March 14, 1939. E. B. CAIRNS 2,150,416

PROCESS AND APPARATUS FOR FORMING TAPERED SPARS

Filed July 25, 1936 2 Sheets-Sheet 1

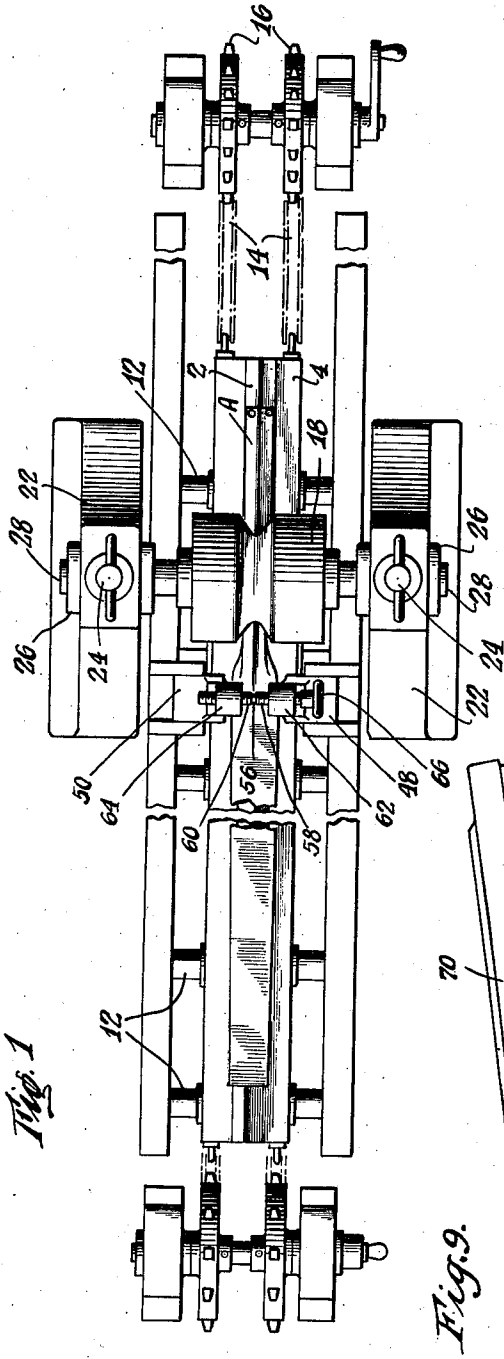


Fig. 1

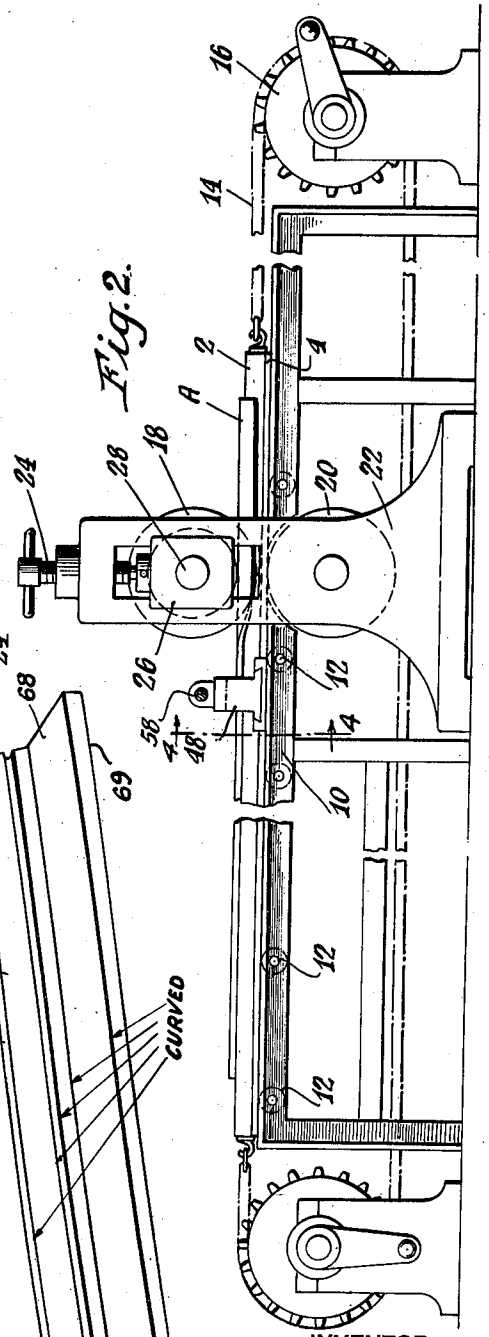


Fig. 2.

