HIGH-REDUCTION DRAWING

Filed Dec. 17, 1964

FIG. 1

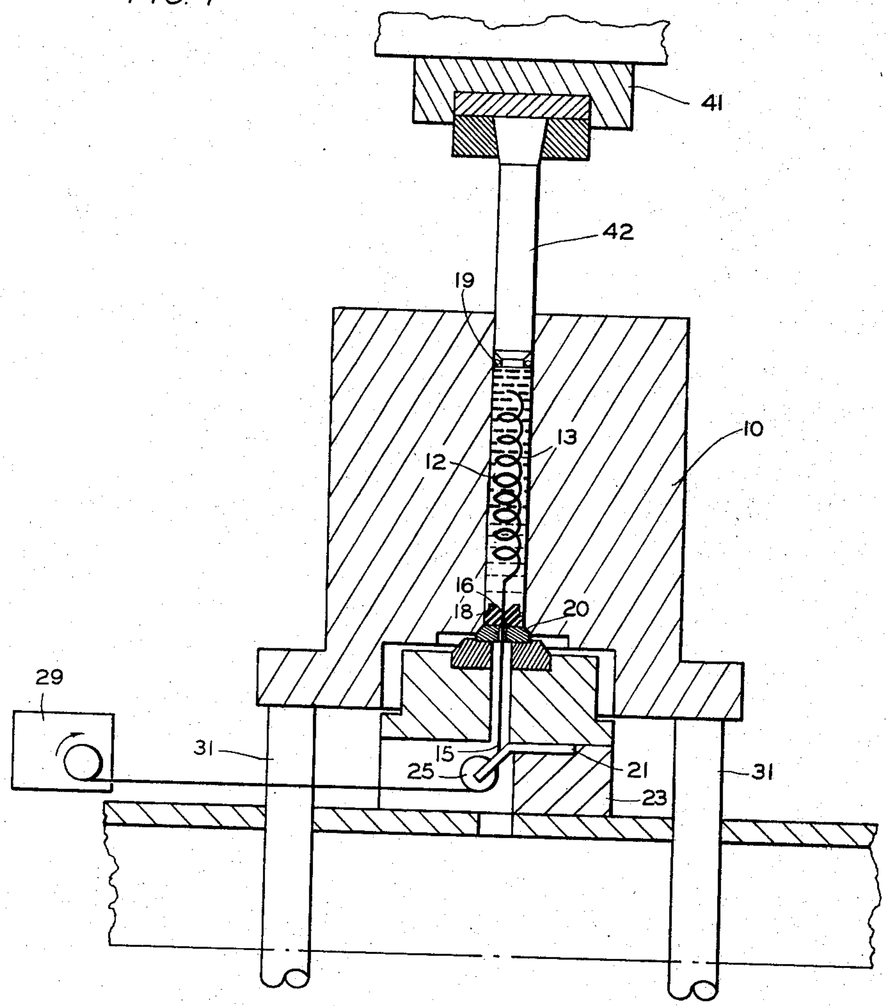
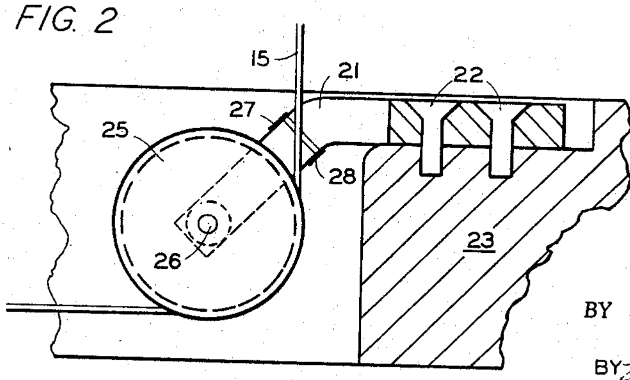


FIG. 2



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July 4, 1967 A. M. SABROFF ETAL 3,328,998

