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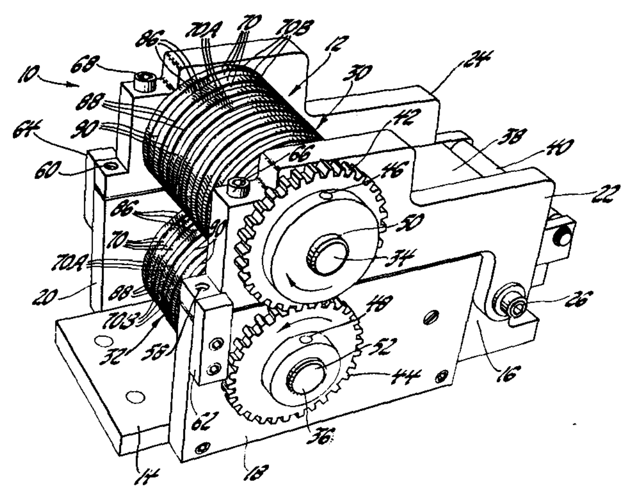
## (54) Roller tooling for forming corrugated strip.

(57) Tooling is disclosed for rolling uninterrupted transversely extending corrugations in strip stock wherein the corrugations have a chevron pattern with vees that point forward and backward relatively to the direction of the strip feed. The tooling comprises a pair of rollers (30, 32) each having transverse rows of discrete teeth (86) extending interruptedly thereacross with selected ones of the teeth in each row being discontinuous with each other so as to be devoid of any forward vee points but otherwise conform to the desired corrugation configuration such that forward vee points are formed in the strip stock in the roller regions (88) devoid of teeth by tension action of the adjoining teeth so as to produce complete corrugations in the strip stock with distributed and thereby minimized strain at the forward vee corrugation points.



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# ROLLER TOOLING FOR FORMING CORRUGATED STRIP

This invention relates to roller tooling for forming corrugated strip and more particularly to corrugated strip where the corrugations have a chevron pattern.

In the manufacture of corrugated strip with a chevron pattern using roller tooling, it is known that splits and tears in the material can be minimized in several ways. For example, a thicker or more ductile material may be selected and/or the corrugation pattern may be altered such that the roller tooling can then be sufficiently radiused at the peak stress points to substantially reduce the maximum strain. However, increasing the material thickness adds size, weight and cost and a more ductile material may not be feasible for the end use. On the other hand, altering the corrugation pattern to avoid rips and tears such as by radiusing the angular juncture or point of the diagonal chevron stripes generally results in higher tooling costs. Moreover, the resulting corrugation pattern as it approaches more of a sinusoidal wave form may not be feasible for the end use. And thus, all these alternatives act to limit design flexibility.

For example, it has been found that a highly efficient monolithic catalytic converter substrate for automotive use can be constructed of corrugated metal foil strip having a straight-stripe chevron pattern of uninterrupted transversely extending corrugations. Because of the use, the material selection is restricted, and most of the suitable high temperature resistant alloys exhibit only limited ductility. So one solution to avoiding splits and tears in the formation of the corrugations has been to increase the foil thickness provided the resulting increase in size, weight and cost of the converter is acceptable and justifiable. Alternatively, the straight-stripe chevron pattern has been shown to exhibit sufficiently high heat transfer and low friction with little pressure drop so that curving the corrugation pattern to avoid splits and tears in the foil not only adds to the cost of the tooling but may adversely affect the performance of the resulting monolithic substrate.

In arriving at the present invention, it was found that biaxial strains are induced in the material because the corrugations in a chevron or herringbone pattern are inclined at an angle to the direction of feed of the strip into the rollers and because the orientation sense of the corrugations reverses across the strip width. If the magnitude of these biaxial strains exceeds the maximum strain which can be tolerated by the material, then splits and tears will result.

In analyzing the magnitude of the strains induced during rolling, it has been found that the state of strain varies smoothly across the strip width ranging from essentially balanced biaxial strain at the root of what will be called the "forward" vees of the corrugations to plane strain at the root of what will be called the "backward" vees of the corrugations. As to the "forward" and "backward" nomenclature, the chevron pattern (which may also be called a herringbone pattern) can be viewed as being formed from a collection of V-shaped elements. When the V-shaped elements point in the same direction as the direction of the strip stock motion through the rollers, they are considered forward vees. On the other hand, when the V-shaped elements point in a direction opposite to the direction of the strip stock through the rollers, they are considered backward vees. The most deletrious condition in the formation of the chevron or herringbone straight-strips corrugations has been found to be that of the balanced biaxial strain which occurs at the point or apex of the forward vees.