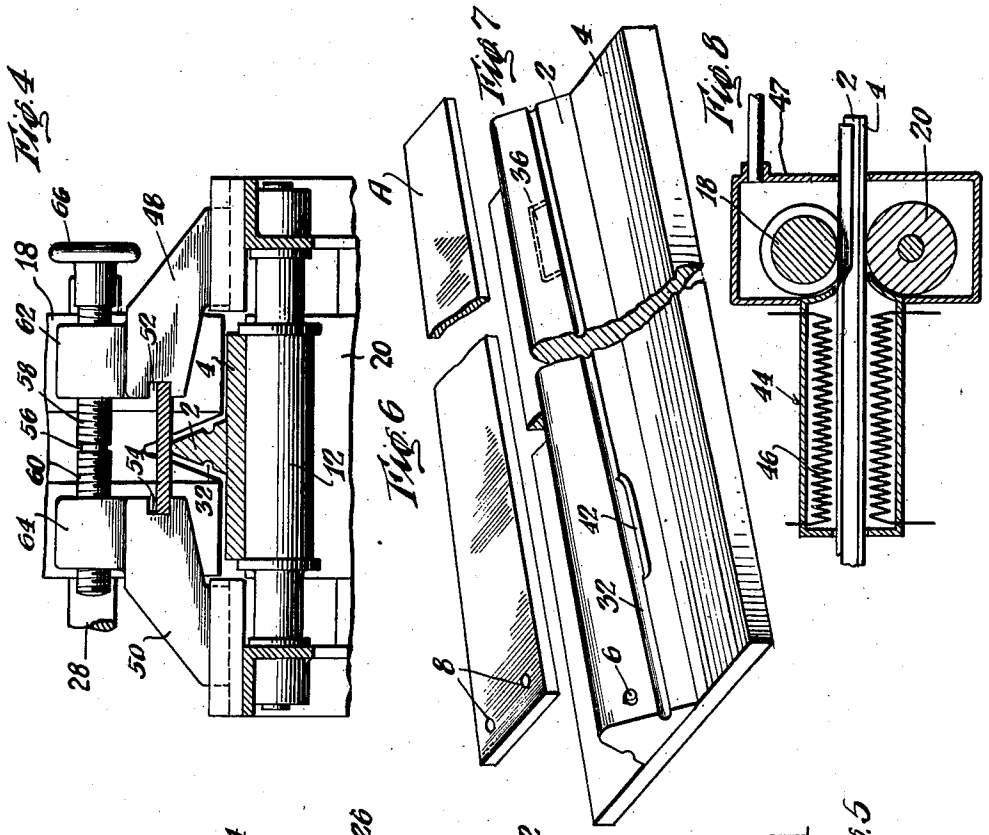
Fig. 9.

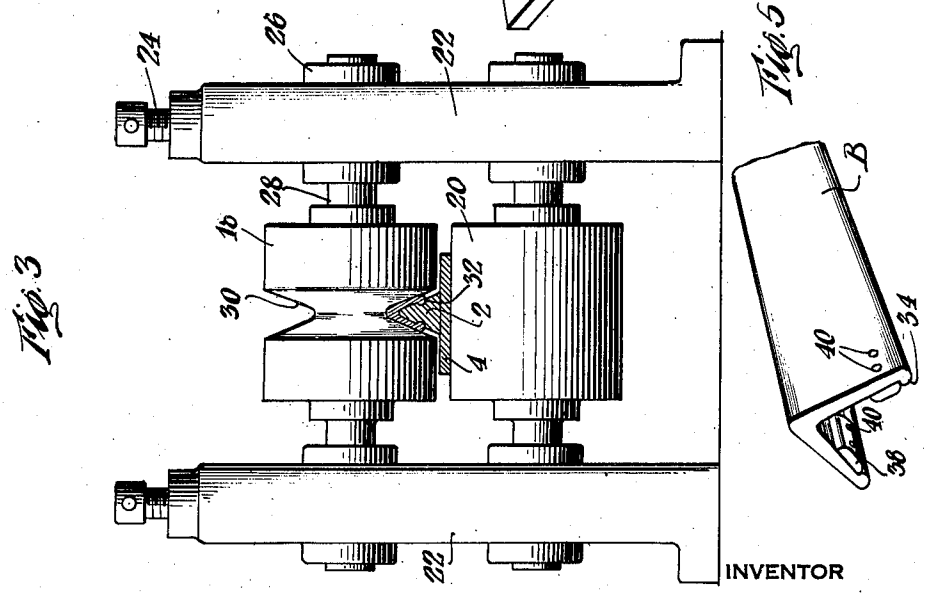
INVENTOR
Edmund B. Cairns
BY
Mogust, Neary & Campbell
ATTORNEYS