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FIG. 4

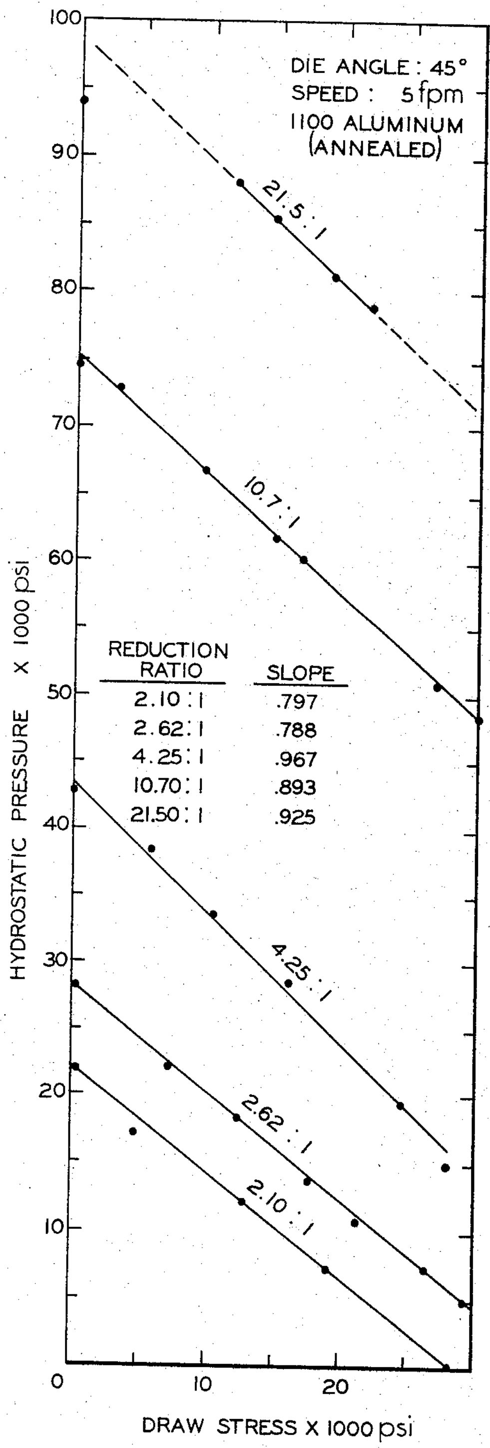

FIG. 3

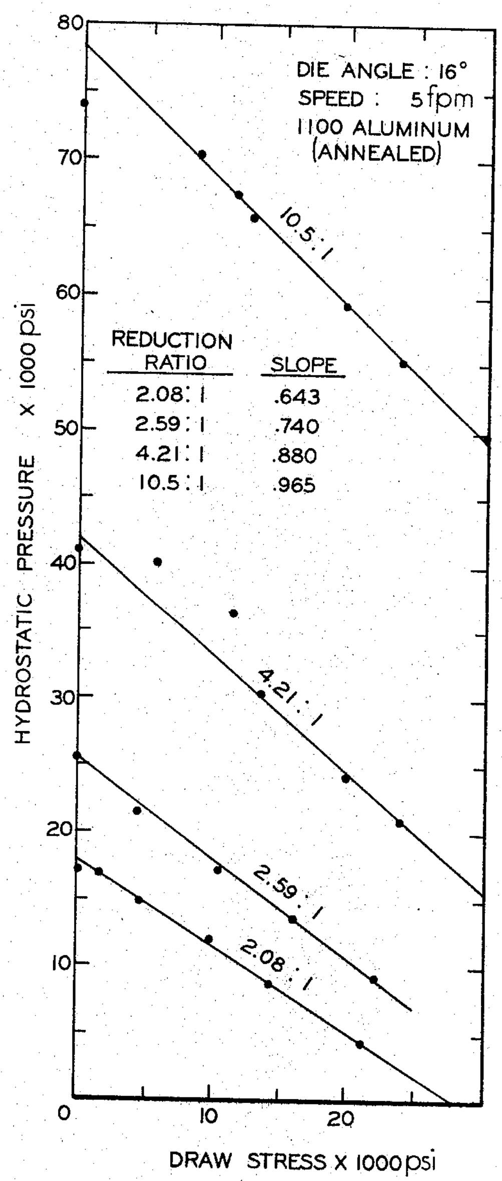

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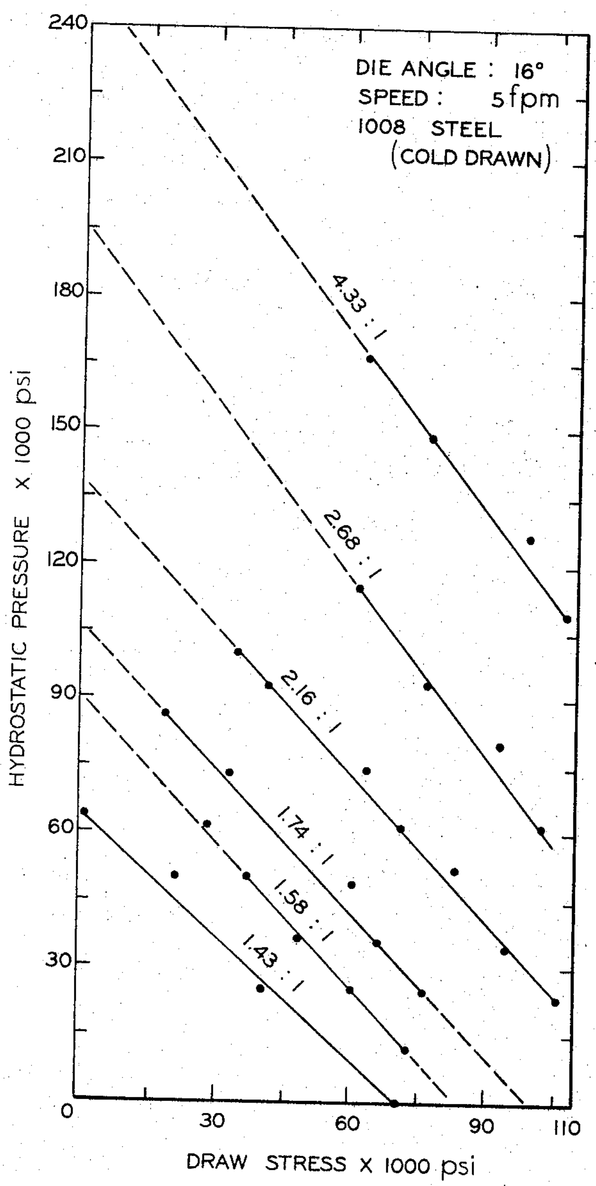
FIG. 5



