March 13, 1962 A. W. SCRIBNER 3,024,896

METAL DRAWING

Filed Nov. 10, 1960 2 Sheets–Sheet 1

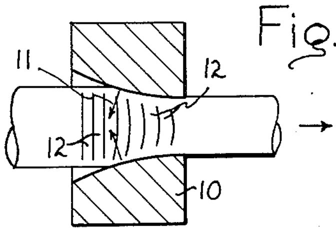

Fig. 1

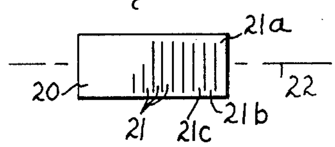

Fig. 2

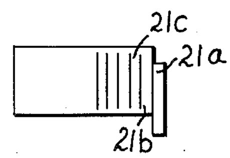

Fig. 3

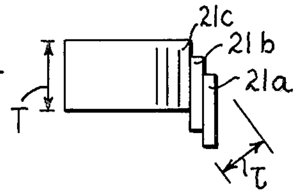

Fig. 4

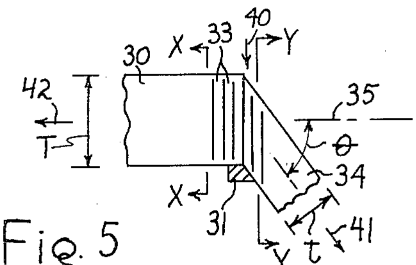

Fig. 5

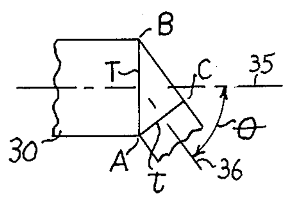

Fig. 6

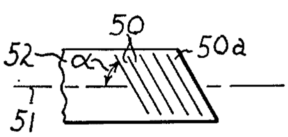

Fig. 7

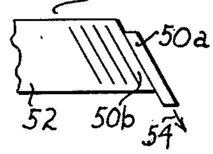

Fig. 8

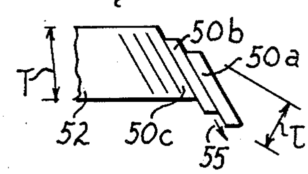

Fig. 9

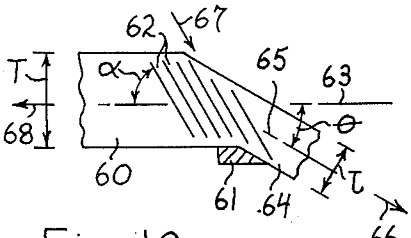

Fig. 10

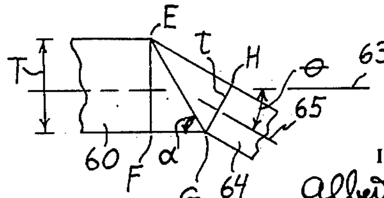

Fig. 11

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METAL DRAWING

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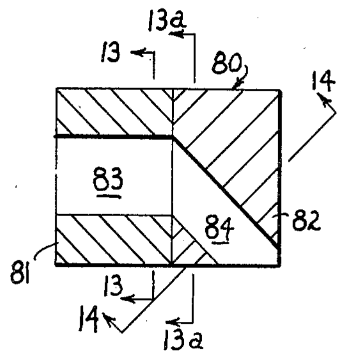