March 14, 1939. E. B. CAIRNS 2,150,416

PROCESS AND APPARATUS FOR FORMING TAPERED SPARS

Filed July 25, 1936 2 Sheets-Sheet 2





INVENTOR
Edmund B. Cairns
BY
Moguet, Neary & Campbell
ATTORNEYS

Patented Mar. 14, 1939 2,150,416

UNITED STATES PATENT OFFICE

2,150,416

PROCESS AND APPARATUS FOR FORMING TAPERED SPARS

Edmund B. Cairns, Naugatuck, Conn., assignor to Cairns Metals Corporation, a corporation of New York

Application July 25, 1936, Serial No. 92,557

11 Claims. (Cl. 80—19)

The present invention is directed to apparatus and a process for producing tapered structural members and the resultant product. Such tapered metal structural members have many uses and are particularly adapted for use as spars, ribs and struts in the fabrication of airplanes and their parts.

The airplane industry has, during recent years, endeavored to substitute parts made of light metals and their alloys for parts previously made of non-metallic substances. While such light metals may have far greater strength by volume than the materials previously used, they are also characterized by a greater weight. It is therefore desirable that the metallic structural elements should be reduced to a size and weight comparable with material replaced, without sacrificing strength. Furthermore, it is highly desirable to obtain metallic elements of uniform strength.

Inasmuch as the metals from which the elements are fabricated are usually more expensive than the materials of the structures replaced, it is preferable that the metal elements be fabricated simply, at low unit cost and with a minimum excess of metal present.

Such metals, for example, as aluminum, magnesium, and stainless steel alloys are difficult to work as they are not susceptible to rolling processes commonly used in working iron and steels. The metals tend to crack and tear during the ordinary rolling and bending action. Also such a rolling action tends to produce a crystalline structure in the metal which is neither uniform nor sufficiently rearranged to give desired maximum and uniform strength characteristics through the element.

The present invention has for an object the production of light metal or metal alloy structural elements having a cross-sectional shape best calculated to withstand and distribute stresses applied thereto and without excessive weight.

A further object of the invention is to produce structural elements which are tapered lengthwise in order to reduce their weight and at the same time retain sufficient thickness at the points of greatest stress to be able to withstand without distortion the maximum calculated stresses applied thereto.

A further object of the invention is to produce a process and apparatus for economically and uniformly producing such structural elements.

To achieve the objects of the invention, I have developed an apparatus for forming structural elements for example, spars from metal blanks, which apparatus preferably combines several metal working operations, such as drawing, swaging and forging. I have found this apparatus to be capable of rapidly forming spars suitable for mass assembly and at a low unit cost.

More specifically my preferred apparatus includes a pair of freely rotating rollers having a predetermined spacing. Between these rollers there is adapted to pass a blank and a forming element capable of constantly varying the working distance between the cooperating rolls. One of the cooperating rolls may have, as is shown in my preferred form, a complementary groove coacting with the forming element.

Preferably in the production of aircraft wing spars the forming element or the draw bar is of generally triangular cross-sectional shape. The complementary groove in the roll is of a V-shape, the angle of the walls of the V-shape groove being less than the angle at the apex of the triangular forming element. I have found in some operations that a desirable spacing between the apex of the triangular forming member and the bottom of the groove at least at the beginning of the operation upon the blank may be a distance substantially equal to the thickness of the metal blank being shaped.

A strip having a preliminary longitudinal taper in width is usually used as the starting blank. The preliminary taper given to this strip is preferably such that when it passes through the rolls acquiring the tapering thickness, there is no excessive increase in the width of the finished element or spar from end to end. The strip is drawn out so that there may be material increase in length. By using a blank charge tapering in width, the internal stress on the strip is gradually reduced as the narrowing strip passes through the rolls thus tending to reduce the possibility of extending or stretching the metal beyond its elastic limit.

