Nov. 21, 1961 A. M. MESHULAM 3,009,510

APPARATUS AND METHOD FOR CORRUGATING SHEET METAL STRIP

Filed April 25, 1958 2 Sheets-Sheet 1

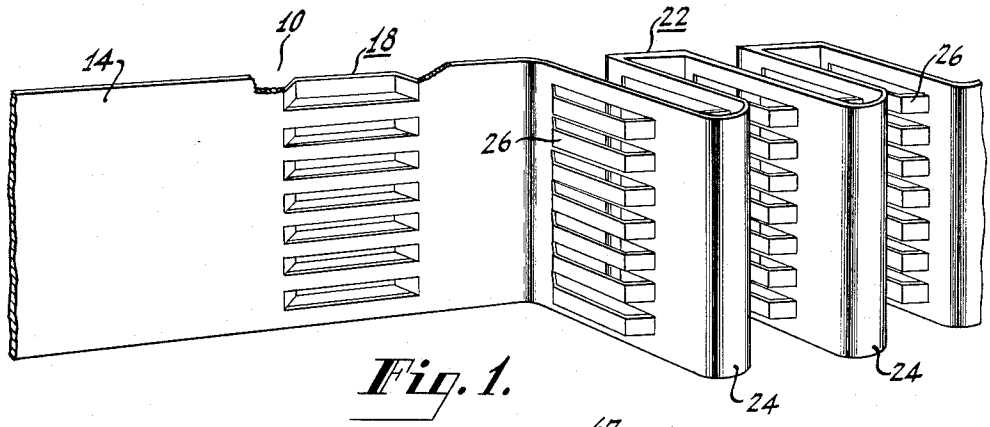


Fig. 1.

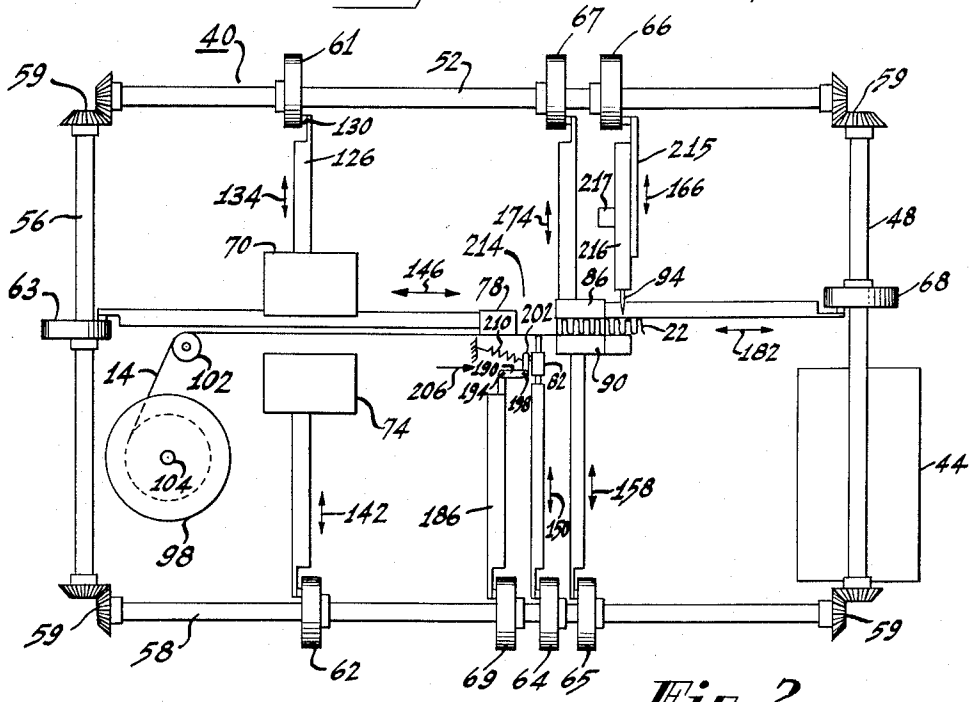


Fig. 2.