REDUCTION RATIO	SLOPE
1.43 : 1	.907
1.58 : 1	1.072
1.74 : 1	1.050
2.16 : 1	1.070
2.68 : 1	1.300
4.33 : 1	1.315

FIG. 8B

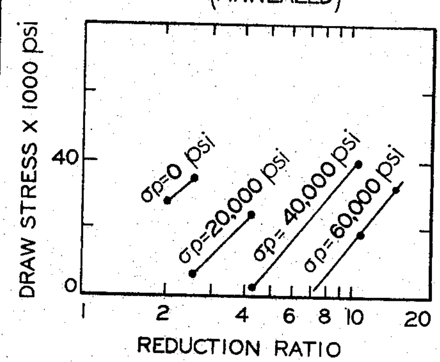


FIG. 8A

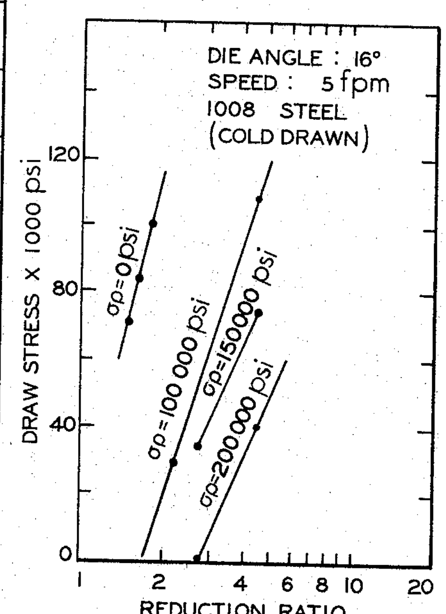


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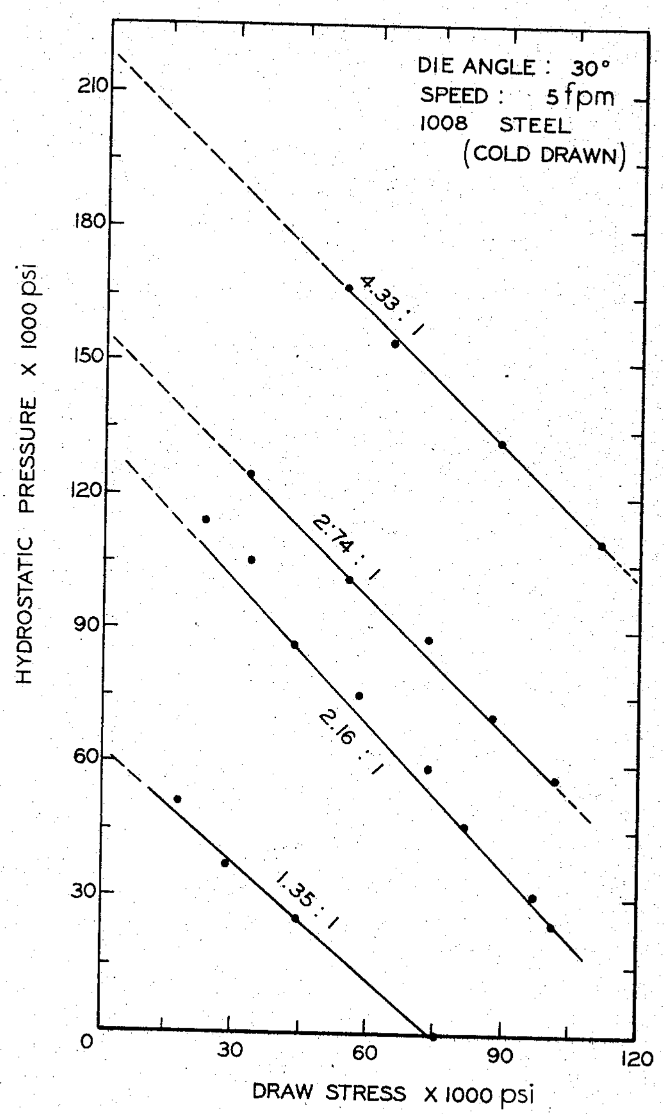
