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[54] **VARIABLE ORIFICE, ZERO FRICTION DRAW DIE**
10 Claims, 7 Drawing Figs.
[52] U.S. Cl..... **72/194,**
72/205, 72/224
[51] Int. Cl..... **B21b 21/00**
[50] Field of Search..... **72/224,**
225, 189, 194, 205

[56] **References Cited**
UNITED STATES PATENTS
3,240,045 3/1966 Sellars et al..... **72/205**

ABSTRACT: A tube tapering arrangement including at least three rotatable and equiangularly spaced circular disc dies. The die circumferences are identically contoured with variable depth die peripheries that are aligned adjacent one another in a geometric pattern defining a die orifice. During tube tapering of elongated workpieces, the disc dies are rotated synchronously so that the workpiece is deformed to the desired taper configuration.

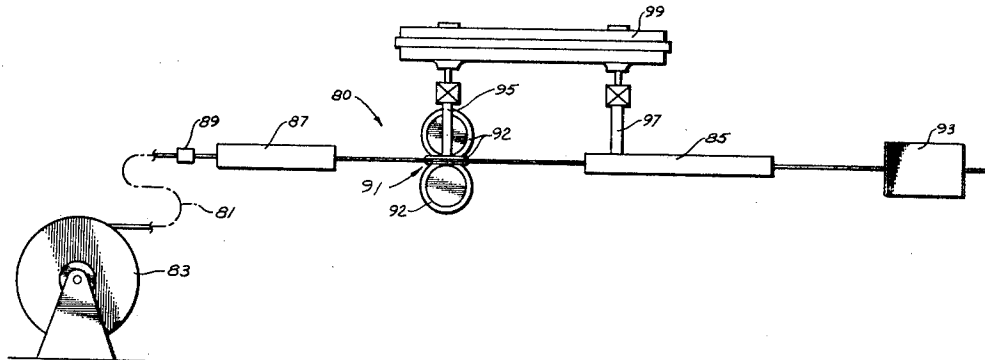


FIG. 1

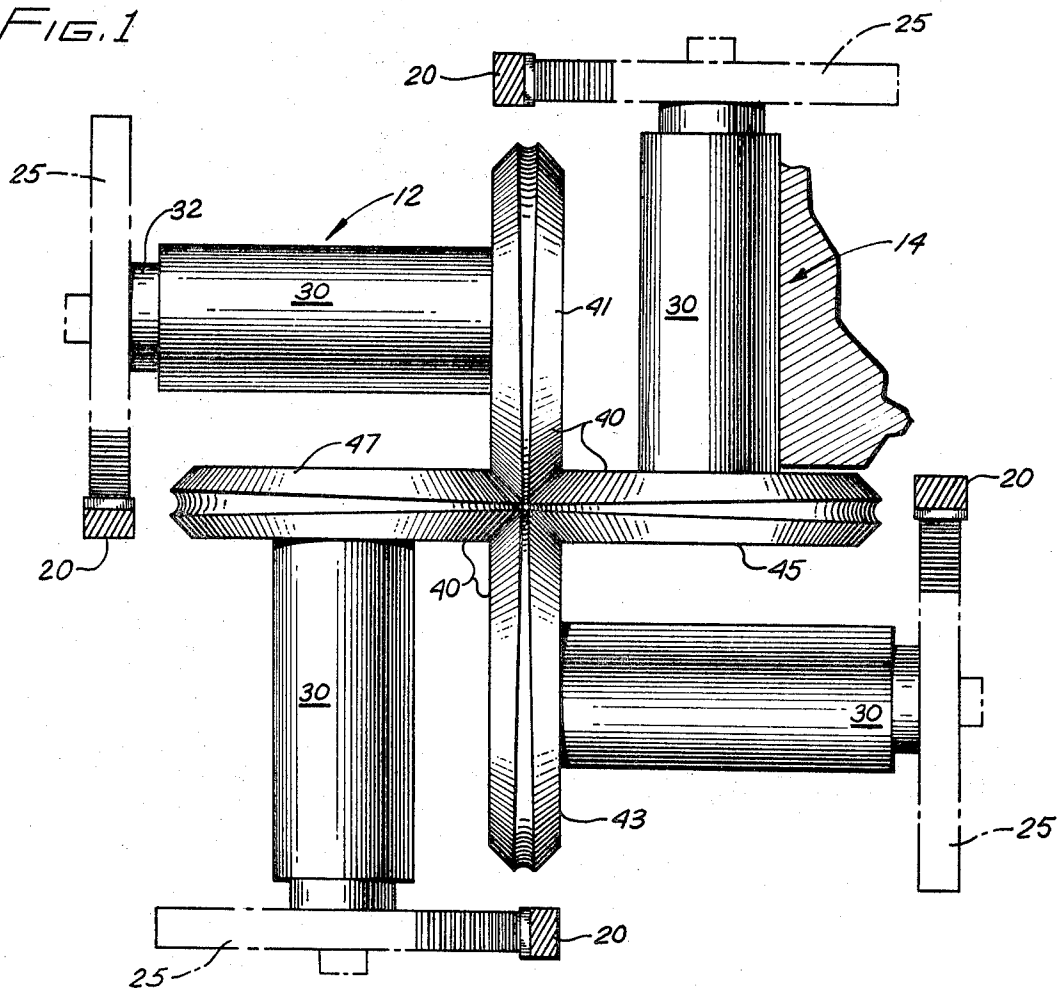
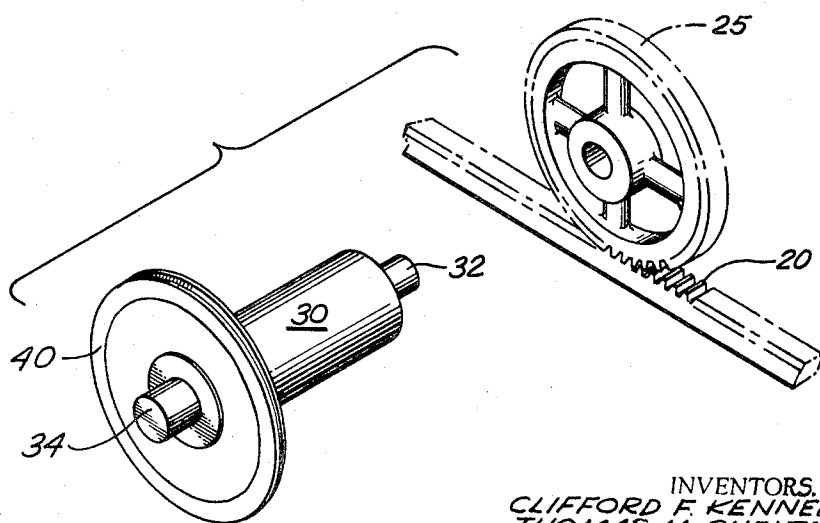