The present invention attacks the very root of the splitting and tearing problem which is the point of the forward vees. And the solution is an improved roller tooling design of simple low-cost construction that does not alter or require changes in the desired chevron or herringbone pattern of corrugations while permitting the use of a thinner material than before possible. Conventionally, the roller tooling comprises a pair of toothed rollers each having uninterrupted transversely extending teeth conforming to the desired chevron or herringbone pattern. According to the present invention, each of the rollers is provided with transverse rows of discrete teeth extending interruptedly rather than uninterruptedly thereacross with selected ones of the teeth in each row being discontinuous with each other. The selection is such that the toothed rollers are devoid of any forward vee points or apices but otherwise conform to the desired corrugation configuration. Nevertheless, forward vees are completely formed in the strip stock in the roller regions devoid of teeth by tension action of the adjoining teeth so as to produce the complete corrugations in the strip stock with distributed and thereby reduced strain in the forward vee corrugation regions. In the preferred embodiments of the improved roller tooling design, each of the rollers comprises a ganged set of toothed wheels arranged side-by-side and with the teeth on each wheel all arranged diagonally at the same angle. In one embodiment, the forward vee points are then simply eliminated by chamfering the opposing ends of the teeth all around the two adjacent wheels at said forward vee location. In another embodiment, the same effect is accomplished simply by employing a spacer between the toothed wheels where their teeth would otherwise form the point of the forward vees. Moreover, in the case where the state of plain strain induced at the point of the backward vees is also found to promote splits and tears such as with the use of thicker material, the point of the backward vees may also be similarly eliminated with the teeth still remaining capable of forming the complete corrugations.

These and other objects, advantages and features of the present invention will become more apparent from the following description and drawings in which:

Figure 1 is a side view of a corrugating machine of the roller type incorporating one embodiment of the roller tooling according to the present invention.

Figure 2 is a top view taken along the line 2-2 in Figure 1.

Figure 3 is a sectional view taken along the line 3-3 in Figure 2.

Figure 3a is an enlarged fragmentary view of the toothed wheels in Figure 3.

Figure 4 is an isometric view of the corrugating machine in Figure 1.

Figure 5 is a plan view of a section of corrugated metal strip formed with the corrugating machine in Figure 1.

Figure 6 is an isometric view of another embodiment of the roller tooling according to the present invention adapted for use in the corrugating machine in Figure 1 to produce a corrugated metal strip similar to that in Figure 5 but with less chevrons extending thereacross.

Referring to the drawings, there is shown in Figures 1-4 a corrugating machine 10 of the roller type incorporating one embodiment 12 of the roller tooling constructed according to the present invention capable of forming the corrugated strip shown in Figure 5. The corrugating machine generally comprises a base 14 having an integral pedestal 16, a pair of parallel rectangular-shaped side frame plates 18 and 20 bolted to the sides of the base and pedestal, and a pair of parallel L-shaped lever arms 22 and 24 overhanging the respective side frame plates 18 and 20 at their legs and pivotally supported and connected at their toes by shoulder bolts 26 and 28 to opposite sides of the pedestal 16.

The roller tooling generally comprises a pair of toothed rollers 30 and 32 arranged one over the other with the upper roller 30 rotatably supported through a shaft 34 by and between the lever arms 22 and 24 and the lower roller 32 rotatably supported through a shaft 36 by and between the side frame plates 18 and 20. The strip to be corrugated is fed from right to left between the toothed rollers across the top 38 of the pedestal with the assistance of a plain roller pin 40 supported on the pedestal as shown. The corrugation-forming teeth of the two rollers 30 and 32 are synchronized to interleaf or mesh with clearance with respect to each other by meshing gears 42 and 44 which also serve to drivingly interconnect the rollers and are secured by respective tapered pins 46 and 48 to respective extensions 50 and 52 at one end of the respective shafts 34 and 36 projecting outward from the side frame plate 18 and lever arm 22 respectively.

Drive to the toothed rollers from a suitable power source such as a geared motor (not shown) is taken by another extension 54 formed on the lower roller shaft 36 projecting outward from the other side frame plate 20. Thus, the lower roller 32 is directly driven while the upper roller 30 is driven through the meshing gears 42 and 44.

