Sept. 27, 1966 S. O. EVANS 3,274,812

METHOD AND APPARATUS FOR VIBRATORY SQUEEZE-FORMING OF METALS

Filed July 1, 1964 2 Sheets-Sheet 1

FIG. 1

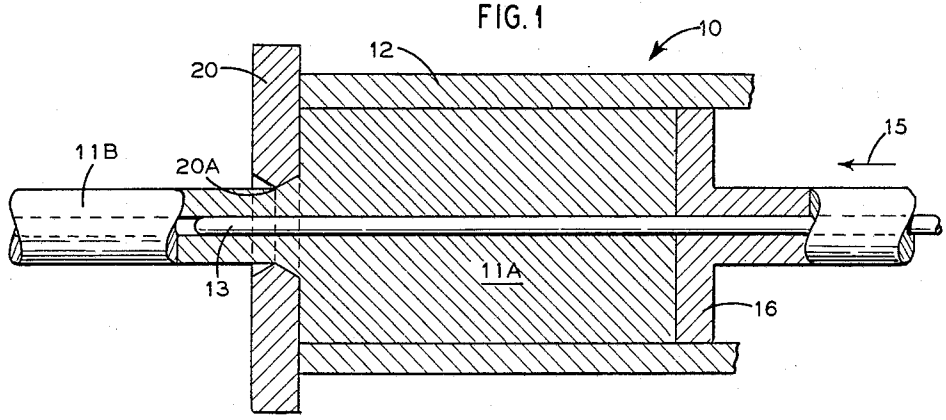


FIG. 2

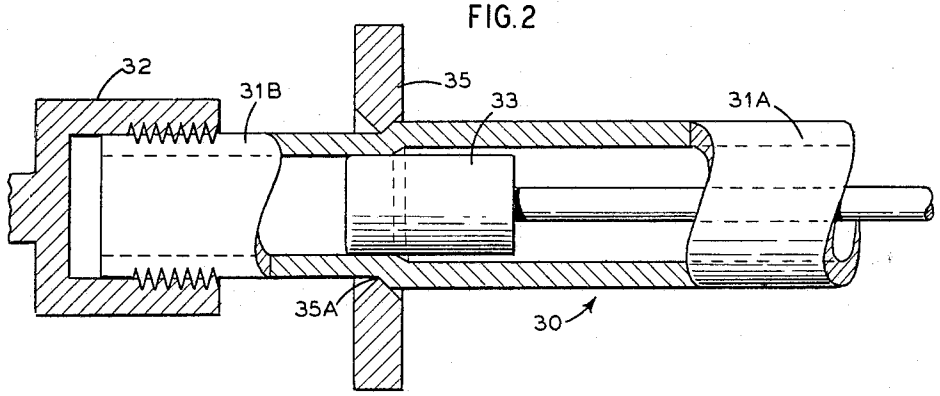
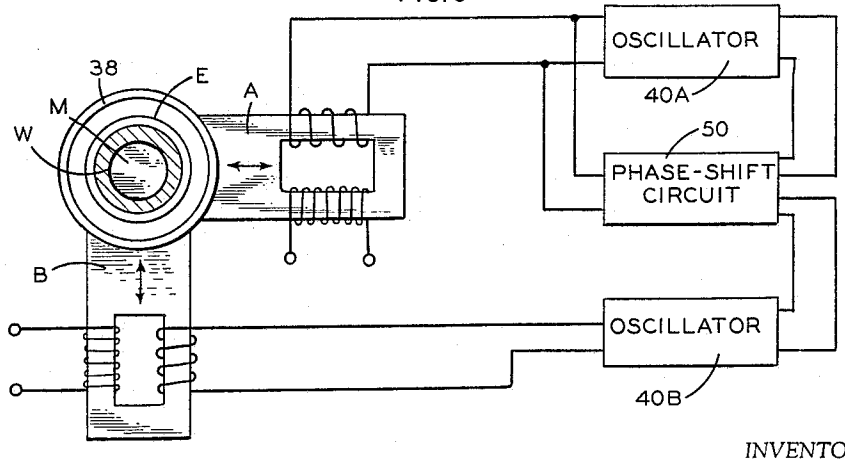