FIG. 2



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FIG. 5

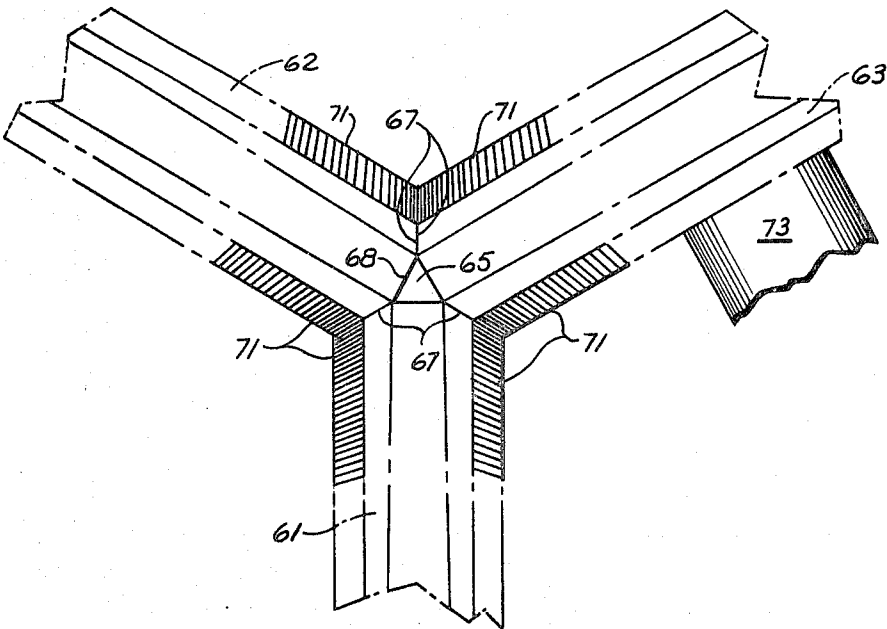
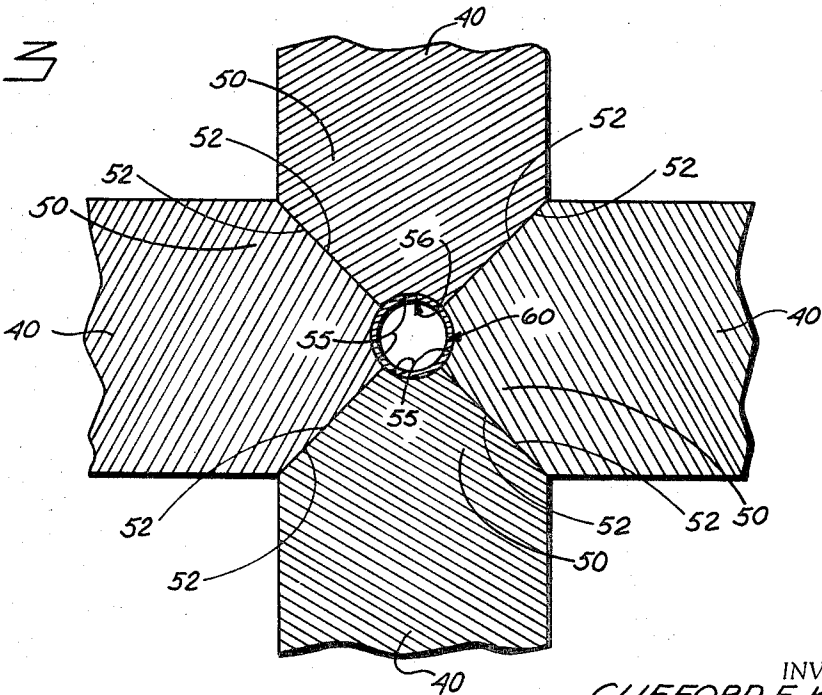