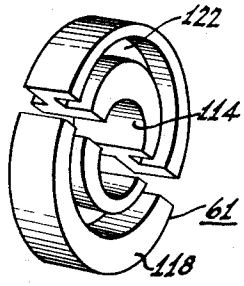


Fig. 3.

INVENTOR.
AVRAM M. MESHULAM
BY
William A. Zalucha
ATTORNEY

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APPARATUS AND METHOD FOR CORRUGATING SHEET METAL STRIP

Filed April 25, 1958 2 Sheets-Sheet 2

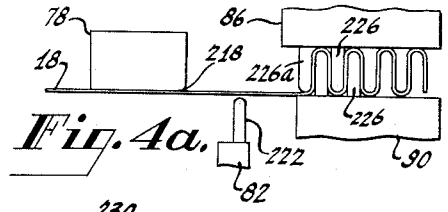


Fig. 4a.

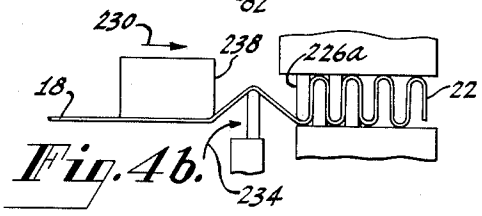


Fig. 4b.

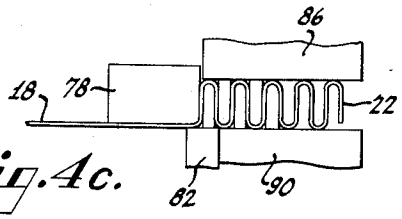


Fig. 4c.

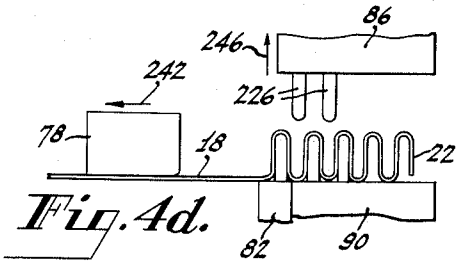


Fig. 4d.

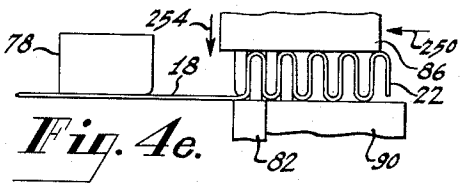


Fig. 4e.

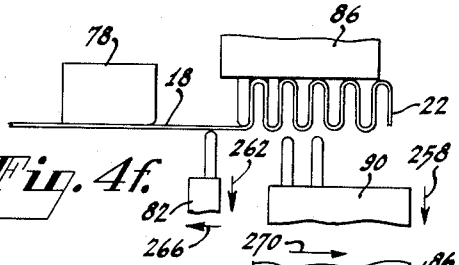


Fig. 4f.

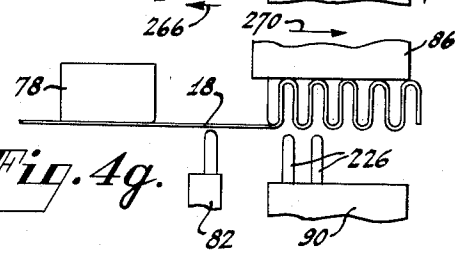


Fig. 4g.

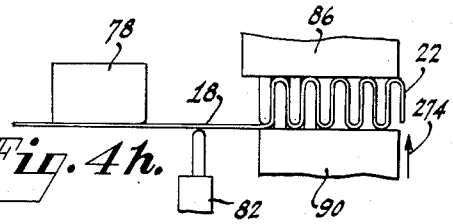


Fig. 4h.