The action and the effect of my treatment on the structure and shape of the metal blank is similar to a die drawing, forging, bending and swaging treatment.

As contrasted with a drawing treatment in which the metal is caused to flow axially, only, of the die, my treatment causes the metal to flow transversely as well as axially of the blank, producing a structure in which the metal crystals are relatively angularly disposed, thereby greatly strengthening and toughening the structure member formed.

As compared to a forging operation, where an interlacing crystalline structure is produced by

repeated localized flowings of the metal under impact, my process produces a generally uniform flowing of the metal, thereby resulting in a homogenous structure. Also I am able to form the spars or structural members at a much higher rate of production than would be possible with a forging treatment.

As compared with a bending operation which would unavoidably produce cracks and tears in the metal adjacent the bend, my treatment causes the metal to be forced toward the bending line. This flow of metal eliminates cracks and fissures along the bending line. In effect, the flow of the metal in my treatment is counter to the direction of flow of metal in a bending treatment and the metal is therefore bent under compression rather than under tension.

My apparatus is especially suitable for forming structural elements which taper in cross-section both as to overall depth and to thickness of the metal having a V-shape in cross section. These spars are particularly suitable for use in aircraft. The wider end of a blank is fixed adjacent the end of the forming and supporting mechanism permitting the greatest working distance between the rolls. The blank and forming mechanism are drawn under the shaping rolls from the wider to the narrower end. As the space for effective working between the forming mechanism and the forming roll varies, because of the increasing taper of the forming mechanism, the metal is worked and caused to flow axially of the bar without restraint. This results in a considerable elongation of the original blank. The flow of the metal upwardly into the apex zone and downwardly in the groove also takes place substantially without restraint. This flow as is shown may be utilized to form beads on the edges of the finished spar by providing appropriate grooves in the forming element or draw bar. The flowing of the metal into the bead edges avoids the formation of cracks at the edges.

With my apparatus it is also possible to form bosses of any desired shape or thickness along the length of the spar for example, by appropriately providing the forming member with depressions or abutments. These are preferably adjacent the bead grooves but may be placed where desired, for example, in the apex.

My apparatus may also be utilized to produce longitudinally curved and preferably tapered structural elements by making the forming member curved gradually from end to end.

For a better understanding of the invention reference may be had to the accompanying drawings in which:

Figure 1 is a plan view of my spar forming device;

Figure 2 is a side elevation of the spar forming device;

Figure 3 is an end view of the forming rolls with the draw plate and forming element shown in section;

Figure 4 is a partly broken sectional view taken on line 4—4 of Figure 2 showing a guide for the blank;

Figure 5 is a perspective view of a portion of one form of spar produced by my process and apparatus;

Figure 6 is a perspective view of a tapered blank prior to forming, partly broken away;

Figure 7 is a perspective view of a draw plate and one form of forming element, partly broken away;

Figure 8 is a diagrammatic view of a modified type of forming device having a furnace and a gas chamber thereon; and

Figure 9 is a side view of a portion of a modified form of draw bar and forming element.

Illustrative of one embodiment of my invention, Figures 1, 2 and 3 disclose an apparatus suitable for forming and shaping a metal blank A (Figure 6), into a spar B (Figure 5) substantially V-shaped in cross-section and tapering overall in metal thickness. The blank A may be cut or formed in a tapered form lengthwise.

The blank A may be shaped and formed over a generally triangular forming member 2. This forming member may be integral with or rigidly attached to a base 4 which tapers in the thickness from end to end as best shown in Figure 7. The wider end of the blank A may be attached to the triangular forming member 2 by means of cooperating pins 6 and apertures 8, the end of the blank A being conformed to the shape of the forming member by any suitable means, such as forging or swaging, the remainder of the blank A merely resting on the apex of the forming member 2. The draw bar 4 and attached blank A are than placed upon a table or support 10 provided with a plurality of supporting rollers 12 which allow the draw bar to be drawn along the table by any suitable means, such as chains 14, attached to the ends of the draw bar 2 and passing over sprockets 16. Cables and a winding drum may be readily used instead of chains and sprockets for advancing the forming member, if desired. Any suitable power means (not shown) may be used to draw the blank A between freely rotatable rollers 18 and 20, the latter acting as a support for the draw bar 4. The forming rolls 18 and 20 are rotatably mounted in a heavy framework 22, the roll 18 being adjustable relative to roll 20 through the medium of screw-threaded shafts 24 swivelled in sliding journal blocks 26 carrying the roll supporting shaft 28.