The depth of corrugation is controlled by the center-to-center distance between the corrugating rollers and this is made adjustable by the pivotable upper roller support 22, 24 which functions as a trailing arm. For such adjustment, there is simply provided a pair of set screws 58 and 60 which are threaded to the swingable ends of the respective lever arms 22 and 24 and engage the top of the respective side frame plates 18 and 20. Lateral or transverse movement of the lever arms 22 and 24 and thus the upper roller 30 is prevented by a pair of rectangularly shaped containment fingers 62 and 64 which are bolted to the outboard side of the respective side frame plates 18 and 20 and contact with the outboard side of the lever arms where the adjustment screws 58 and 60 are located. Once the proper adjustment is made by the adjustment screws, this position of the pivotable upper roller is fixed by tightening a pair of shoulder bolts 66 and 68 which extend downward through the respective lever arms 22 and 24 between the adjusting screws and the top roller and threadably engage with the respective side frame plates 18 and 20 at the top of the latter. Thus, the rollers 30 and 32 can readily be adjusted to accommodate strip stock with slightly different thickness or ductility.

Describing now the details of the corrugating rollers 30 and 32, they are each formed of a ganged set of toothed wheels 70 which are identical except for certain important features as will be described later and are double in number to the number of chevrons in the pattern (in this case sixteen wheels 70 to produce the eight-chevron pattern in Figure 5). The toothed wheels 70 each have a central hole 72 by which they are received in side-by-side arrangement on the respective roller shafts 34 and 36. The toothed wheels 70 are fixed for rotation with the shafts 34 and 36 by respective key and slot connections 74 and 76 while their axial containment thereon is provided by radial shoulders 78 and 80 formed integral with the respective shafts at one end of the ganged wheel sets and by respective snap rings 82 and 84 at the opposite end.

The teeth 86 on each wheel extend diagonally thereacross at the same angle with alternate ones 70A of the toothed wheels arranged in opposite angular sense to that of the adjacent wheels 70B so that the ganged set of wheels by the opposite angular sense of their diagonal teeth thus form the desired chevron or herringbone forming pattern for the corrugating rollers 30 and 32. With the direction of feed of the strip stock as earlier described, the chevron pattern of the forming teeth on the rollers identifies those V-shaped elements of the teeth which point in the same forward direction as the direction of the strip stock motion through the rollers and those V-shaped elements which point in the opposite or backward direction. The resulting forward and backward vees as previously defined and as formed by the diagonal teeth 86 where they intersect are identified respectively as 88 and 90 in Figures 2 and 3 which with the ganged set of toothed wheels on each corrugating roller occurs at the junction of the two adjacent wheels bearing these oppositely angled teeth.

According to the present invention, the points or apices of the forward vees 88 are eliminated by forming a chamfer 92 on the opposing ends of the teeth all around the two adjacent wheels of oppositely angled teeth at each such forward vee location as best seen in Figures 2, 3 and 3a. Each of the corrugating rollers 30 and 32 is thus formed with transverse rows of discrete teeth extending interruptedly rather than uninterruptedly thereacross as is normal, with the selected ones of the teeth in each row (i.e. those forming the forward vees 88) being discontinuous with each other, where they would normally come together, by the formation of the chamfers 92. The corrugating rollers are thus devoid of any forward vee points or apices but otherwise conform to the desired chevron or herringbone corrugation configuration. Nevertheless, it has been discovered that forward vee points or apices are still formed in the strip stock in the roller regions devoid of teeth (i.e. at the pairs of chamfers 92) by tension action of the adjoining teeth 86 forming the forward vees 88 so as to produce the complete corrugations in the strip with distributed and thereby reduced strain in the forward vee corrugation regions. For example, the corrugated strip shown in Figure 5 was formed from stainless steel foil using the toothed rollers 30 and 32 and it will be seen that the forward vee points were nevertheless produced albeit relatively blunt as compared with the backward vee points where the corrugating teeth remained continuous.

Moreover, in the case where the state of plain strain induced in the strip stock at the points of the backward vees is also found to produce splits and tears such as with the use of thicker material or material having less ductility, the points or apices of the backward vees 90 may also be similarly eliminated with a complete corrugation nevertheless being formed in the strip stock.