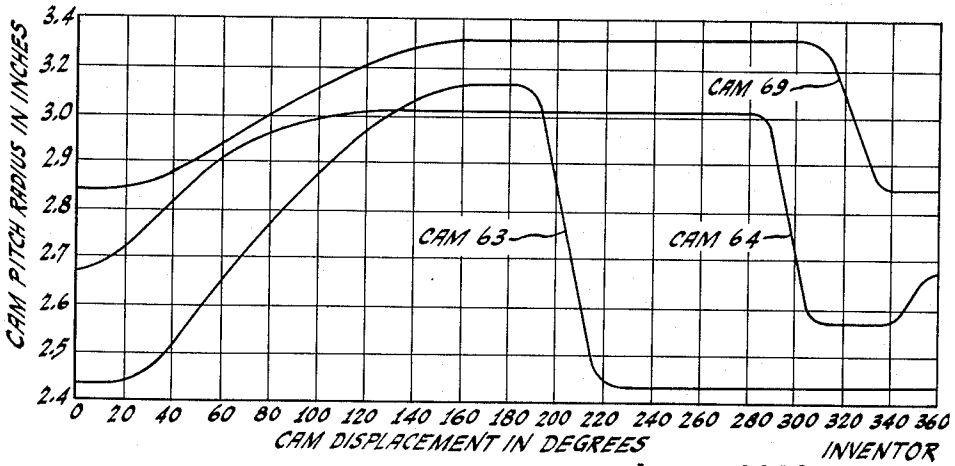


Fig. 5.

INVENTOR
AVRAM M. MESHULAM
BY William A. Galeski
ATTORNEY

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3,009,510

APPARATUS AND METHOD FOR CORRUGATING SHEET METAL STRIP

Avram M. Meshulam, Lancaster, Pa., assignor to Radio Corporation of America, a corporation of Delaware

Filed Apr. 25, 1958, Ser. No. 731,019
3 Claims. (Cl. 153—76)

This invention relates to apparatus and a method for transversely corrugating a continuous strip of sheet metal. Such corrugated strip material is particularly useful in making fin-type, heat dissipating radiators for external-anode electron tubes.

Corrugated metal strip used for making heat radiators must frequently consist of relatively fine corrugations and be very accurately formed in order to meet fabrication requirements of a specific electron tube. The problem of fineness of corrugation is made even more pronounced due to a preferred incorporation in each fin of a stamped-out, louvered construction (see FIG. 1) which tends to lessen the space between adjacent corrugations. The small space between corrugations is, of course, reflected in the size, and hence the ruggedness, of forming tools which can be used to fabricate the strip. This factor, along with the consideration of inherent fragility of a finely corrugated strip, presents various problems when prior art machines, methods, and techniques are used.

Since the forming tools themselves must be small, and hence relatively fragile, it is essential that the forming operation exert little or no bending force on the tools. Insofar as the corrugated strip is concerned, in order to obtain a high degree of accuracy, it is necessary that excessive lateral movement of the work strip prior to forming, stretching or scraping of the work strip during forming, and pulling of the previously formed work back and forth be avoided. Furthermore, it is highly desirable that the forming apparatus and method be suitable for incorporation on a conventional four-slide machine and that it be such as to provide self-feeding of the work strip so that the need for a separate feed mechanism is avoided. This latter feature is desirable since an inherently less complex apparatus results and, hence, one not as susceptible to breakdown. Automatic self-feed achieved by the forming operation also dispenses with the need for a complex synchronizing mechanism to relate the feed of the work strip to the forming thereof.

Accordingly, it is an object of my invention to provide improved apparatus and method for corrugating a continuous sheet metal strip wherein small, fragile forming tools are not subjected to injurious bending forces; wherein feeding of the work strip is automatically provided by the forming operation itself; wherein stretching, scraping, and undesired bending of the work strip is minimized; and wherein the apparatus and method themselves are suitable for incorporation on a conventional four-slide machine.

Briefly, according to my invention, corrugations are folded into a continuous strip of sheet metal by a series of four cooperating tools. These tools are driven in predetermined, synchronized, relative motion by drive means, such as a series of cams.