The shaping roll 18 may be provided with a peripheral groove 30 of generally V-shape, the walls of which are inclined at a slightly less angle than the angle of the walls of the triangular forming member 2. When a blank A is drawn under the roll 18, the blank will be pressed, drawn, bent and forged, and caused to elongate and flow upwardly and downwardly between the walls of the roller groove 30 and the triangular member 2, as previously described. The upper roller 18 is preferably adjusted so that the distance between the bottom of the groove 30 and the apex of the forming member 2 is substantially equal to the gauge of the blank A.

The edges of the spar may be readily provided with a flashed bead by providing the forming element 2 with a longitudinally extending groove 32 (Figure 7) into which the metal of the blank is caused to flow because of the tapered groove between the roller 18 and forming member 2. If desired, the groove 32 may be inclined slightly to the axis of the forming member, in accordance with the taper in width of blank A. This groove acts to form a bead 34 such as is shown in Figure 5. Likewise the forming member 2 may be provided with a series of depressions 36, shown in dotted lines on Figure 7, whereby bosses 38 will be formed on the interior of the spar B to compensate for metal removed when screw, bolt or rivet holes 40 are drilled therethrough. Likewise, such bosses may extend below the beads and are produced by providing depressions, such as 42, at the edges of the flash grooves 32.

It should be noted that there is no means pro-

vided for restraining the flow of the metal of blank A in the groove between roller 18 and forming member 2. The metal may flow in such a manner that a uniform crystalline rearrangement may be brought about and uniform stresses are set up throughout the finished spar. This action differs from the usual molding and rolling operation.

While a number of the lighter metals and alloys may be shaped in a cold state, such metals as magnesium and stainless steels are preferably worked in a heated condition. A suitable temperature for working magnesium is in the vicinity of 450° F. and for working stainless steel is in the vicinity of 1650° F. For heating these metals prior to working, I have provided a muffle furnace 44 ahead of the shaping rollers 18 and 20 through which the blanks A and draw plate 4 and forming element 2 are passed to bring the blank A to the desired temperature. While any desired heating means may be utilized I have disclosed an electric heater 46. Also, if desired the shaping roller 18 may be provided with heating means, although generally this is not necessary.

To prevent scaling of the metal, due to the heat of working and oxidation of the surface, I may also provide the device with a jacket 47 through which or into which a non-oxidizing gas may be passed.

A particularly suitable means for guiding the blank A into and through the forming rollers, without placing any restraint thereon, or restricting flow of the metal while shaping, is disclosed in detail in Figure 4 and as applied to the apparatus in Figures 1 and 2. The guiding means consists of a pair of jaws 48 and 50 slidably mounted in the framework 10 and provided with opposed grooves 52, 54 receiving the blank A in the plane of the apex of forming member 2. As the blank A passes between the jaws 50 and 48 they may be moved toward each other to compensate for decrease in the width of the blank by means of shaft 56 having oppositely directed threaded portions 58 and 60 threaded into lugs 62 and 64 on members 48 and 50, respectively. The shaft 56 may be rotated mechanically by any suitable means, but I have illustrated it as being manually rotated by a knob 66.

While I have disclosed the shape of the spar B as being generally of a V-shape in cross-section, it will be understood that it may be made L-shaped or U-shaped without deviating from the invention. Also as shown in Figure 9 of the drawings, the draw bar 67 may be formed with a curved upper surface 68 which converges toward a plane lower surface 69. The forming member 70 is likewise curved to conform to the surface 68 of the draw bar 67 and is of uniform cross-sectional shape throughout its length. The forming member 70 has grooves 71 therein for forming beads on the edges of the structural member.

It will be understood that the blank A may be varied in shape, such as by decreasing its thickness by tapering on straight or curved lines from end to end and that the width of the bar can be tapered from end to end likewise on curved lines. Appropriate protuberances extending from the edge portion of the blank may also be provided for purposes of strengthening the finished structural member in any desired place.

The specific modifications disclosed should therefore be considered as illustrative only and not as limiting the scope of the appended claims.