FIG. 3



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FIG. 7

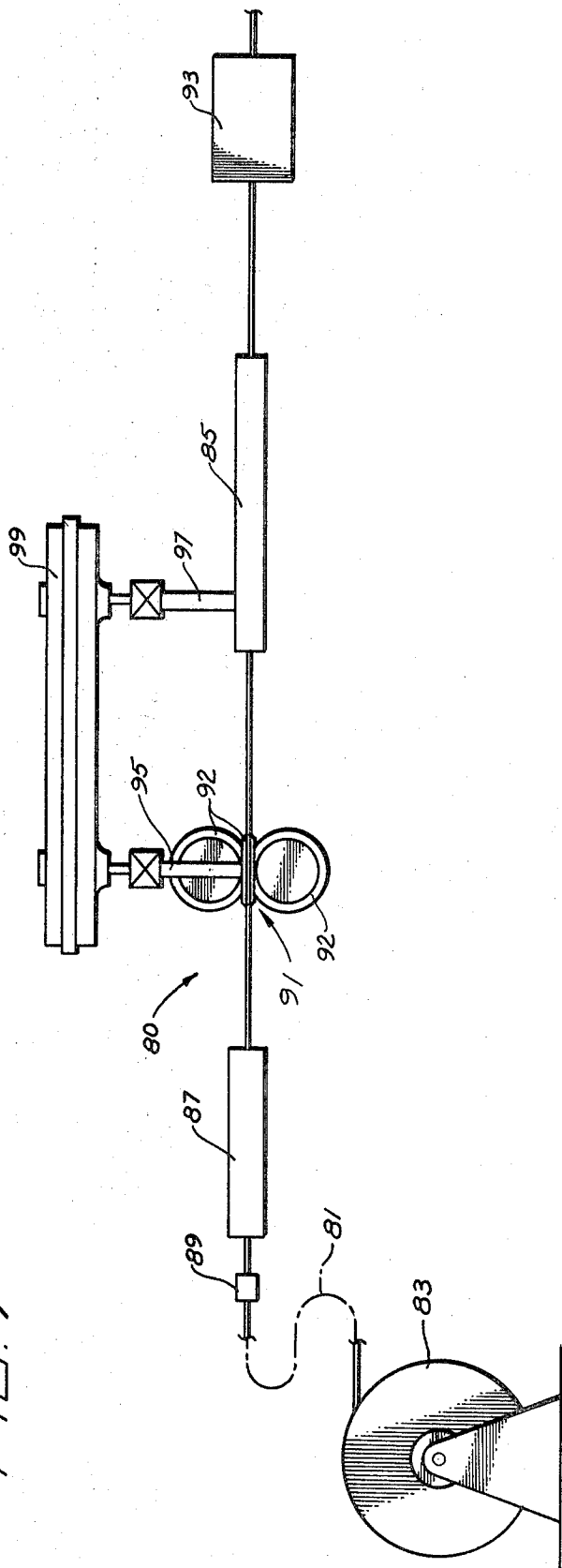


FIG. 4

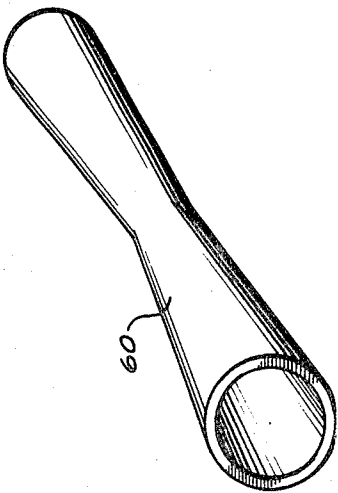
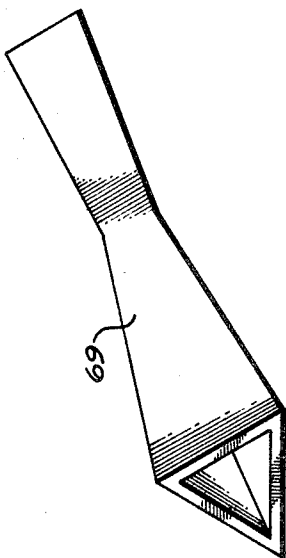


FIG. 6



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VARIABLE ORIFICE, ZERO FRICTION DRAW DIE

BACKGROUND OF THE INVENTION

This invention relates to tapering elongated workpieces, and more specifically to tapering tubular or solid rod workpieces by drawing them through a variable die orifice.

Numerous approaches and techniques for tapering tubes are well known in the prior art. In the case of workpieces of circular cross section it is often desirable to reduce their diameter over sections of their lengths. In the case of elongated workpieces of different cross-sectional configurations, it is often desirable to taper various sections along their lengths to congruent geometries. One type of conventional variable die orifice arrangement known in the prior art includes a pair of roller dies formed with concave die grooves that bear against opposing sides of the elongated workpiece as it is being drawn through the orifice. A serious problem encountered by this arrangement, so long as the die and workpiece are not rotated relative to one another, is that it is virtually impossible for the dies to avoid causing the workpiece to laterally extrude. This results because the arcs defined by the die grooves are not truly 180° and therefore as the dies press against the workpiece, tending to flatten the workpiece, portions of it bulge laterally. Another serious defect is that the edges of the concave die peripheries tend to dig into the workpiece. This results because there is insufficient clearance between the die edges and the larger diameter portions of the workpiece. The resulting interference causes galling and eventually gouging. To avoid this problem there have been attempts to smooth the die edges into convex shapes. However, this results in diminishing the bearing area which for best results ought to circumscribe the workpiece. Thus, attempts to diminish digging and gouging results in a greater risk of lateral extrusion and, therefore, the rejection rate of these workpieces, when exacting standards must be satisfied is very high. To obviate both of these defects, mechanisms for rotating the draw die assembly and workpiece relative to one another have been proposed. These mechanisms, as well as being complex and expensive, require additional space and present a greater risk of mechanical failure in the drawing operation.

Another variable draw die orifice arrangement (e.g., U.S. Pat. No. 3,240,045 to Sellars et al.) includes a plurality cylindrical rollers having variable depth die grooves formed on one end. The cylinders are arranged so their grooves coact to constitute a variable die orifice. The cylindrical axes are eccentric relative to the die orifice resulting in poor force distribution, the need for complex gearing, severe vibrations, and potential disruption. Arranging the dies to fully circumscribe the workpiece results in sliding between the cylinders with concomitant severe friction. As opposed to rolling contact, this sliding contact hampers high quality tapering.