Two of the tools somewhat resemble rack gears. These tools mesh with each other and serve to clamp a previously formed portion of the corrugated strip so as to hold the work srtip for a succeeding forming operation. A block-like backing tool and a single toothed forming tool are disposed on opposite sides of, and back along, the unworked strip from the clamping tools. With the previously corrugated portion of the work strip clamped against movement, the forming tool moves

against the strip and both it and the backing tool move toward the clamping tools. These movements continue until the forming tool is sandwiched between the backing tool and the clamping tools, with a single corrugation fold being formed around the single tooth of the forming tool. The tools are then backed away from the work and the work advanced a distance equal to the thickness of one corrugation fold, thus readying the work strip and tools for a succeeding folding operation.

In the drawings:

FIG. 1 is a perspective view with parts broken away of a strip of sheet metal having totally unformed portions, louvered but unfolded portions, and completely louvered and corrugated portions fabricated according to my invention;

FIG. 2 is a schematic plan view of the tools and the synchronizing drive means according to a preferred embodiment of my invention;

FIG. 3 is a perspective view of a cam suitable for use in the apparatus of FIG. 2;

FIG. 4*a* to 4*h* are schematic plan view illustrations of the tools and the work strip shown in various successive stages of the forming operation; and

FIG. 5 is a graphical representation of some of the cams of the apparatus of FIG. 2 suitable for producing the synchronized forming motions according to my invention.

FIG. 1 shows a strip of sheet metal **10** suitable for being transversely corrugated according to my invention. The strip **10** is shown to comprise an unformed portion **14**, an unfolded but louvered portion **18**, and a finished corrugated louvered portion **22** having U-shaped folds **24**. The unformed portion **14** illustrates the nature of the stock strip prior to any forming operation; the flat louvered portion **18** illustrates the nature of the strip following the first step of stamping the louvers **26** therein; and the corrugated louvered portion **22** illustrates the finished product fabricated according to my invention.

In accordance with a suggested use of the finished corrugated strip **22** formed in accordance with my invention, a length thereof may be wrapped around an external cylindrical anode and brazed to the anode to provide a series of longitudinally disposed heat-radiating fins.

FIG. 2 illustrates schematically a preferred arrangement of apparatus **40** for fabricating the strip of FIG. 1 according to my invention. The apparatus **40** is incorporated on a conventional four-slide machine. A mechanical drive **44**, e.g., an electric motor, is coupled to one of four rectangularly disposed drive shafts **48**, **52**, **56**, and **58**. The rectangularly arranged drive shafts are geared together at their ends by identical sets of conventional beveled gears **59**. As such, all four drive shafts are caused to rotate in unison in response to operation of the mechanical drive **44**. A series of nine cams **61–69** keyed to the four drive shafts serve to provide proper movement to stamping, forming, and cutting tools of the apparatus as hereinafter described. These tools include a pair of louver stamping dies **70** and **74**, a fold backing tool **78**, a fold forming tool **82**, a pair of clamping tools **86** and **90**, and a cut-off tool **94**. In operation, unformed stock strip **14** is fed from a supply reel **98** over a feed roller **102** and then in the order named between the louver stamping dies **70** and **74**, between the backing and forming tools **78** and **82**, between the clamping tools **86** and **90**, and past the cut-off tool **94**.

FIG. 3 illustrates the general type of the cams **61–69** according to a preferred embodiment of my invention.

All nine of the cams **61–69** are similar as to type and differ from each other only as to the contour of their camming surfaces. Cam **61**, representative of this type, comprises a disk-like member having a central aperture

114 therethrough to permit mounting of the cam 61 on the drive shaft 52. One side surface 118 of the cam is provided with a groove 122 encircling the aperture 114 and contoured to produce the desired motion of the die 70 coupled thereto. The cam 110 is split along a diameter thereof to facilitate mounting on the drive shaft 52. Suitable means are provided for clamping the two halves of the cam 61 together and for keying the cam to the drive shaft 52.