FIG. 3



INVENTOR.
Sidley O. Evans
BY
ATTORNEY

METHOD AND APPARATUS FOR VIBRATORY SQUEEZE-FORMING OF METALS

Filed July 1, 1964 2 Sheets-Sheet 2

FIG. 4

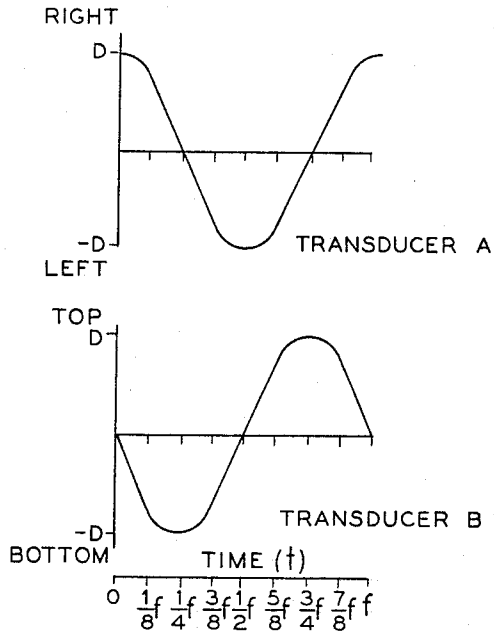
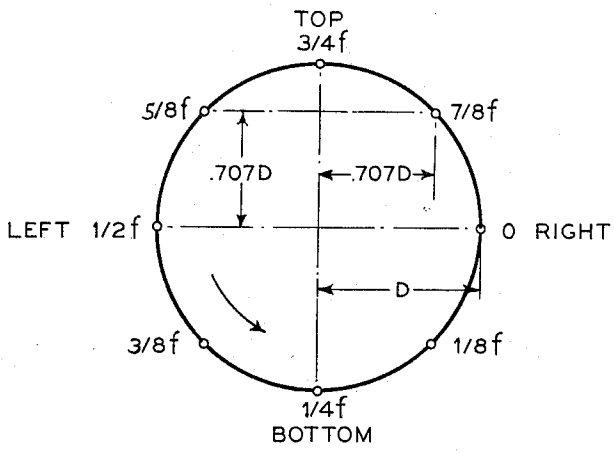


FIG. 5



United States Patent Office 3,274,812 Patented Sept. 27, 1966

3,274,812

METHOD AND APPARATUS FOR VIBRATORY SQUEEZE-FORMING OF METALS

Sidley O. Evans, Beaver Falls, Pa., assignor to The Babcock & Wilcox Company, New York, N.Y., a corporation of New Jersey

Filed July 1, 1964, Ser. No. 379,497
10 Claims. (Cl. 72—60)

The present invention generally relates to the squeeze-forming of metals, and more particularly to an improved process and apparatus for applying vibratory energy to a solid state metal member as it is being squeeze-formed.

The phrase "squeeze-forming of metals," used in this specification is intended to cover any of the processes whereby a metal member in a substantially solid state is forced through a die whereby work is performed on the member and a reduction in the cross-sectional area of the member is effected. Squeeze-forming is thus intended to cover all types of hot or cold drawing or extrusion processes, whether the process is carried out with the metal being in its normally hard condition at ambient temperature, or whether the metal is in a softened or plastic condition at elevated temperatures.