The same effect is also accomplished simply by employing a spacer between the toothed wheels where their teeth would otherwise form the point of forward vees and secondarily that of the backward vees. This is shown in Figure 6 in the construction of one such corrugating roller understanding that the other roller would be similarly formed. In this embodiment, the toothed roller identified as 96 is for a double chevron or herringbone pattern and as a result has a ganged set of only four toothed wheels 98 secured to the shaft 100 as before. In this case, the forward vees are formed in the strip stock by what may be viewed as the two outboard pairs of wheels 98A and their juncture is made devoid of teeth by simply inserting an annular spacer ring or washer 102 therebetween mounted on the shaft, leaving what can be viewed as the intermediate pair of toothed wheels 98B to adjoin in forming the point of the backward vees. Then as in the previous embodiment, should the point of backward vees also tend to cause splits and tears, an additional spacer could be inserted between the intermediate pair of toothed wheels 98B.

Furthermore, it will be understood that while in the preferred embodiments the rollers are formed of a ganged set of toothed wheels for their ease of manufacture and the implementation of chamfer or spacers to eliminate the point of the forward vees and secondarily that of the backward vees, it will be understood that the corrugating rollers may otherwise be constructed within the teachings of the present invention in the avoidance of those tooth portions which tend to rip and tear the stripped material. For example, the corrugating rollers could be formed of one piece with the forward vee points, and secondarily the backward vee points, then machined out along with the formation of the teeth.

The above described preferred embodiments are thus illustrative of the invention which may be modified within the scope of the appended claims.

Claims:

1. A pair of toothed rollers (30,32;96) for rolling uninterrupted transversely extending corrugations in strip stock wherein the corrugations have a chevron pattern with vees that point forward relative to the direction of the strip feed into and between said rollers, characterised in that each of said rollers (30,32;96) has transverse rows of discrete teeth (86;98) extending interruptedly thereacross, the teeth in each row being discontinuous with each other (92) so as to be devoid of any forward vee points but otherwise conform to the desired corrugation configuration such that, when strip stock is rolled between said pair of toothed rollers, forward vee points are formed in the strip stock in the roller regions (88;102) devoid of teeth by tension action of the adjoining teeth (86;98) so as to produce complete corrugations in the strip stock with distributed and thereby minimized strain at the forward vee corrugation points.

2. A pair of toothed rollers (30,32;96) according to claim 1, for rolling uninterrupted transversely extending corrugations in strip stock wherein the corrugations have a chevron pattern with vees that point forward and backward relative to the direction of the strip feed into and between said rollers, characterised in that each roller (30,32; 96) has transverse rows of discrete teeth (86;98) extending uninterruptedly thereacross, selected ones of the teeth in each row being discontinuous with each other so as to be devoid of any forward and backward vee points but otherwise conform to the desired corrugation configuration such that forward and backward vee points are formed in the strip stock in the roller regions (88;102) devoid of teeth by tension action of the adjoining teeth (86;98) so as to produce complete corrugations in the strip stock

with distributed and thereby minimized strain at the forward and backward vee corrugation points.

3. A pair of toothed rollers (30,32;96) according to claim 1, for rolling uninterrupted transversely extending corrugations in strip stock wherein the corrugations have a chevron pattern with vees that point forward and backward relative to the direction of the strip feed into and between said rollers (30,32;96), characterised in that each of said rollers (30,32;96) comprises a ganged set of toothed wheels (70;98) each of said toothed wheels (70;98) having teeth (86) extending diagonally thereacross at the same angle, the toothed wheels (70;98) in each of said sets being arranged side-by-side with their teeth (86) oppositely angled so as to define transverse rows of discrete teeth (86) extending across each of said rollers(30,32;96) and selected pairs (70A,70B;98A) of said toothed wheels being devoid of tooth form where said toothed wheels adjoin so that the teeth (86) in each of said rows are devoid of any forward vee points but otherwise conform to the desired corrugation configuration.

4. A pair of toothed rollers (30,32;96) according to claim 2, characterised in that each of said rollers (30,32;96) comprises a ganged set of toothed wheels (70,98), each of said toothed wheels (70;98) having teeth (86) extending diagonally thereacross at the same angle, the toothed wheels (70;98) in each of said sets being arranged side-by-side with their teeth (86) oppositely angled so as to define transverse rows of discrete teeth (86) extending across each of said rollers (30,32;96), and said toothed wheels (70;98) being devoid of tooth form where said toothed wheels adjoin so that the teeth (86)

in each of said rows are devoid of any forward and backward vee points but otherwise conform to the desired corrugation configuration.