The mechanism comprising the cam 61 and the louver stamping die 70, as well as its operation, is representative of the general nature of all of the cam and tool mechanisms and operations excepting that imparted by cam 69. According to this representative mechanism and operation a drive linkage 126 is pivotally connected to the louver stamping die 70 and carries a cam follower roller 130 which seats in the cam groove 122. When the cam 61 is rotated, the cam follower roller 130 rides in the groove 122 and is moved toward and away from the axis of the drive shaft 52. Such movement results in a general longitudinal motion of the drive linkage 126 thereby imparting the desired rectilinear reciprocating movement to the louver stamping die 70 perpendicular to the drive shaft 52 as indicated by the arrows 134. Similarly, cam 62 imparts a rectilinear reciprocating motion to the louver stamping die 74 as indicated by the arrows 142; cam 63 imparts motion to the backing tool 78 as indicated by arrows 146; cam 64 imparts motion to the forming tool 82 as indicated by arrows 150; cam 65 imparts motion to the clamping tool 90 as indicated by arrows 158; cam 66 imparts motion to the cut-off tool 94 as indicated by arrows 166; cam 67 imparts a first motion to the clamping tool 86 as indicated by arrows 174; and cam 68 imparts a second motion to the clamping tool 86 as indicated by arrows 182. It will be appreciated that the clamping tool 86 is provided both with motions perpendicular to and parallel to the drive shaft 52. The nature and purpose of these two motions will be more fully described hereinafter.

Unlike the representative cam and tool operations hereinbefore described, cam 69 serves to move the forming tool 82 parallel to the drive shaft on which the cam 69 is mounted. This is effected by the cam 69 acting through a linkage 186 and a bell crank 190. Cam 69 imparts generally longitudinal reciprocating motion to the linkage 186 similar to that of the other cam-and-linkage assemblies. The linkage 186 is pivotally connected at one end by a pin 194 to one arm of the bell crank 190. The bell crank 190 is in turn pivotally mounted by a pin 198 to some fixed member, e.g., the frame (not shown) of the apparatus 40. Thus, as the linkage 186 is moved generally longitudinally, the bell crank 190 is caused to pivot about the pin 198. This causes the free end 202 of the bell crank 190 to move against the side of the forming tool 82 and in turn move it in the direction of the arrow 206. The forming tool 82 is returned in the opposite direction by a tension spring 210.

In the operation of the apparatus 40, sheet metal strip 14 is fed from the supply reel 98 over the feed roller 102 and between the louver stamping dies 70 and 74. The supply reel 98 is frictionally constrained against rotation, as for example by selective fit on its shaft 104. This provides a desired tensioning of the work strip 14 as it is fed to the forming stations so as to keep it taut.

In response to motions imparted by the cams 61 and 62 the stamping dies 70 and 74 are closed together upon the strip 14. These dies are such as to provide the strip 14 with a pair of sets of louvers 26 as shown in the louvered portion 18 of the strip of FIG. 1. Alternate sets of louvers 26 are stamped from opposite sides of the strip 14 such that when the strip is folded to the form indicated by portion 22 of FIG. 1, the louvers will be oriented in the same direction.

The louver stamping operation of the apparatus 40 is conventional and may or may not be incorporated with the subsequent operation of corrugating the strip. The louver stamping should by no means be considered an essential part of the corrugation folding method and apparatus for which applicant hereby seeks Letters Patent.

After passing the louver stamping station, the louvered sheet metal strip 18 is fed to the corugating station 214 comprising the backing tool 78, the forming tool 82 and the clamping tools 86 and 90. Here corrugation folds 24 are made in the louvered strip 18 to produce the finished corrugated louvered strip 22. As successive folds are fabricated in the louvered strip 18, the finished corrugated strip 22 is fed from the corrugating station 214 to the cut-off tool 94.

At selected intervals, after a predetermined number of folds 24 have passed the cut-off tool 94, that tool is operated by the cam 66 to sever the corrugated strip 22. In order to permit actuation of the cut-off tool 94 by the cam 66 only in response to preselected revolutions of the drive shaft 52, a split linkage and associated locking means are provided. The split linkage comprises a first member 215 driven by the cam 66 and a second member 216 which carries the cut-off tool 94. These members are slidably mounted relative to each other. A solenoid 217 is mounted on the second member 216 and includes a plunger which can be extended through the second member 216 and into the first member 215 to lock the two together. Rectilinear motion of the member 215 imparted by cam 66 thereby produces a corresponding advance of the cutting tool 94 to perform a cut-off operation. Actuation of the solenoid plunger is controlled by a counter associated with the fold forming operation. Thus, uniform, predetermined lengths having a predetermined number of folds 24 are produced.