Squeeze-forming of metals has attained an important commercial status, and a wide variety of products are now being formed by one or more of the several squeeze-forming methods which have been developed. It has been found that the application of vibratory energy to the metal being worked aids significantly in reducing the amount of axial force or pressure required to pass the workpiece through the die and/or permits increasing the speed at which the metal may be passed through the die upon the application of a given force. Furthermore, the use of vibratory energy has been found to be effective in improving the overall quality of the finished product. U.S. Patent 3,002,614, issued October 3, 1961, in the name of J. B. Jones, shows for instance, the application of vibratory energy to the various components of a squeeze-forming apparatus. In applying the vibratory energy to the apparatus, it has been recognized that the transducers or vibration inducing devices must be connected to the part of the apparatus through which the vibrations are to be transmitted to the workpiece by a force-insensitive support of the type shown, for example in U.S. Patent 2,891,180, issued June 16, 1959, in the name of W. C. Elmore, in order to effect efficient utilization of the vibratory energy and to concentrate the vibrations in the area being worked on. It will be understood that this application envisions the use of such a force-insensitive mount or its equivalent.

It is an object of this invention to provide a method and apparatus for applying, in a particular manner, vibratory energy to the solid state metal member being formed in a squeeze-forming process. This invention is particularly applicable to the squeeze-forming of tubular members, and it is a further object of the present invention to provide a method of applying vibratory energy to the tubular member being formed in such a manner so as to improve the concentricity of the member.

To attain these objects, an apparatus for squeeze-forming a solid state metal member is provided which includes a die having an opening formed therein, the minimum cross-sectional area of the opening being less than the cross-section of the member as defined by its outer original dimensions. Provisions are also made for axially forcing the metal member through the die opening, thus performing work on the member whereby a reduction in the cross-sectional area of the member is effected. A plurality of vibrating devices, disposed with respect to each other preferably in a substantially common plane perpendicular to the axis of the member, are constructed

and arranged to impart equal amounts of flexural or transverse vibratory energy to the member as it passes through the die. The vibrating devices are maintained uniformly out of time phase with respect to each other so as to impart a rotating circular vibrational movement to the member, thereby causing tangential flow of the workpiece material and consequent improvement in workpiece concentricity. This result may most advantageously be obtained by utilizing a pair of vibrating devices maintained 90° out of time phase with each other and mutually disposed at right angles in a common plane perpendicular to the axis of the member.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

In the drawings:

FIG. 1 is a schematic diagram of the basic elements of an extrusion press;

FIG. 2 is a schematic diagram of the essential elements of a drawing apparatus;

FIG. 3 is a diagram showing the application of vibratory energy from two transducers to a die according to the present invention;

FIG. 4 is a graphical depiction of the vibration wave forms applied by the transducers; and

FIG. 5 is an enlarged diagram of the cumulative vibrational movement of the workpiece produced by the apparatus shown in FIG. 3 when vibrated in the cyclic manner shown in FIG. 4.

Referring to FIG. 1, the extrusion press **10** is constructed and arranged to form a product or tube **11B** from a metal member or billet **11A**. In the operation of the press **10** the billet **11A** is preferably raised to an elevated temperature below its melting point so that it is in a softened or plastic condition, and then placed into a chamber formed within the cylinder **12**. The mandrel **13**, which is slidably engaged in an appropriate opening in the ram **16**, is then extended through the billet (in the direction indicated by the arrow **15**) until its forwardmost end extends through the opening **20A** in the die **20** which is rigidly attached to the forward end of the cylinder **12**. The minimum dimensions of the opening **20A** thus define the outer shape and size of the tube **11B**, and the outer dimensions of the mandrel **13** define the cross-sectional shape and size of the longitudinal opening in the tube **11B**. Axial force in the forward direction (indicated by the arrow **15**) is then exerted on the billet **11A** by the ram **16** to squeeze the metal of the billet **11A** outwardly through the annular space formed between the opening **20A** and the mandrel **13**. During the extrusion process the mandrel **13** and the ram **16** move forward together, thus distributing along the length of the mandrel **16** the intense pressures and temperatures which are prevalent at the die orifice.

