surface 26 which will contact the underside of the metal stock during a folding operation.

The folding mechanism 20 also includes a pivotal connection 27 to a crank arm 28. The crank arm 28 is in turn connected to a crank shaft 29 which rotates about an axis 30. The crank shaft 29 receives power from the drive arrangement 3, in order to drive movement of the folding mechanism 20. Preferably, the drive shaft 29 receives continuous circular drive motion, converting this into reciprocating movement of the folding mechanism 20. When this is the case, the folding mechanism 20 will be driven in continuous reciprocating movement (i.e. continuous oscillations) to perform a series of folding operations. The drive arrangement may include a suitable motor.

FIG. 4 also shows part of the clamp arrangement 21, including a clamp die 32 which, when the clamp arrangement 21 is in a clamped position, sits against an upper surface of the metal stock. A surface 33 of the clamp die 32 is shaped to facilitate the folding operation. This shape may be a curved shape and may be suited to a particular folding radius, or a range of folding radii. Alternatively, the surface 33 may be shaped to suit a minimum desired fold radius, with the actual fold radius produced dependent on other parameters, as discussed below.

FIGS. 3 and 4 show the clamp arrangement 21 in an unclamped position, such that the metal stock can be moved through the folding apparatus 10.

FIG. 5 is a second cross-section of the folding apparatus 10 along the line 3-3, showing the folding apparatus performing a folding operation where α=12°. FIG. 6 is a more detailed view of a part (marked 6 in FIG. 5) of the cross-section of FIG. 5.

In FIGS. 5 and 6, the clamp arrangement 21 is in a clamped position, in which it holds the metal stock against a surface 35. Note that the position of the crankshaft 29 with respect to the axis 30 has changed, the crankshaft 29 having rotated around the axis 30. The folding mechanism 20, driven by the crank arm 28 has pivoted upwards to bend the metal stock around the surface 33 of the clamp die 32.

FIG. 7 is a cross-section along the line 7-7 in FIG. 2 where β=32.5°. This view shows the axis 23 about which the folding mechanism 20 rotates.

The folding mechanism 20 also includes a contact surface 40 which strikes against a cooperating surface 41 of the clamp arrangement 21.

In use, the rotation of the folding mechanism causes the contact surface 40 to strike against the cooperating surface 41. This results in a slight upward movement of the clamp arrangement 21 sufficient to allow the metal stock to be moved through the folding apparatus. Thus, movement of the clamp arrangement 21 is caused by a mechanical link with the folding mechanism 20 rather than a separate control and actuation arrangement.

Here, "mechanical link" does not imply a permanent connection. Rather, this term indicates that movement of the folding mechanism causes, via mechanical means, movement of the clamp arrangement.

In use, the crankshaft 29 is driven in continuous circular motion by the drive arrangement 3. This continuous movement is converted by the crank mechanism into continuous reciprocating movement of the folding mechanism 20. The folding mechanism therefore moves continuously between the position shown in FIGS. 3, 4 and 7, and the position shown in FIGS. 5 and 6. In the position of FIGS. 3, 4 and 7 the folding mechanism is not acting to fold the metal stock, and the clamp arrangement 21 has been lifted clear of the metal stock, to allow its movement through the apparatus 10. In the position of FIGS. 5 and 6 the folding mechanism pivots upwards to fold the metal stock, while the clamp arrangement 21 holds the metal stock against the surface 35, preventing its movement through the apparatus 10.

The mechanical link between the folding mechanism 20 and the clamp arrangement 21 increases the speeds at which the apparatus can perform a series of incremental folding operations. In particular, the clamp arrangement 21 is automatically released at the appropriate stage of the folding cycle, so that no separate control over the clamp arrangement 21 is required.

The feed arrangement (not shown in the drawings) may grip the metal stock in some way, preferably using a vacuum holding system. The feed arrangement moves the metal stock through the apparatus 10 in a controllable, indexed manner. That is, metal stock is moved by a predetermined distance between each incremental folding operation. The feed arrangement may be controlled by a servo motor, preferably using a ball screw on a carriage underneath the metal stock.

Alternatively, the feed arrangement may be linked to the clamp arrangement 21 or folding mechanism 20, or otherwise to the drive arrangement 3. This would mean that a separate drive source would not be required for the feed arrangement. Such a link may also simplify the control required over the feed mechanism.

The feed of material through the machine may be triggered in many different manners. For example, when a control signal is given to commence the folding operation, the same or another signal could cause the feed arrangement to begin feeding metal stock. The feed arrangement could simply use a timed cycle of indexed movement, followed by a waiting period, followed by indexed movement etc. This method is likely to be the simplest because of the limited control requirement for the feed arrangement, but there is some risk associated with the lack of such control.