SUMMARY OF THE INVENTION

Briefly stated, the instant invention is a variable die orifice tapering arrangement for tapering tubular or solid rod workpieces. At least three circular disc dies are arranged equiangularly with their circumferences identically contoured with variable depth die peripheries. The die peripheries may be generally flat or concave. The edges of the die peripheries are aligned contiguously to constitute a variable die orifice. The planes of the discs intersect in a mutual straight line that passes through the die orifice center. The discs are rotated synchronously to impart the desired taper to the workpiece. In one embodiment the discs are driven by separate and simultaneously movable shafts. In another embodiment the discs are formed with bevel gears that intermesh so that rotary movement of one disc rotates the other discs through the same motion. The workpiece is pulled through the die orifice at a speed equivalent to the rotary speeds of the discs so that zero friction results between the die and the workpiece. This zero friction eliminates the risk of galling.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-described advantages, as well as additional advantages, of this invention will be fully appreciated when the following detailed description of the invention is studied in conjunction with the drawings in which:

FIG. 1 is a front and partially fragmented view showing a variable draw die assembly including four disc dies;

FIG. 2 is a perspective and exploded view showing one disc die and gearing for rotating the disc die;

FIG. 3 is an enlarged view of the junction of the four disc dies shown in FIG. 1 that defines the variable orifice;

FIG. 4 is a perspective view of a section of a workpiece tapered by the device shown in FIG. 1;

FIG. 5 is a front and partially fragmented view of another variable draw die assembly having three disc dies;

FIG. 6 is a perspective view of a section of a workpiece tapered by the device shown in FIG. 5;

FIG. 7 is a schematic view of an assembly for tapering a continuous supply of workpiece under zero friction conditions.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, FIG. 1 shows the essential components of a variable draw die assembly 12 constituting one embodiment of this invention. To best illustrate assembly 12, it is shown partially removed from its housing 14 which, as will be explained, may be connected in a carriage (not shown). Draw die assembly 12 incorporates four parallel equally spaced racks 20 that may be fixed to a common support frame (not shown). The teeth of racks 20 intermesh with the teeth of four identical spur gears 25. Spur gears 25 are arranged so that the plane of each gear perpendicularly intersects the planes of its two adjacent gears. As best shown in FIG. 2, each spur gear 25 is rigidly connected to a drive shaft 30 by way of a bearing 32. At the opposite end of each drive shaft 30 is a bearing 34 for connecting each shaft 30 to a circular disc die 40. Two of the four disc dies 41 and 43, referring again to FIG. 1, lie in the same plane and in a similar manner the other two discs 45 and 47 lie in the same plane, the planes being mutually perpendicular.

As shown in FIG. 3 which is an enlarged view of the junction of disc dies 40 the circumference 50 of each disc die 40 converges outwardly terminating in a tapered periphery 52. Between the inner edges of each pair of tapered peripheries 52 is a concave die periphery 55 that curves through and an arc of 90°. Individual die peripheries 55 are aligned contiguously to constitute a die orifice 56, which, as will be explained, is variable in size to taper a workpiece 60 to the desired configuration. Die orifice 56 substantially fully circumscribes workpiece 60, i.e., the gaps between adjacent die peripheries 55 are negligible. The discs 40 are designed to rotate synchronously which may be accomplished by simultaneous movement of the racks 20 or alternatively by movement of the die assembly carriage (not shown) over stationary racks. During this rotation the tapered peripheries 52 of adjacent discs 40 make smooth rolling contact with one another.

In this embodiment the die peripheries 55 are contoured identically, varying from maximum to minimum depths. In FIG. 1 the minimum depth portions of all the die peripheries 55 constitute a die orifice 56 for deforming tube 60 to a minimum diameter. The maximum depths are diametrically opposite the minimum depths. The discs 40 are equiangularly spaced and their planes intersect in a mutual straight line that passes through the center of die orifice 56. The angular spacing between adjacent discs need not be equal. By arranging the discs so their planes pass through the center of die orifice 56, direct forces will be exerted on tube 60 from a plurality of directions. By avoiding eccentrically applied forces to the tube the disadvantages of vibration, severe flexing and strain on the dies is substantially minimized.