It is recognized that various refinements and ramifications have been developed in conjunction with the operation of extrusion presses of the type shown schematically in FIG. 1, and it is contemplated that the present invention may be used in conjunction with any or all of these improvements. It should also be recognized that the present invention may be utilized in conjunction with an extrusion apparatus producing solid or non-tubular products, although the benefits of eccentricity correction are applicable primarily to tubular products.

Referring to FIG. 2, the drawing mechanism **30** is constructed and arranged to effect a reduction in the cross-section of the incoming metal member or tube **31A** to form the final product or tube **31B**. To accomplish this, the forward end of the tube **31** is grasped by means of suitable jaws **32** and is pulled through the opening **35A** in the die **35**, the inner dimension of the die defining the outer configuration and size of the finished tube **31B**. A mandrel **33** is held in position within the opening **35A** and defines the inner configuration and size of the finished tube **31B**. In the drawing of solid workpieces, the mandrel would, of course, not be used. Here again it is recognized that improvements in the art have been made to the basic apparatus shown, and it is contemplated that the present invention may be used in conjunction with any or all of these improvements.

In considering the present invention it should be recognized that it can readily be used in conjunction with either the extrusion press **10** or the drawing apparatus **30** as generally discussed above. In the use of vibratory energy in such an apparatus, the specific application of vibrations to certain parts may be physically difficult or practically ineffective. For example, the nature and location of the mandrels **13** and **33** would make their effective vibration extremely difficult. Moreover, the effectiveness of applying transverse vibratory energy to the ram **16** of the extrusion press **10** or the jaw **32** of the drawing apparatus **30** would be minimal because of the constantly changing relative positions of these elements and the area in which it is desired to concentrate the vibrations, i.e., primarily the working surface between the die and the workpiece. It therefore seems obvious that the optimum location for the physical application of the vibratory energy to the squeeze-forming device would be through either the die (**20** or **35**), or through the cylinder **12** which is rigidly connected to the die **20**. Accordingly, the description that follows is in terms of introducing vibratory energy into a tubular workpiece W in a squeeze-forming apparatus through a die, which will hereinafter be generally designated as E; however, the scope of the invention is intended to encompass the introduction of vibratory energy into the workpiece W through any possible physical elements of the squeeze-forming apparatus which will effect the desired result.

FIG. 3 shows a die E having physically connected thereto, by suitable forced-insensitive coupling means **38**, a pair of vibrating devices or transducers A and B disposed at right angles to each other and perpendicular to the axes of the die E and the mandrel M. The direction of movement of the tubular workpiece W coincides with the axes of the die E and the mandrel M, i.e., it is perpendicular to the plane of the paper on which FIG. 3 is drawn. The transducers A and B may be of any type suitable for imparting to the die E vibrational energy in the form to be described hereinafter. The transducers A and B are preferably in a common plane perpendicular to the axis of the die E, or in immediately adjacent parallel planes (the transducers A and B are substantially in a common plane. Generally, the transducers A and B may suitably be positioned with respect to the die E in any angular relationship by which transverse vibrational energy may be imparted to the die E, flexural or transverse vibration being defined for the purposes of this application as any vibration having a component of movement in a direction perpendicular to the direction of movement of the workpiece W.

The excitation coils of the transducers A and B are fed from respectively associated oscillators **40A** and **40B** which cause the transducers to produce a vibration having the form of a sine wave as shown graphically in FIG. 4. A phase shift circuit **50** feeds control voltages to the oscillators **40A** and **40B** which are so displaced in phase that oscillator **40A** causes transducer A to vibrate 90° out of time phase with the vibrations of transducer

B caused by oscillator **40B**, as can be noted in the comparison of the wave form depictions for transducers A and B in FIG. 4. The displacement d of the vibration of transducer A may be defined as:

$$d_A = D \cos 2\pi ft$$

and the corresponding displacement for transducer B is:

$$d_B = D \cos \left(2\pi \text{ ft.} + \frac{\pi}{4}\right)$$

where D is the maximum displacement or amplitude, f is frequency and t is time.