Fig. 12

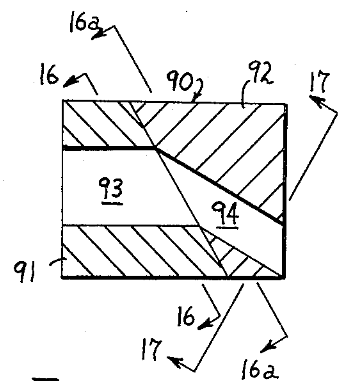

Fig. 15

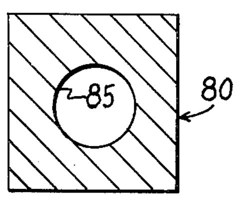

Fig. 13

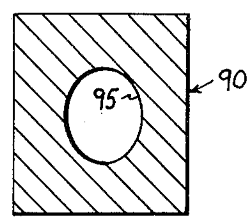

Fig. 16

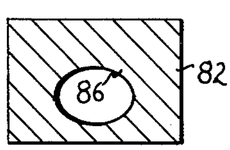

Fig. 14

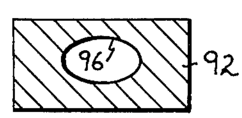

Fig. 17

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United States Patent Office

3,024,896
Patented Mar. 13, 1962

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3,024,896
METAL DRAWING
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Filed Nov. 10, 1960, Ser. No. 68,535
7 Claims. (Cl. 205—8)

This invention relates to an improved method and apparatus for continuously reducing work blanks such as metal wire, rods and the like.

This application is a continuation in part of my copending application Serial No. 665,034, filed June 11, 1957, and entitled Reduction of Metal, now abandoned.

In conventional type metal reducing operations such as swaging, drawing, etc., the work blank is reduced by being subjected to compressive type working forces which effect a decrease in the cross sectional area and an axial elongation of the work material. In such operations the direction of application of said forces is usually oriented at an angle of 90 degrees or a little less with respect to the general convergent directions of flow of that portion of the metal which is actually being reduced; hence a complex stress and metal flow pattern is thereby set up in said work material. Under such conditions the reducing operation is accompanied by a considerable amount of turbulent internal flow in the work metal and such will not only adversely affect the efficiency of the working operation but will necessitate the application of greater working forces in order to effect a given reduction of the workpiece.

One object of the instant invention is to provide a method and apparatus for improving the speed and efficiency of a metal reducing operation.

Another object of the invention is to provide a novel method and apparatus for drawing a work blank whereby the blank material being worked progressively partakes of a laminar type of flow.

Another obejct of the invention is to provide a method and apparatus for drawing a metal blank whereby the reduction of the blank is accomplished by effecting a metal displacement in substantially one direction only.

Another object of the invention is to provide a method and apparatus for drawing a metal workpiece whereby the mutually adjacent elemental transverse layers of metal are relatively displaced in substantially parallel shear planes.

Another object of the invention is to provide a novel method and apparatus for drawing metal whereby the axis of the work immediately before the reducing operation is disposed at an angle with respect to the axis of the work immediately after the reducing operation.

Still another object of the invention is to provide a novel method and apparatus for drawing metal whereby the sectional profiles of the work, immediately before and after the reducing operation, are substantially the same when taken in parallel planes that are disposed at an angle with respect to the axis of the work immediately before the reducing or drawing operation.

Other objects of the invention will become apparent as the disclosure progresses.

In the drawings:

FIGURE 1 is a side elevational view taken partial section of a work blank which is being reduced by a conventional type method and apparatus.

FIGURES 2, 3, 4 and 5 are diagrammatic views which illustrate the nature of the instant method.

FIGURE 6 is a diagrammatic view showing the geometric characteristics of the reducing operation of FIGURES 2–5.

FIGURES 7, 8, 9 and 10 are diagrammatic views corresponding to FIGURES 2, 3, 4 and 5 and illustrate

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an alternate method of reducing a workpiece where the elemental layers of metal are oriented at an acute angle with respect to the axis of said workpiece.

FIGURE 11 is a diagrammaic view illustrating the geometric characteristics of the metal reducing operation of FIGURES 7–10.

FIGURE 12 is an axial sectional view showing one embodiment of the instant drawing die.

FIGURES 13 and 14 are sectional views respectively taken along section lines **13—13** and **14—14** of FIGURE 12.

FIGURE 15 is an axial sectional view of another embodiment of a drawing die.

FIGURES 16 and 17 are sectional views respectively taken along section lines **16—16** and **17—17** of FIGURE 15.