As is the case of the louver stamping operation, the cut-off operation need not be incorporated with the corrugating operation and should not be considered an essential part thereof. The nature of operation of the corrugating tools 78, 82, 86 and 90 are more fully described with reference to FIGS. *4a–4h*.

FIGS. *4a–4h* illustrate successive stages of the folding of corrugations 24 into the louvered strip 18 to produce the corrugated strip 22. To illustrate the fabrication of a single U-fold 24 it will be assumed that the apparatus 40 is in operation and has already fabricated a number of folds 24. In these figures the louvered strip 18 is fed to the tools shown from left to right. FIG. *4a* illustrates the relative position of the backing, forming, and clamping tools preparatory to their fabricating the next fold.

As shown in FIG. *4a*, the backing tool 78 comprises simply a block having a rounded edge 218 around which the louvered strip 18 is folded; the forming tool 82 includes a single flat tooth 222 having a rounded end around which a fold 24 is formed; and the clamping tools 86 and 90 each include two teeth 226 similar to the single tooth 222 of the forming tool 82. The teeth 226 of each clamping tool are sized to engage a fold 24 previously formed by the tooth 222 and are adapted to then mesh with the teeth 226 of the other clamping tool.

In the condition as shown in FIG. *4a* the clamping tools 86 and 90 are meshed together over a pair of previously formed folds 24. The backing tool 78 is disposed back along the louvered strip 18 such that its rounded edge 218 is spaced from the nearest tooth 226*a* of the clamping tool 86 a distance substantially equal to the linear strip length of a single fold 24. The rounded end of the forming tool tooth 222 is in contact with the side of the strip 18 opposite that contacted by the backing tool 78 and is disposed midway between the corner 218 of the backing tool and the nearest tooth 226*a* of the clamping tool 86. To fabricate a single fold 24 the backing tool 78 moves to the right while

simultaneously the forming tool **82** moves both to the right and perpendicularly against the louvered strip **18**. These movements are illustrated in FIG. *4b* by the rectilinear and arcuate arrows **230** and **234** respectively. The backing and forming tools **78** and **82** are shown in FIG. *4b* to have partially completed their described movements. The movements of the backing tool **78** and of the forming tool **82**, as illustrated by the arrows **230** and **234**, are so synchronized that the louvered strip **18** is carried to the right along with the backing tool **78** such that there is no sliding of the strip **18** relative to surfaces of the backing and forming tools contacted thereby. Consequently, the only force exerted on the slender, fragile tooth **222** of the forming tool **82** is a compressive one longitudinal to the tooth. No lateral bending force is exerted on the tooth **222**. Moreover, since the louvered strip **18** is carried along with the backing tool **78**, feed of the strip is automatically achieved.

The synchronized motions of the backing and forming tools as described with reference to FIG. *4b* continue until a fold **24** has been completed around the tooth **222** of the forming tool **82** and is sandwiched between the end **238** of the backing tool and the first tooth **226***a* of the clamping tool **86**. This condition is illustrated by FIG. *4c*.