Alternatively, movement of the clamp or folding mechanism could trigger movement of the feed arrangement. For example, a proximity sensor could be provided on the
folding mechanism or clamp such that a trigger signal is sent to the feed arrangement at the appropriate point in the folding cycle. Similarly, a trigger signal could be based on movement of the motor or crank mechanism.

Various parameters may affect the final form of the folded metal material.

The fold tooling, including the surface 26 of the folding mechanism 20 and the surface 33 of the clamp die 32 may be shaped for a specific bend radius. In this case, the fold tooling may need to be changed if a bend of a different radius is desired. Alternatively, the fold tooling may be designed for use over a specific range of bend radii.

The fold tooling could be designed for a minimum desired bend radius, with bends of greater radius available by reducing the fold angle provided by the folding mechanism 20 (i.e. by altering the position of the folding mechanism at the end of the folding cycle—see FIG. 6). This angle may be adjusted by altering the properties of the crank mechanism. For example, altering the offset between the centre 43 (FIGS. 4 and 6) of the crank shaft 29 with respect to the axis 30 alters the final angle achieved by the folding mechanism 20. If the offset were reduced to zero the folding mechanism 20 would of course not move, and increasing the offset increases the degree of movement and therefore the fold angle achieved.

The crank offset may be adjusted manually, using a pin or the like to secure the crank mechanism in a desired position. Alternatively, the crank offset could be adjusted using an actuator connected to a ball screw, pneumatic cylinder or similar adjustment means.

Altering the crank offset may also alter the angle of the folding mechanism 20 at the beginning of the fold cycle (i.e. the position shown in FIG. 4). If this is unacceptable, the length of the crank arm 28 may be adjusted to compensate, or the position of the pivoting connection 27 may be offset.

The radius of a bend built up from a number of incremental bends is also dependent on the spacing between the incremental bends. This can be adjusted by altering the rate at which the metal stock is fed through the folding apparatus.

In one embodiment, the apparatus provides a fixed folding angle, with the final radius of the bend dependent only on the spacing between incremental folds. This has the advantage of simplicity, since no adjustment of the crank mechanism or changing of the fold tooling is required. A wide range of bends is then possible with a single set of tooling. However, the resulting fold may be of a somewhat lesser quality than would be provided by changing the fold tooling. Clearly the larger the spacing between incremental folds, the less "smooth" the overall fold.

The parameters above, particularly the distance between incremental folding operations, could be adjusted dynamically if necessary in order to create a bend with different curvatures in different regions of the bend.

The fold angle chosen will depend on the application. A small fold angle gives minimal over bend or spring-back for each fold, which may be useful in some applications including matching to pre-folded edges. A larger fold angle may require fewer incremental bends (and therefore a shorter time) to build up an overall fold.

For some applications, a fold angle in the range 1 to 20 degrees, preferably 5 to 15 degrees, more preferably around 12 degrees may be suitable.

FIG. 8 is a cross-section along the line 8-8 in FIG. 2.

FIG. 9 is a cross-section along the line 9-9 in FIG. 7, showing the structure of the crank mechanism. This drawing shows the drive shaft 45 which carries circular drive motion from the drive arrangement 3, rotating about drive axis 30. The offset of the centre of the crank shaft 29 with respect to the drive axis 30 is clearly shown.

The crank shaft 29 may be formed integrally with the drive shaft 45 and is connected via a bearing assembly 46 with the crank arm 28. The crank arm 28 is in turn connected by pivoting connection 27 with the folding mechanism 20.

Means for adjusting the crank offset may be incorporated in the crank shaft 29 or the bearing assembly 46.

The apparatus may include a controller (not shown in the drawings) for controlling the folding operations. The controller may control the drive arrangement 3 to turn the drive on or off and to control the drive rate. The controller may control the feed arrangement to control the rate at which metal stock is fed through the apparatus. This in turn allows control over the spacing between incremental folds. The controller may control one or more of the crank offset, the length of the crank arm and the pivoting connection offset, via suitable adjustment means such as ball screws or hydraulic cylinders.

The controller may be a programmable controller such as a programmable logic controller or other computer-based controller.

The folding apparatus described above may be incorporated in a metal forming system. For example, the apparatus could be part of a production line, performing a folding operation preceded by or followed by other metal forming operations performed by other pieces of equipment. Such other operations include folding, stamping, pressing, roll forming and any other suitable operations.

FIG. 10 is a perspective view, FIG. 11 is a side view and FIG. 12 is a top plan view of a larger folding system 50 including two incremental folding apparatuses 10. The system 50 is particularly suited for use in a metal forming production line.