The calculated values of the displacement of the individual transducers A and B for progressive fractions of t are shown on the following tabulation:

time (t)	Transducer A	Transducer B
0	(+) 1 × D	0
1/8 f	(+) .707 D	(−) .707 D
1/4 f	0	(−) 1 × D
3/8 f	(−) .707 D	(−) .707 D
1/2 f	(−) 1 × D	0
5/8 f	(−) .707 D	(+) .707 D
3/4 f	0	(+) 1 × D
7/8 f	(+) .707 D	(+) .707 D
f	(+) 1 × D	0

A combination of these values results in a circulator rotating cumulative vibration of the die E and workpiece W, as shown diagrammatically in FIG. 5. Thus, it can be seen that by using a pair of transducers A and B, disposed at right angles to eac hother and in a substantially common plane perpendicular to the direction of movement of the workpiece W, where the transducers have imposed thereon equal sinusoidal vibration wave forms which are maintained 90° out of time phase with each other, a transverse vibratory energy is imparted to the workpiece so as to effect a circular rotating vibratory movement of the die E and the workpiece W.

Although the invention has been described in terms of effecting circular vibratory motion, it should be recognized that by altering the wave forms of the vibrations and/or the synchronization of the vibrations, other types of rotating vibrational movement can be effected. For example, it would be possible to produce a vibration describing an elliptical or oval path. For the purposes of the specification, the term "orbicular" is used to describe all of the rotating vibrational movements encompassed by the present invention, and more particularly to describe all closed paths having a continuously inwardly curving configuration. It should also be recognized that the invention is not intended to be limited to a pair of transducers arranged as described above. Rather it is contemplated that the invention include any plurality of transducers so displaced and operated as to impart an orbicular vibrational movement to the workpiece W in a squeeze-forming apparatus.

While in accordance with the provisions of the statutes there is illustrated and described herein a specific embodiment of the invention, those skilled in the art will understand that changes may be made in the form of the invention covered by the claims, and that certain features of the invention may sometimes be used to advantage without a corresponding use of the other features.

What is claimed is:

1. A process for squeeze-forming metals which includes forcing a substantially solid state metal member through a die opening by applying axial pressure to said member to perform work thereon whereby a reduction in the cross-section of said member is effected, simultaneously applying transverse vibratory energy to said member from a plurality of vibrating devices which are angularly disposed with respect to each other, and maintaining said vibrating devices out of time phase with each other so as to impart an orbicular vibrational movement to said member.

2. A process for squeeze-forming metals which includes forcing a substantially solid state metal member through a die opening by applying axial pressure to said member to perform work thereon whereby a reduction in the cross-section of said member is effected, simultaneously applying equal amonuts of transverse vibratory energy to said member from a plurailty of vibrating devices which are angularly disposed with respect to each other, and maintaining said vibrating devices uniformly out of time phase with each other so as to impart a substantially circular vibrational movement to said member.

3. A process for squeeze-forming a substantially solid state metal workpiece to form therefrom a tubular product, said process comprising the steps of axially forcing said workpiece through an annular space formed between the innermost boundary of a die opening and a mandrel positioned therein, simultaneously applying equal amounts of transverse vibratory energy to said workpiece from a pair of vibrating devices which are disposed at right angles to each other, and maintaining said pair of vibrating devices 90° out of time phase with each other so as to impart a circular vibrational movement to said workpiece, whereby concentricity of said tubular product is improved.

4. Apparatus for squeeze-forming a substantially solid state metal member including a die having an opening formed therein, means for axially forcing said metal member through said opening to perform work on said member whereby a reduction in the cross-section of said member is effected, a plurality of vibrating devices constructed and arranged to impart transverse vibratory energy to said member, said vibrating devices being angularly disposed with respect to each other, and means for maintaining said vibrating devices out of time phase with each other so as to impart an orbicular rotating vibrational movement to said member.