5. A pair of toothed rollers (30,32) according to claim 3, characterised in that selected pairs 70A,70B) of said toothed wheels have a chamfer (92) therearound at one end of their teeth (86) so as to be devoid of tooth form where said toothed wheels adjoin so that the teeth (86) in each of said rows are devoid of any forward vee points (88) but otherwise conform to the desired corrugation configuration,

6. A pair of toothed rollers (30,32) according to claim 4, characterised in that selected pairs (70A,70B) of said toothed wheels have a chamfer (92) therearound at both ends of their teeth (86) so as to be devoid of tooth form where said toothed wheels adjoin so that the teeth (86) in each said row are devoid of any forward (88) and backward (90) vee points but otherwise conform to the desired corrugation configuration.

7. A pair of toothed rollers (96) according to claim 3, characterised in that spacers (102) are located between selected pairs (98A) of said toothed wheels so that the teeth in each of said rows are devoid of any forward vee points but otherwise conform to the desired corrugation configuration.

8. A pair of toothed rollers (96) according to claim 4, characterised in that there are spacers (102) spacing said toothed wheels (98) from one another so that the teeth in each of said rows are devoid of any forward and backward vee points but otherwise conform to the desired corrugation configuration.

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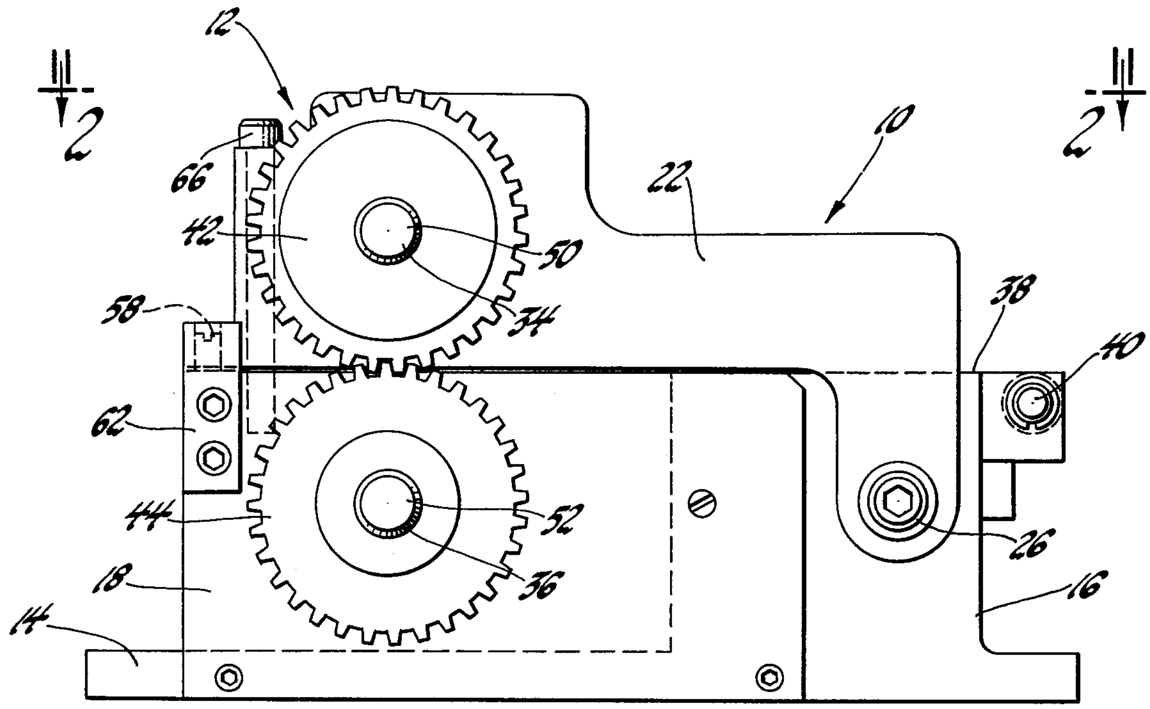