I claim:

1. An apparatus for making tapered structural members, comprising a freely rotatable forming roll, an annular groove in the roll, a draw-bar having a longitudinal taper from end to end, a forming member fixed to the draw-bar substantially complementary to the groove in the forming roll and of substantially uniform cross-section throughout its length, means for supporting the draw-bar for movement beneath the forming roll, means for fixing a strip of metal to one end of the draw bar and means for moving the draw-bar axially with the forming member in but spaced from the roll groove, whereby the spacing between the bottom of the groove and the top of the forming member will vary inversely as the taper of the draw-bar and the strip of metal will be bent, expanded longitudinally and transversely and metal will be caused to flow toward the edges of the strip and to the zone of bending.

2. An apparatus for making tapered structural members, comprising a freely rotatable forming roll having a circumferential groove therein, a forming member having a cross-section generally complementary to said roll groove with the faces of the forming member at a greater angle than the sides of the groove, means for fixing one end of a strip of metal to the forming member at its leading end, means for moving the forming element axially and adjacent the roll in such relationship that the strip is worked between the faces of the forming element and the sides of the groove and allowed to expand longitudinally and transversely and means for gradually decreasing the working distance between the forming element and the roll as the forming element moves.

3. The device set forth in claim 2 comprising a pair of adjustable jaw members disposed on opposite sides of and in the plane of the top of the forming member and means for adjusting the jaw members to engage and guide the strip of metal into the working zone between the roll and the forming member.

4. The device set forth in claim 2 in which the forming member comprises a groove in each of the faces opposing the grooved roll adapted to form a bead on an edge of the metal strip.

5. An apparatus for making tapered structural members, comprising a freely rotatable forming roll having a circumferential groove formed therein, a draw bar having a varying effective thickness from end to end, a forming member fixed to said draw bar, said forming member having a cross-section generally complementary to said roll groove with the faces of the said forming member at a greater angle than that defined by the sides of the groove, means for fixing a metal strip to be worked to the forming member at the zone of least effective thickness of the draw bar, means for moving the draw bar axially and in working relationship to the roll, said roll and forming mechanism being in such relationship that the metal strip being worked is free to expand longitudinally and transversely.

6. An apparatus for making tapered structural members, comprising a freely rotatable forming roll having a generally V-shaped circumferential groove formed therein, a draw-bar having a varying effective thickness from end to end, a forming member fixed to the draw-bar and adapted to cooperate with said grooved roll to work a metal strip, said forming member having a cross section generally complementary to said roll groove with the angle formed by the faces of said forming member greater than that defined by the sides of said groove, said forming member and said grooved roll being in such rela-

tion that a metal strip on said forming member is free to expand transversely and longitudinally, means for fixing a metal strip to be worked to said forming member at the zone of least effective thickness of said draw-bar, means for supporting the draw-bar for movement beneath the forming roll, and means for moving the forming member axially and in working relationship to the roll groove.

7. The method of making tapered structural members, which comprises fixing a metal strip at one end to a forming member, bending the metal strip along a longitudinal line, progressively increasing the amount of working upon the strip sufficiently to cause a flow of metal away from said fixed end of said strip while permitting free expansion of metal longitudinally, maintaining a lower pressure in a zone along the longitudinal bending line of said strip than along zones intermediate the bending line and the edges of said strip to cause a flow of said metal to the bending zone and maintaining a pressure along said edges below that at said intermediate zones to cause the metal to flow to said edges.

8. The method of making tapered structural members which comprises fixing a metal strip at one end to a forming member, bending the metal strip along a longitudinal line, progressively increasing the amount of working upon the strip sufficiently to cause a flow of metal away from said fixed end of said strip, while permitting a free expansion of metal longitudinally, flowing metal into a zone along the longitudinal bending line of said strip and flowing the metal toward the edges of the strip.

9. The method of making tapered metal structures comprising fixing a metal strip at one end to a forming member of generally V-shaped cross-section, moving the forming member and strip relatively to a rotatable roll having a circumferential groove therein which is generally complementary to the forming member with the angle between the sides of the groove being less than the angle between the faces of the forming member, forcing the strip into the groove in the roll to work and bend the strip along a longitudinal line and causing a flow of metal to the zone adjacent the bending line and toward the edges while allowing flow of the metal both transversely and longitudinally and gradually decreasing the working distance between the forming member and the roll to taper the strip longitudinally.

10. The process set forth in claim 9 which comprises heating the strip during its movement relative to the roll.

11. The process set forth in claim 9 which comprises heating the strip in an atmosphere of inert gas during its movement relative to the roll.

EDMUND B. CAIRNS.