In FIGURE 1 there is illustrated a typical pattern of metal displacement which occurs in a workpiece that is being conventionally cold worked by being drawn through the usual type drawing die **10**. As the work is being reduced by application of the compressive forces **11** the vertical extremes of the respective successive transverse elemental layers or strata **12** of the metal are brought nearer to the axis of the workpiece while the respective centers thereof receive a relative axial displacement to the right. This cupping or bowing of said layers **12** serves to diminish the vertical thickness of the metal and to produce an axial elongation thereof. The progressive cupping of said layers **12** is produced by causing the various portions of the metal being worked to flow in various convergent directions toward the work axis. This type of metal displacement gives rise to a significant amount of turbulent internal metal flow which adversely affects the efficiency and allowable speed of a reducing operation. Likewise, due to the fact that the elongation of the metal does not occur in the same general direction as the above mentioned convergent flow or the operative working forces **11**, the mechanical efficiency of the system is apt to be relatively low. For a showing of the turbulent internal metal flow pattern occurring during the hot working of metal reference may be made to U.S. Patent 2,142,704.

FIGURES 2, 3 and 4 diagrammatically illustrate one specie of the method for continuously reducing metal as contemplated by the instant invention. In FIGURE 2 the metal rod or wire **20** may be considered to be comprised of a plurality of transverse elemental layers or strata **21** the respective widths of which have, for the sake of clarity, been greatly exaggerated in the drawings. If the terminal elemental layer **21***a* is displaced vertically downward with respect to the next adjacent layer **21***b* as shown in FIGURE 3, and the elemental layer **21***b* is similarly displaced downward with respect to the next layer **21***c* as shown in FIGURE 4, and so forth, then the workpiece **20** will be progressively reduced from a thickness of T to a thickness of t, FIGURE 4. The relative displacement between each successive elemental layer **21** will occur in one direction, which is substantially perpendicular to the axis **22** of said workpiece **20**, and in transverse shear or slip planes which are substantially parallel with each other.

FIGURE 5 diagrammatically illustrates a workpiece **30** which is being reduced in accordance with the above described method. Said workpiece is progressively moved or fed longitudinally into a work station which for the present discussion is diagrammatically illustrated at **31**. At station **31** the successive transverse elemental layers **33** of metal are successively and relatively displaced in a manner similar to that described in connection with FIGURES 2–4. The reduced work **34** leaves station **31** at an angle θ with respect to the workpiece **30** entering said station.

The value for the angle θ between the axis 35 of the workpiece 30 and the axis 36 of the reduced work 34 may be determined with reference to FIGURE 6 which illustrates the geometric characteristics of the reducing operation of FIGURE 5. The line AB represents the initial thickness T of the workpiece 30 and the line AC represents the reduced thickness t of said work 34. It will be apparent that the angle BAC is equal to the angle θ, hence the ratio of the said thicknesses t and T may be expressed as a cosine function of the angle θ, or:

$$t/T=\cos\theta \tag{1}$$

Thus there will be a determinable geometric relation between the amount of reduction of the work metal and the angular relationship between the respective axes of the workpiece 30 and the reduced work 34. Although the work in FIGURES 1–5 is shown as being reduced in thickness it will be understood that the width thereof remains substantially constant. It will be noted that the reduced work 34, FIGURE 5, in leaving the work station 31, will have a component of velocity in a direction parallel to said axis 35 which is substantially equal to the longitudinal velocity of the workpiece 30 entering said station.

The sectional profiles of the work metal taken in the parallel vertical planes X—X and Y—Y of FIGURE 5 are substantially the same. This will also be the case where the workpiece 30 is circular in cross section; in which case the cross sectional profile of the reduced work 34 will define an ellipse whose major axis is substantially equal to the diameter of the workpiece 30. A further reduction of equal percent of the reduced work 34, in accordance with the instant method and in a direction parallel to said major axis, will thereby reduce said elliptical cross sectioned work 34 to a circular cross sectional profile having a diameter which is substantially equal to the minor axis of said ellipse.