Fig. 1

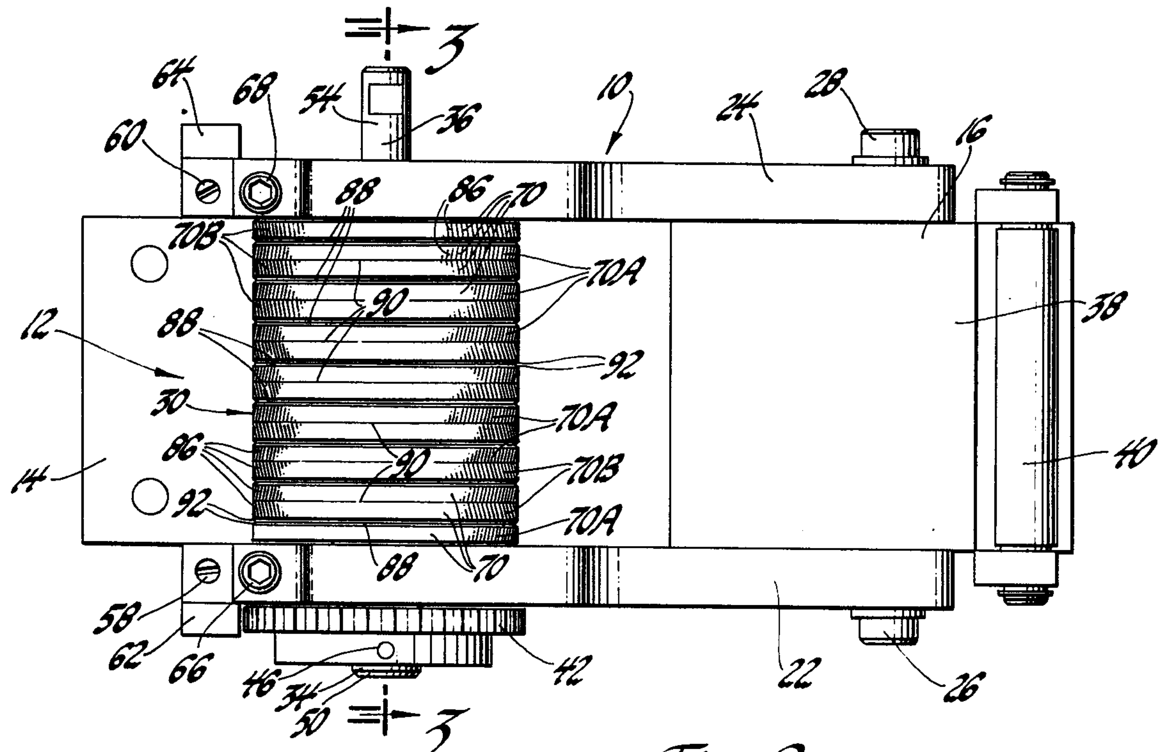


Fig. 2

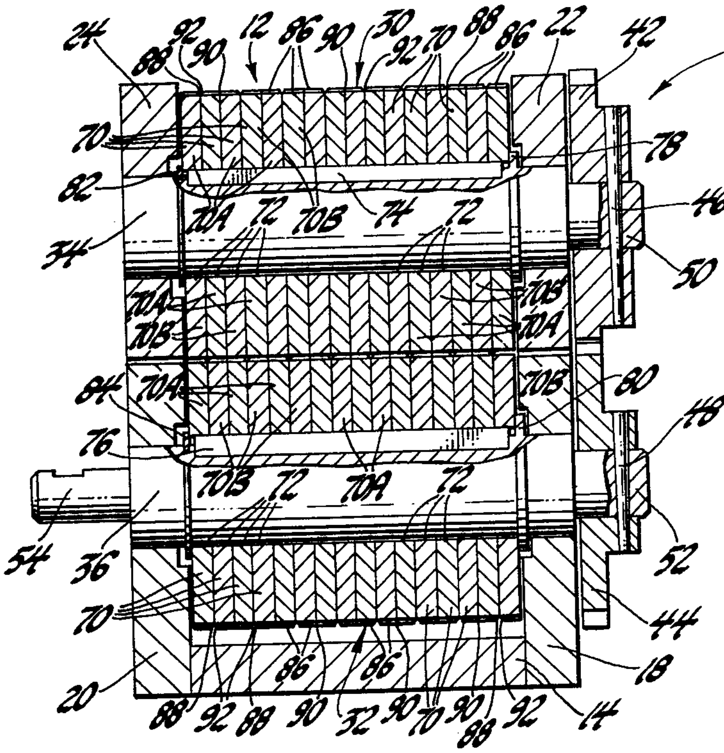


Fig. 3