In practicing the embodiment of this invention described above for tapering a tubular or solid rod workpiece, the workpiece would be maintained under tension at a stress slightly

above the yield point of the material from which the workpiece is constructed. A suitable tension applying device for accomplishing this is fully described in U.S. Pat. application Ser. No. 622,168 filed on Mar. 10, 1967, on an invention which has been assigned to the assignee of this invention. A carriage (not shown) would then propel die assembly 12 along stationary rack 20 causing the disc dies 40 to rotate synchronously. As the discs rotate, die orifice 56 constantly changes size so as to make a predetermined variable taper on the workpiece. A workpiece section 60 which is variably tapered is shown in FIG. 4. It should be noted the die peripheries 55 need not be constantly tapered over the entire circumference of the discs 40 but in fact may be of constant depths for certain segments and may also have portions of stepped contouring. By this arrangement, the workpiece being tapered is subjected to biaxial forces, i.e., tensile force along its axis and compressive force exerted by the disc dies against its outer periphery. The workpiece may be precut to a length which is identical to the circumferential distances of the disc dies. In this case a single cycle of simultaneous rotation by the disc dies would totally taper the workpiece to the desired shape. After one cycle the finished workpiece could be removed and replaced by another precut workpiece. Optionally the die peripheries could be characterized by a repeated pattern so that a plurality of identical workpiece segments could be made during a complete revolution of the dies.

Another tube tapering arrangement made in accordance with this invention as shown in FIG. 5 includes three circular disc dies 61, 62 and 63 that are equiangularly spaced from one another at 120°. As in the case of the other described embodiment the planes of the discs intersect in a mutual straight line that coincides with the axis of a die orifice 65. The circumferences of the disc dies have tapered peripheries 67 which are inclined at 60° to the planes of the disc dies. Adjacent tapered peripheries may be sloped at any suitable inclination so long as they add up to 120°. Centrally formed on the circumferences of the discs are substantially identical flat die peripheries 68. Flat die peripheries 68 are identically tapered to form tapered workpieces such as workpiece 69 shown in FIG. 6 that has a triangular cross section. Die peripheries 68 are aligned contiguously and combine to constitute variable die orifice 65. It should be noted that the number of flat walls of the tapered workpiece may be dictated by the number of disc dies used. For example, any desired polygonal shape may be formed such as an octagonal cross section if eight disc dies were used. For some applications, it may be economical or otherwise desirable to dispose a mandrel within a hollow workpiece to define the interior wall of a completed workpiece. However, when the workpiece is held in tension the need for using a mandrel as a support against flattening and rupturing is eliminated.

The outer sections of the circumferences of the discs are formed with bevel gears 71. Bevel gears 71 of adjacent discs intermesh so that rotation of any one disc automatically produces simultaneous and synchronous movement of the other two discs. In this arrangement for synchronizing the rotary movement of the disc dies only a single drive shaft 73 attached to a single disc die 63 is necessary. Rotary movement of drive shaft 73 transmits rotary motion to disc 63 which in turn automatically rotates discs 61 and 62 thereby achieving the synchronous rotation. It should be noted that the rack and plural drive shaft assembly disclosed in FIG. 1 could be used in the disc die assembly shown in FIG. 5. Conversely, the four disc dies of FIG. 1 could be formed with intermeshing beveled gears so as to achieve synchronous rotation. Although in the two described embodiments all of the die peripheries are either concave or flat, it is possible that the die peripheries in a single die pattern may be different, i.e., in the case of four disc dies, oppositely facing pairs may be flat and concave to form an irregular cross section. By utilizing a number of disc dies in excess of two, the prior art problem of digging into the workpiece by edges of the die peripheries is avoided.