The relative displacement between the adjacent layers or strata 33 of FIGURE 5 may be produced by exerting on the successive layers an effective vertical shear force 40 which acts along the transverse slip planes between said strata 33. Said displacement may also be effected by subjecting the work metal being reduced to a tension force 41 acting through the reduced work 34 and, if desired, to a "back tension" force 42, or to combinations of said forces 40, 41 and 42. The metal being reduced as shown in FIGURE 5 will partake of a uniform transverse pattern of laminar flow thereby substantially eliminating any turbulent internal metal flow. Here also the primary working forces 40 and/or 41 applied to the metal being reduced will be more nearly directionally aligned with the elongation of said metal. These factors will greatly improve the efficiency of the metal flow occurring during the working operation and will reduce the amount of mechanical energy required to effect a given reduction of the workpiece.

The above method for continuously reducing a metal workpiece has been discussed under the assumption that the elemental layers 33, FIGURE 5, of the work lie in planes which are initially substantially perpendicular to the axis 35 of the workpiece 30. The elemental layers of metal may however be considered to lie in parallel planes which are each disposed at an acute or obtuse angle with respect to the axis of the work as shown in FIGURE 7. Here the elemental strata or layers 50 lie in planes which are oriented at the angle α with respect to the axis 51 of the workpiece 52. If the terminal elemental layer 50*a* is displaced downwardly, as shown by arrow 54, relative to the next adjacent layer 50*b* as illustrated in FIGURE 8, and the layer 50*b* is similarly displaced as shown by arrow 55 relative to the next layer 50*c* as illustrated in FIGURE 9, and so forth, then the workpiece 52 will be progressively reduced from a thickness of T to a thickness of t, FIGURE 9. Here the laminar flow of the successive elemental layers of metal will occur in substantially one direction and in parallel planes which are disposed at the angle α with respect to said work axis.

FIGURE 10 diagrammatically illustrates a workpiece 60 which is being reduced from a thickness T to a thickness t in accordance with the method described in connection with FIGURES 7–9. Here the workpiece is moved longitudinally into a work station which for the present discussion is diagrammatically illustrated at 61. At said station the elemental layers 62 are successively and relatively displaced in a manner similar to that described in connection with FIGURES 7–9. The axis 65 of the reduced work 64 is disposed at an angle θ with respect to the axis 63 of the workpiece 60 entering said station.

The value of the angle θ may be determined with reference to FIGURE 11 which illustrates the geometric characteristics of the reducing operation of FIGURE 10. Line EF represents the thickness T of the work 60 while line GH represents the thickness t of the reduced work 64. It may be readily shown that:

$$\text{Angle } GEH=\alpha-\theta \tag{2}$$

and by the law of sines that:

$$\frac{\sin\alpha}{T}=\frac{\sin(\alpha-\theta)}{t} \tag{3}$$

or

$$\frac{t}{T}=\frac{\sin(\alpha-\theta)}{\sin\alpha} \tag{4}$$

In that

$$\sin(\alpha-\theta)=\sin\alpha\cos\theta-\cos\alpha\sin\theta \tag{5}$$

expression (4) may be written:

$$\frac{t}{T}=\frac{\sin\alpha\cos\theta-\cos\alpha\sin\theta}{\sin\alpha} \tag{6}$$

which reduces to the expression

$$t/T=\cos\theta-\cos\alpha\sin\theta \tag{7}$$

Thus there will be a determinable relation between the amount of reduction of the metal, the angular relationship between the work axes 63 and 65, and the angular relationship between the axis 63 of the work and the inclined parallel planes of the said elemental layers or strata 62. It will be seen that when the value of α becomes 90 degrees, which is the case when said layers 62 are disposed in planes which are perpendicular to said axis 63, as in FIGURES 2–5, then expression (7) reduces to the expression (1). The value of α and/or θ may be made greater than 90 degrees. Again it will be noted that the reduced work 64, FIGURE 10, in leaving work station 61 will have a component of velocity, in a direction parallel to the said axis 63, which is substantially equal to the longitudinal velocity of the work 60 entering said station.

The relative displacements of said elemental layers 62 of FIGURE 10 may be effected by the several or combined uses of the various tension, inclined shear and "back tension" forces 66, 67 and 68 respectively, FIGURE 10, in a manner corresponding to the above described application of the forces 40–42 of FIGURE 5.