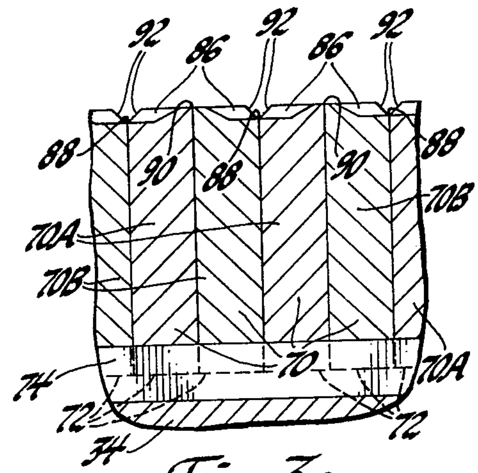


Fig. 3a

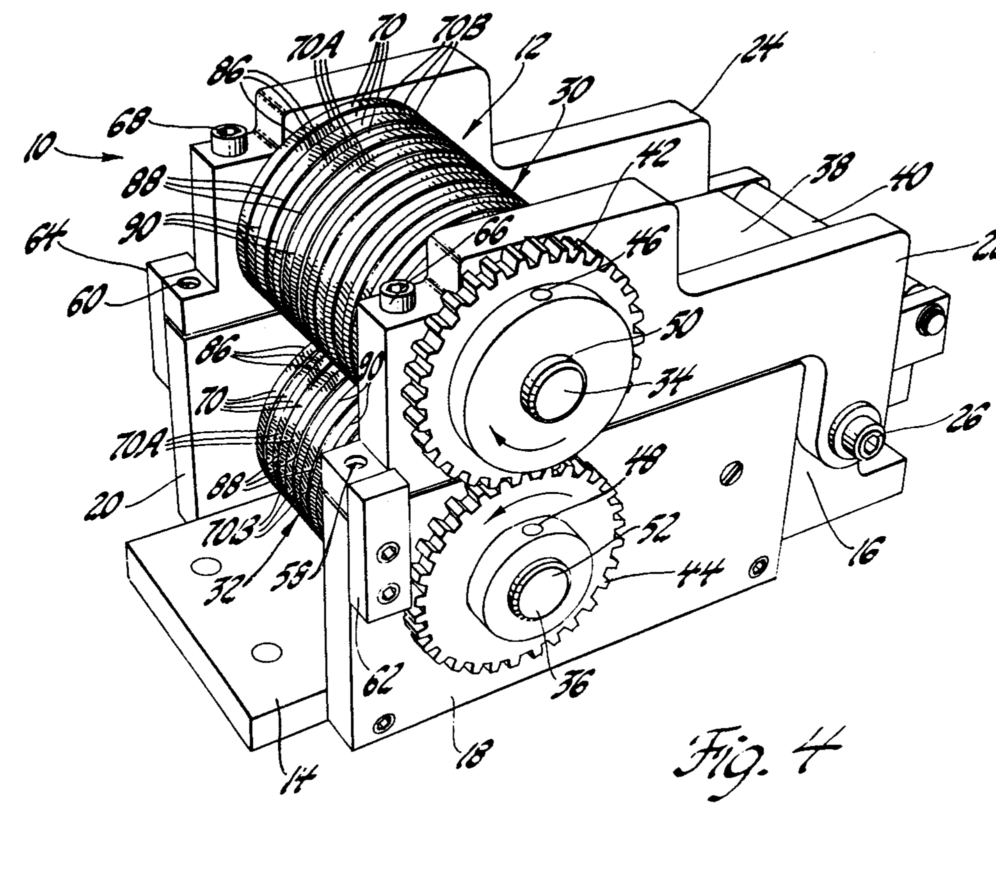


Fig. 4

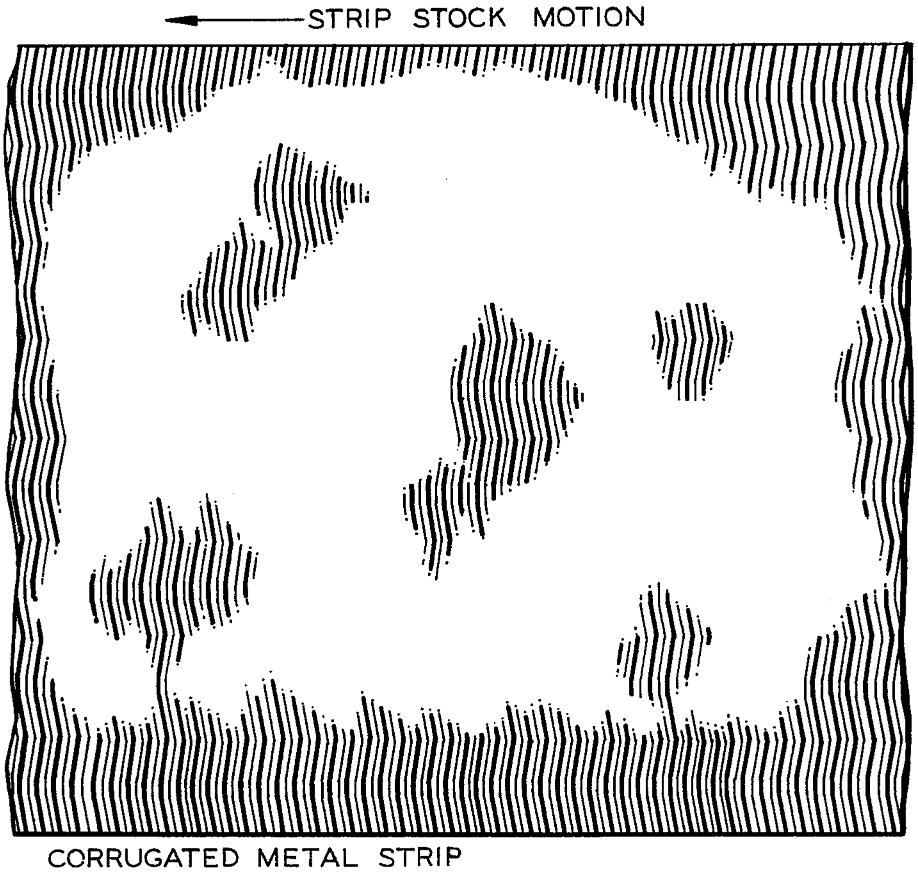