The apparatuses 10 are supported on a framework 51 and metal stock is fed through between the apparatuses 10 in the direction indicated by the arrow 52. The feed arrangement includes a transfer module 53 (FIGS. 11 and 12) which translates on a linear track 54 parallel to the direction 52. The transfer module 53 may use a number of vacuum inlets 55 to grip the metal stock.

The feed arrangement also includes a fold feed module 57 which translates on linear tracks 58 and is driven by a ball screw 59. The fold feed module 57 also may use vacuum inlets 60 to grip metal stock to be folded. As discussed above, the fold feed module is controlled for indexed feed of metal stock through the folding apparatus 10 for incremental folding.

The system 50 shown in FIGS. 10 to 12 allows indexed feeding of metal stock into either of the two apparatuses 10. This allows folds to be formed at either side of a piece of material and therefore contributes to versatility of a production line including the system 50. Other embodiments may provide indexed movement of the apparatuses 10, so that incremental folds can be formed by both apparatuses 10 simultaneously.
The configuration of the crank shaft and folding mechanism allows continuous circular drive motion from a motor or other power source to drive continuous reciprocating motion of the folding mechanism. As the folding mechanism drives release of the clamp arrangement the time between consecutive incremental folding operations is less than with conventional folding machines.

The drive arrangement may provide circular drive motion to the crank shaft 29 at a rate which drives the folding mechanism to form incremental folds at a rate in the range 60 to 500 folds per minute, more preferably 80 to 200 folds per minute, still more preferably around 100 folds per minute. In smaller metal working shops, slower speeds may be more suitable than those used for production lines.

Furthermore, the link between the folding mechanism and the clamp arrangement leads to a simplified control arrangement, since no control is required over the clamp arrangement. However, adjustment of the biasing means of the clamp arrangement may in some circumstances be desirable and suitable adjustment and/or control means may be provided.

There is no need to trigger the beginning of each individual folding operation. Rather, the apparatus automatically performs a series of incremental folding operations.

The surface 26 of the folding mechanism 20 may be configured to limit damage to the metal stock and/or a separate surface such as leaf spring 22 may be provided for this purpose. This helps to limit surface damage or effects on the metal thickness (such as 'stretching' effects, for example). The surface 26 may be formed from a flexible or resilient material, or may be a floating surface such that it slides with respect to the attachment 25 or the beam 24 rather than sliding over the surface of the metal stock.

When the surface 26 is a floating surface, it may include a spring or similar biasing means to return it to a starting position at the end of each incremental folding operation. Clearly the leaf spring embodiment shown in the drawings is also biased to return to its starting position.

The folding apparatus may employ a tangent bending method. In tangent bending flow of material in the metal stock being bent is always at a point where the surface 26 of the folding mechanism 20 is parallel to a tangent of the folding die (i.e. the surface 33 of the clamp arrangement 21). Tangent bending has the advantages of tight control and reduced surface defects such as wrinkling, pressure marks, crazing and the like. Because of the lack of surface damage, tangent bending can be used with pre-painted metal stock. This is especially the case when a leaf spring 22 is used to protect the surface.

The apparatus may be used for folding sheet metal stock, or could be adapted for folding other types of metal stock, such as pipes, rods etc.

While the present invention has been illustrated by the description of the embodiments thereof, and while the embodiments have been described in detail, it is not the intention of the Applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative apparatus and methods, and illustrative examples shown and described. Accordingly, departures may be made from such details without departure from the spirit or scope of the Applicant's general inventive concept.

1. An incremental metal folding apparatus including:
   i. a folding mechanism configured to move so as to fold metal stock;
   ii. a feed arrangement configured to move metal stock through the folding mechanism; and
   iii. a clamp arrangement configured to hold metal stock while it is being folded;

   wherein the folding mechanism, feed arrangement and clamp arrangement are arranged to work together to perform a plurality of spaced incremental folding operations so as to build up a fold from a plurality of incremental folds; and

   wherein the folding mechanism and the clamp arrangement are mechanically linked, such that movement of the folding mechanism causes movement of the clamp arrangement.

2. A folding apparatus as claimed in claim 1 wherein movement of the folding mechanism causes release of the clamp arrangement.

3. A folding apparatus as claimed in claim 1, wherein movement of the folding mechanism following completion of an incremental folding operation causes release of the clamp arrangement.

4. A folding apparatus as claimed in claim 1, wherein the folding mechanism includes a contact surface configured to act against a cooperating surface of the clamp arrangement to cause movement of the clamp arrangement from a clamped position into an unclamped position.

5. A folding apparatus as claimed in claim 1, including a crank mechanism arranged to convert circular drive motion into reciprocating motion of the folding mechanism.

6. A folding apparatus as claimed in claim 5 wherein the crank mechanism converts continuous circular drive motion into reciprocating motion of the folding mechanism to produce continuous oscillations of the folding mechanism.