The drawing die apparatus for carrying out the above described method will have a work conducting passage which is shaped in accordance with the geometry discussed in connection with FIGURES 6 and 11. Referring to FIGURE 12 there is shown a drawing die arrangement for effecting the method illustrated in FIGURES 2–6. A composite die body 80 is provided having an angular work forming passage formed therethrough. Die body 80 comprises first and second die body portions 81 and 82 which are respectively formed with entrant and exit apertures 83 and 84 whose axes are disposed at angle with one another whereby said apertures cooperatively define said work forming die passage. The sectional profiles of said passage taken in the parallel sectional planes 13—13 and 13a—13a are substantially the same, said planes being disposed substantially normal to the axis of said aperture 83. If for example the aperture 83 is circular then both of said sectional profiles will have the same circular profile such as shown at 85 of FIGURE 13. Here the cross sectional contour of the aperture 84 taken along the section plane 14—14 will be substantially elliptical in shape as illustrated at 86 of FIGURE 14. As will be apparent any elliptical cross sectioned wire formed by the die body 80 of FIGURE 12 may be passed through another similar die having an entrant aperture which is elliptically shaped the same as said elliptical sectioned wire and an exit aperture which is circular in shape having a diameter equal to the minor axis of said elliptical shape of the related entrant aperture.

Referring to FIGURE 15 there is shown a die arrangement which is adapted to carry out the method described in connection with FIGURES 7-11. A die body 90 is provided with an angular work forming passage therethrough. The die body 90 comprises first and second die body portions 91 and 92 which are respectively formed with entrant and exit apertures 93 and 94 whose axes are disposed at an angle with one another whereby said apertures cooperatively define said angular work forming passage in the die body 90. The sectional profiles of this work forming passage taken in parallel planes 16—16 and 16a—16a are substantially the same; these planes being disposed at an acute angle with respect to the axis of said aperture 93. For example both of the profiles taken along planes 16—16 and 16a—16a may each have the same oval or elliptical shape as shown at 95, of FIGURE 16. Here the cross sectional profile of aperture 94 taken along section plane 17—17 would have an oval or elliptical shape as illustrated at 96 of FIGURE 17.

Instead of having an abrupt directional change in the work flow the transition between the two directions of flow may occur over a short arcuate path.

While several embodiments of the invention have been shown and described, it will be apparent to those skilled in the art that numerous variations and modifications may be made in the particular construction without departing from the underlying principles of the invention. It is therefore desired by the following claims, to include within the scope of the invention all such variations and modifications whereby substantially the results of the invention may be obtained by the use of substantially the same or equivalent means.

The invention claimed is:

1. A method of drawing metal; comprising the steps of feeding the metal in a first direction and into a drawing die passageway, applying a tension force to the metal leaving said die passageway so that the metal leaving said passageway moves in a second direction which is disposed at an angle with respect to said first direction to cause shearing of the metal at the junction of the first and second directions so that the respective sectional profiles of the metal taken before and after said junction and taken in parallel planes that are disposed at an angle to said first direction are substantially the same.

2. The method defined by claim 1 wherein said parallel planes are disposed normal to said first direction.

3. The method defined by claim 1; additionally comprising applying a back tension to the work metal moving in said first direction.

4. A drawing die: comprising a die body defined by first and second die body portions and having a work conducting passage formed therethrough; the axis of the part of said passage through said second die body portion being disposed at an angle with respect to the axis of the part of said passage through said first die body portion; the sectional profiles of the respective parts of said passage through said first and second die body portions, respectively taken in parallel planes disposed at an angle with respect to the axis of the part of said passage through said first die body portion, being substantially the same.

5. A drawing die as defined by claim 4 wherein said parallel planes are disposed normal with respect to the axis of the part of said passage in said first die body portion.

6. A drawing die as defined by claim 5 wherein the respective sectional profiles are substantially circular in shape.

7. A drawing die as defined by claim 4 wherein said sectional profiles are substantially elliptical in shape.

No References Cited.