5. Apparatus for squeeze-forming a substantially solid state metal member including a die having an opening formed therein, means for axially forcing said metal member through said opening to perform work on said member whereby a reduction in the cross-section of said member is effected, a plurality of vibrating devices constructed and arranged to impart transverse vibratory energy to said member through said die, said vibrating devices being angularly disposed with respect to each other, and means for maintaining said vibrating devices out of time phase with each other so as to impart a substantially circular rotating vibrational movement to said member.

6. Apparatus for squeeze-forming a substantially solid state metal member including a die having an opening formed therein, means for axially forcing said metal member through said opening to perform work on said member whereby a reduction in the cross-section of said member is effected, a plurality of vibrating devices constructed and arranged to impart equal amounts of transverse vibratory energy to said member, said vibrating devices being angularly disposed with respect to each other in a substantially common plane perpendicular to the axis of said member, and means for maintaining said vibrating devices uniformly out of time phase with each other so as to impart a circular rotating vibrational movement to said member.

7. Apparatus for squeeze-forming a substantially solid state metal member including a die having an opening formed therein, means for axially forcing said metal member through said opening to perform work on said member whereby a reduction in the cross-section of said member is effected, first and second vibrating devices constructed and arranged to impart transverse vibratory energy to said member through said die, said first and second vibrating devices being disposed at right angles

to each other, and means for maintaining said first and second vibrating devices 90° out of time phase with each other so as to impart an orbicular rotating vibrational movement to said member.

8. Apparatus for squeeze-forming a solid state metal member including a die having an opening formed therein, means for axially forcing said metal member through said opening to perform work on said member whereby a reduction in the cross-section of said member is effected, the minimum cross-sectional area of said opening being less than the cross-section of said member as defined by its outer dimensions, first and second vibrating devices constructed and arranged to impart equal amounts of transverse vibratory energy to said member through said die, said first and second vibrating devices being disposed at right angles to each other in a common plane perpendicular to the axis of said member, and means for maintaining said first and second vibrating devices 90° out of time phase with each other so as to impart a circular rotating vibrational movement to said member, the amount of axial force applied being less than the requisite amount of axial force required to pass said member through said opening in the absence of the applied vibratory energy.

9. Apparatus for squeeze-forming a substantially solid state metal workpiece to produce therefrom a tubular product having a final cross-sectional area less than the original cross-sectional area of said workpiece, said apparatus comprising a die having an opening formed therein, a mandrel extending into said opening, means for axially forcing said workpiece through the space formed between the mandrel and the innermost boundary of said opening to perform work on said workpiece, a plurality of vibrating devices constructed and arranged to impart equal amounts of transverse vibratory energy to said workpiece, said vibrating devices being angularly disposed with respect to each other in a substantially common plane perpendicular to the axis of said workpiece, and means for maintaining said vibrating devices uniformly out of time phase with each other so as to impart a circular rotating vibrational movement to said workpiece, whereby concentricity of said tubular product is improved.

10. Apparatus for squeeze forming a substantially solid state metal workpiece to produce therefrom a tubular product having a final cross-sectional area less than the original cross-sectional area of said workpiece, said apparatus comprising a die having an opening formed therein, a mandrel extending into said opening, means for axially forcing said workpiece through the space formed between the mandrel and the innermost boundary of said opening to perform work on said workpiece, first and second vibrating devices constructed and arranged to impart equal amounts of transverse vibratory energy to said workpiece through said die, said first and second vibrating devices being disposed at right angles to each other in a substantially common plane perpendicular to the axis of said workpiece, and means for maintaining said first and second vibrating devices 90° out of time phase with each other so as to impart a circular rotating vibrational movement to said workpiece, whereby concentricity of said tubular products is improved.

References Cited by the Examiner

UNITED STATES PATENTS

3,002,614 10/1961 Jones ---------- 207—2

FOREIGN PATENTS

955,943 1/1957 Germany.

CHARLES W. LANHAM, *Primary Examiner.*

E. D. O'CONNOR, *Assistant Examiner.*