STRIP STOCK MOTION
CORRUGATED METAL STRIP

Fig. 5

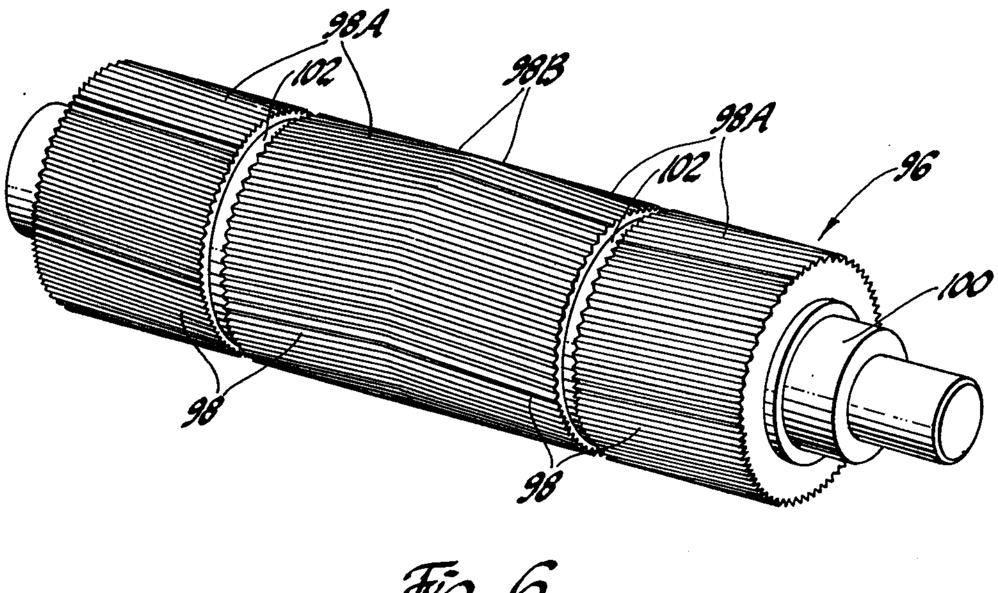
98A
102
98B
98A
102
96
100
98
98

Fig. 6