Another aspect of this invention involves reducing the friction between the periphery of the workpiece being tapered and the die peripheries to zero so as to eliminate galling. FIG. 7 schematically illustrates a tapering system 80 for tapering a continuously supplied workpiece 81 as distinguished from tapering precut workpiece sections as described above. The tubular or solid rod workpiece 81 to be tapered is spirally wound and upon a supply reel 83 from which workpiece 81 is pulled by a friction head draw mechanism 85. Workpiece 81 is first drawn through a pretensioning device 87 that may, for example, be a hydraulically actuated pair of pretension blocks that frictionally engage workpiece 81 from opposing sides. The programmed tension may be monitored and regulated by a suitable regulator 89 which may include a conventional strain gauge system for measuring the tension. The workpiece is pulled through a variable die orifice assembly 91 which includes at least three synchronously disc dies such as those described in conjunction with FIGS. 1 or 5. Die assembly 91, rather than being slid or moved by a carriage, remain stationary. Thus workpiece 81 moves relative to stationary die assembly 91.

Die assembly 91 is powered by a single drive shaft 95 connected to a gear box drive 99. In a similar manner draw mechanism 85 is operated by a drive shaft 97 that is also connected to gear box drive 99. The rotations of shafts 95 and 97 are correlated by gear box drive 99 so that the speed at which workpiece 81 is pulled by draw mechanism 85 is always identical with the rotational speeds of discs 92. With the linear speed of that portion of workpiece 81 which is being tapered made identical with the rotational speeds of the plural die peripheries, all sliding and rubbing is eliminated and therefore zero friction is achieved. The chief advantage of this is the elimination of galling.

The tapered workpiece egressing from draw mechanism 85 passes through a conventional saw. The saw is designed to sever the tapered workpiece 81 into predetermined segments.

In accordance with this invention there is no need to rotate the workpiece about its axis or rotate the die assembly about the die orifice axis, thereby dispensing with complex and expensive gearing. It can now be seen that the instant invention can be used to taper tubes of various cross-sectional shapes without galling or gouging the workpiece.

Although particular embodiments have been chosen to best illustrate the instant invention, it should be noted that the scope of the invention is to be measured only by the claims.

We claim:

1. Apparatus for tapering elongated workpieces comprising: support structure;

at least three spaced circular disc dies connected in the support structure;

die peripheries formed on the circumferences of the disc dies wherein the die peripheries constitute a substantially uninterrupted die orifice and the planes of the disc dies intersect in a mutual straight line that passes through die orifice center;

means to tension the workpiece at a stress slightly above the yield point of the workpiece material;

rotating means for synchronously rotating the disc dies when the workpiece is being tapered; and

means to move said workpiece through said orifice at a linear speed substantially identical to the rotary speed of said disc dies.

2. The structure according to claim 1 wherein the die peripheries are of variable-depth so as to constitute a variable die orifice.

3. The structure according to claim 1 wherein the disc dies are equiangularly spaced.

4. The structure according to claim 1 wherein the die peripheries are flat in cross section so as to make workpieces of polygonal cross section.

5. The structure according to claim 1 wherein the die peripheries are concave so as to make workpieces of round cross section.

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6. The structure according to claim 1 wherein the circumference of each disc die is formed with beveled peripheries on opposite sides of the die peripheries, the beveled peripheries of adjacent dies being in rolling contact.

7. The structure according to claim 6 wherein the rotating means comprises beveled gears formed on the beveled peripheries, the adjacent beveled gears being intermeshed so that rotary movement of one disc rotates the other discs.

8. The structure according to claim 6 wherein the rotary means comprises a drive shaft connected to each disc die, all of the drive shafts being connected to a common actuator capable of rotating the drive shafts simultaneously.

9. The structure according to claim 1 wherein there are four disc dies whose circumference are contoured with die peripheries of variable depth.

10. Apparatus for tapering elongated workpieces comprising:

support structure;

at least three equiangularly spaced circular disc dies

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rotatably connected in the support structure;

die peripheries of substantially identical variable-depth contouring formed on the circumference of the disc dies wherein the die peripheries constitute a substantially uninterrupted die orifice and the planes of the disc dies intersect in a mutual straight line located in the center of the die orifice;

beveled peripheries on the opposite sides of the die peripheries, the beveled peripheries of adjacent disc dies being in rolling contact;

means to tension the workpiece at a stress slightly above the yield point of the workpiece material;

rotating means for synchronizing the rotations of the disc dies when the workpiece is being tapered; and,

means to move said workpiece through said orifice at a linear speed substantially identical to the rotary speed of said disc dies.

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