To recondition the corrugating tools for fabrication of another fold **24**, the backing tool **78** is first withdrawn to its original position as illustrated in FIG. *4a* and the clamping tool **86** is backed away from and out of mesh with the clamping tool **90** and the corrugated strip **22**. These movements are illustrated in FIG. *4d* by the arrows **242** and **246** respectively. Then, as illustrated in FIG. *4e* the clamping tool **86** is moved toward the backing tool **78** (arrow **250**) a distance equal generally to the thickness of one fold **24** and is then remeshed (arrow **254**) with the clamping tool **90** and the forming tool **82**. Fig. *4f* illustrates the movements wherein the clamping tool **90** and the forming tool **82** are backed away from and out of mesh with the clamping tool **86**. Arrows **258** and **262** indicate respectively these movements. Also, as shown in FIG. *4f* the forming tool **82** is repositioned (arrow **266**) toward the backing tool **78** to its original position as allustrated in FIG. *4a*. The clamping tool **86**, now engaging a pair of folds **24** of the corrugated strip **22**, is moved (arrow **270**) away from the backing tool **78** ot advance the work a distance equal to the thickness of a single corrugation fold **24**. This action is illustrated by FIG. *4g*. Thus advanced, the work is again clamped by remeshing (arrow **274**) the clamping tool **90** with the clamping tool **86** to recondition the corrugating tools for the fabricating of the next fold **24**. This condition is illustrated in FIG. *4h*. Thus, the FIGS. *4a* through *4h* illustrate the fabricating of a single fold **24** according to my invention.

It will be appreciated that the heart of my invention is embodied in the portion of the above-described operations as best illustrated in FIG. *4b*. It is here that the movements of the forming tool **82** and the backing tool **78** must be accurately related and synchronized in order to achieve the stated objects of this invention. Likewise, it will be appreciated that the movements of the corrugating tools as illustrated in FIGS. *4c* through *4h* require no such accurate synchronization. All that is necessary in these movements is that the tools do not interfere with each other or are not interferred with by the previously corrugated strip.

Considering in detail the fold-forming operation illustrated in FIG. *4b*, as the backing tool **78** moves toward the clamping tool **86**, the forming tool **82** moves perpendicularly against the louvered strip **18** and simultaneously to the right to maintain its position relative to the backing tool **78** and the clamping tool **86** midway therebetween. As such, the forming tool **82** serves to maintain the length of louvered strip **18** between the backing tool **78** and the clamping tool **86** taut so that the louvered strip **18** is continued to be carried along wtih the backing tool **78** rather than to remain stationary and allow the backing tool **78** to slide relative thereto in its advance.

Although the speed of the right angle component motions of the forming tool **82** need not be constant, it is essential that the path of travel conform substantially to a 90° arc of a circle having a radius substantially equal to the original spacing between the forming and clamping tools. It can be shown mathematically that if the length of louvered strip **18** between the backing tool **78** and the clamping tool **86** is to remain constant so as to prevent sliding of the strip relative to the backing tool, and if the end of the forming tool tooth **222** is not to slide relative to the louvered strip **18**, the tooth **222** must trace a 90° arc path in changing from the condition of FIG. *4a* to FIG. *4c*. Of course, in order to satisfy the requirement of no sliding of the strip **18** relative to the forming tool tooth **222**, the rectilinear component of motion of the forming tool parallel to the motion (arrow **230**) of the backing tool must at any instant have one half the velocity of the backing tool. Stated otherwise, the forming tool tooth **222** must at all times be midway between the edge **218** of the backing tool **78** and the tooth **226***a* of the clamping tool **86**. The variation of velocity of the backing tool **78** during its movement to the condition of FIG. *4c* is immaterial so long as the parallel velocity component of the forming tool movement is made to correspond thereto in a ratio of one-half. It will therefore be appreciated that the nature of velocity variation of the backing and forming tools may be selectively adjusted to obtain different desired operational fold-forming impact and still conform to the teaching of my invention.

According to a preferred embodiment of my invention, the cams **63**, **64**, and **69** as generally described with reference to FIG. 2 are so designed as to produce the precise synchronized movements of the forming tool **82** and the backing tool **78** as hereinbefore described.

FIG. 5 illustrates graphically the contour of the cam groove **122** for each of the three cams **63**, **64**, and **69**. On the graph, angular displacement from 0° to 360° of the cam groove **122** is plotted as an abscissa measurement. Cam pitch radius of the groove **122** in inches is plotted as an ordinate measurement.