7. A folding apparatus as claimed in claim 5 including an offset adjustment mechanism for adjusting the offset of the crank mechanism.

8. A folding apparatus as claimed in claim 7 wherein adjustment of the offset of the crank mechanism alters the final fold angle achieved by the folding mechanism.

9. A folding apparatus as claimed in claim 7 including an actuator configured to drive the offset adjustment mechanism.

10. An incremental metal folding apparatus including:
    i. a folding mechanism configured to move so as to fold metal stock;
    ii. a crank mechanism arranged to convert circular drive motion into reciprocating motion of the folding mechanism;
    iii. a feed arrangement configured to move metal stock through the folding mechanism; and
    iv. a clamp arrangement configured to hold the metal stock while it is being folded;

    wherein the folding mechanism, feed arrangement and clamp arrangement are arranged to work together to perform a plurality of spaced incremental folding operations so as to build up a fold from a plurality of incremental folds.

11. A folding apparatus as claimed in claim 10 wherein the crank mechanism converts continuous circular drive motion into reciprocating motion of the folding mechanism to produce continuous oscillations of the folding mechanism.
12. A folding apparatus as claimed in claim 10 including an offset adjustment mechanism for adjusting the offset of the crank mechanism.

13. A folding apparatus as claimed in claim 12 wherein adjustment of the offset of the crank mechanism alters the final fold angle achieved by the folding mechanism.

14. A folding apparatus as claimed in claim 12 including an actuator configured to drive the offset adjustment mechanism.

15. A folding apparatus as claimed in claim 10, wherein the folding mechanism includes a contact surface configured for reduction of damage to metal stock being folded.

16. A folding apparatus as claimed in claim 15 wherein the contact surface is a resilient, flexible or floating contact surface.

17. A folding apparatus as claimed in claim 15 wherein the contact surface is a floating surface and is biased to return to a starting position after each incremental folding operation.

18. A folding apparatus as claimed in claim 10, wherein the clamp arrangement is biased towards a clamped position.

19. A folding apparatus as claimed in claim 18 wherein the clamp arrangement is biased by a spring or hydraulic or pneumatic cylinder.

20. A folding apparatus as claimed in claim 10, further including a motor arranged to provide circular drive motion to the crank mechanism.

21. A folding apparatus as claimed in claim 10, wherein the folding mechanism forms incremental folds at a rate of about 60 to 300 folds per minute.

22. A folding apparatus as claimed in claim 21 wherein the folding mechanism forms incremental folds at a rate of about 80 to 200 folds per minute.

23. A folding apparatus as claimed in claim 10, wherein the feed arrangement is configured to feed metal stock through the apparatus in predetermined increments.

24. A folding apparatus as claimed in claim 23 wherein the increments are controllable so as to alter the spacing between incremental folding operations.

25. A folding apparatus as claimed in claim 24 wherein the increments and fold angle are such as to result in an overlap between adjacent incremental folds in the range 0 to 1 mm.

26. A folding apparatus as claimed in claim 10, wherein the feed arrangement includes a vacuum holding system for gripping the metal stock.

27. A folding apparatus as claimed in claim 10, wherein fold tooling located on the folding mechanism or opposing the folding mechanism is configured for a minimum required radius.

28. A folding apparatus as claimed in claim 10, wherein fold tooling located on the folding mechanism or opposing the folding mechanism is configured for a specific required fold radius or specific required range of fold radii.

29. A folding apparatus as claimed in claim 10, wherein each folding operation forms a fold with a fold angle in the range 1 to 20 degrees.

30. A folding apparatus as claimed in claim 29 wherein each folding operation forms a fold with a fold angle in the range 5 to 15 degrees.

31. A folding apparatus as claimed in claim 30 wherein each folding operation forms a fold with a fold angle of around 12 degrees.

32. A folding apparatus as claimed in claim 10, configured for tangential folding.

33. A folding apparatus as claimed in claim 10, configured to fold sheet metal stock.

34. A folding apparatus as claimed in claim 10, further including a controller arranged to control one or more of: fold angle and fold spacing.

35. A folding apparatus as claimed in claim 10, further including a controller arranged to control one or more of: fold rate, drive rate and crank offset.

36. A folding apparatus as claimed in claim 35 wherein the controller is a programmable controller.

37. An incremental metal folding apparatus including:
   i. a folding mechanism configured to move so as to tangentially fold metal stock;
   ii. a feed arrangement configured to move metal stock through the folding mechanism; and
   iii. a clamp arrangement configured to hold metal stock while it is being folded;

   wherein the folding mechanism, feed arrangement and clamp arrangement are arranged to work together to perform a plurality of spaced incremental tangential folding operations so as to build up a fold from a plurality of incremental folds.

38-39. (canceled)

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