FIG. 5 represents only one of many suitable cam designs for the three cams in question. Cams made according to the design specifications illustrated in FIG. 5 are essentially low impact cams. However, should it prove desirable to provide greater impact of the backing and forming tools on the louvered strip **18** in forming the corrugation folds **24**, the cam design can be altered. Of course, in so doing it must be remembered that cams **64** and **69** must be so related as to substantially provide a 90° arcuate path of travel for the forming tool **82**, and that cams **63** and **69** must be so related that the instantaneous parallel velocities of the backing tool **78** and the forming tool **82** are at all times maintained respectively in a 2 to 1 ratio.

While I have shown preferred apparatus for imparting to the backing and forming tools the properly synchronized motions according to my invention, it will be appreciated that my invention is not limited to such apparatus. Any conventional means to impart the desired synchronized movements to the backing and forming tools can be used. In fact, corrugation fold **24** can be fabricated according to my invention by hand operation of the forming and backing tools, provided the proper relationship of the tool movements are maintained.

What is claimed is:

1. Apparatus for forming transverse folds in planar sheet material comprising a pair of restraining tools disposed in facing relation on opposite sides of a predetermined plane and adapted to engage opposite faces of said planar sheet material, a backing tool spaced from said restraining tools and disposed adjacent said plane and

adapted to engage one face of said planar sheet, a fold forming tool disposed on the other side of said plane midway between said restraining tools and said backing tool and adapted to engage the other face of said planar sheet, said fold forming tool including a rectilinear tooth extending transversely toward and in normal relation to said plane and adapted to engage said sheet material in a folding operation, said backing tool being mounted for rectilinear movement parallel to said plane, said fold forming tool being mounted for movement simultaneously perpendicular to and parallel to said plane while preserving said tooth in said normal relation to said plane and in a predetermined synchronization to provide a ratio of two to one between the instantaneous velocities of said backing tool and said forming tool in said plane, and means for moving said restraining tools into engagement with said opposite faces prior to the movements of said backing and forming tools, for restraining movement of a portion of said planar sheet material during said movements of said backing and forming tools.

2. Apparatus for forming corrugation folds in a strip of sheet metal comprising a fold backing tool including a block disposed with a flat surface thereof adjacent a predetermined plane, said block having a rounded edge along said flat surface, a fold forming tool having a flat plate-like tooth disposed generally perpendicular to said plane and spaced a predetermined distance from said rounded edge of said backing tool and on the opposite side of said plane from said backing tool, said rounded edge and the end of said flat plate-like tooth adjacent said plane being parallel to each other, a first cam coupled to said backing tool for imparting motion to said backing tool parallel to said plane and generally toward said forming tool, a second cam coupled to said forming tool for imparting a component of motion to said forming tool perpendicular to and through said plane; a third cam coupled to said forming tool through a bell crank pivotally mounted on a fixed member for imparting a single component of motion to said forming tool parallel to said plane and in a direction generally away from said backing tool, said second and third cams being so related as to move said forming tool along a 90° arcuate path having a radius of curvature substantially equal to said predetermined distance, said forming tool having a structure preserving its said generally perpendicular relation to said plane during the movement thereof in said arcuate path; said first and third cams being so related as to effect a ratio of 2 to 1 of the velocity of said backing tool to the velocity of said forming tool parallel to said plane; and restraining means spaced from said forming tool in a direction remote from said backing tool and adapted to engage and restrain movement of a portion of said strip.

3. Method of forming a U-fold in a strip of planar sheet material; comprising restraining against motion one portion of said strip; engaging with a backing tool one face of a second portion of said strip spaced from said one portion; engaging the opposite face of a third portion of said strip, intermediate said one and second portions thereof, with a free end of an elongated forming tool disposed normal to said plane; simultaneouly moving said backing tool at a predetermined velocity toward said forming tool in the plane of said sheet material while moving said forming tool in an arcuate path including a first component of motion in said plane and a second component of motion normal to said plane, said first component of motion having a velocity of one half of said predetermined velocity, and preserving said forming tool in said normal relation to said plane during said movement thereof in said arcuate path for preventing a sliding reaction between said forming tool and said sheet material.

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