FIG. 6



REDUCTION RATIO	SLOPE
1.35 : 1	.835
2.16 : 1	1.048
2.74 : 1	.982
4.33 : 1	.972

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FIG. 7

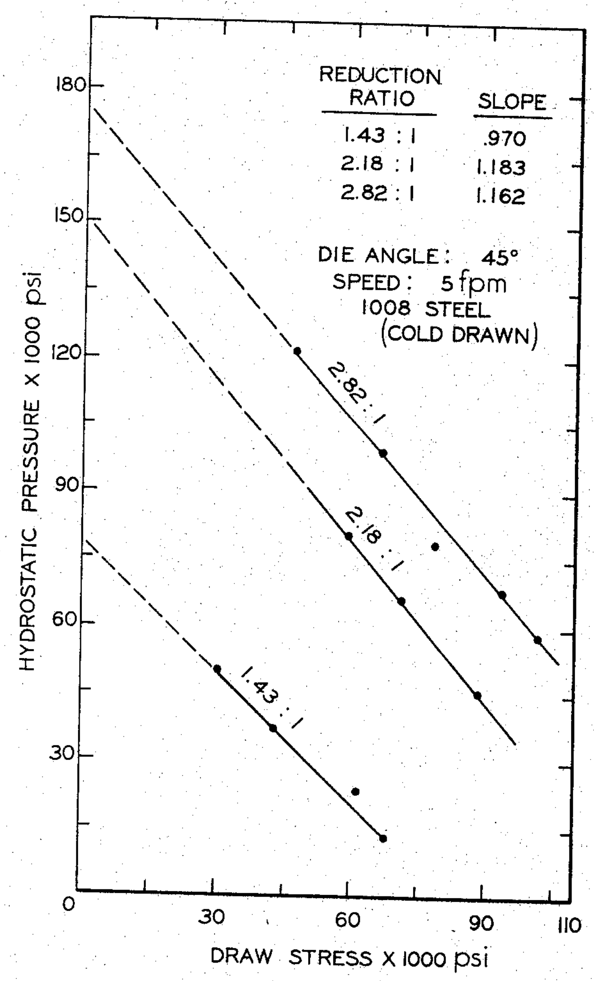
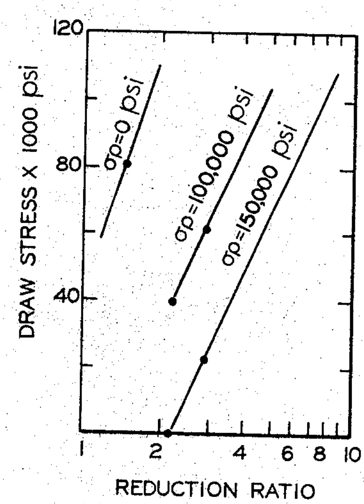


FIG. 9A



DIE ANGLE: 45°
SPEED: 5 fpm
1008 STEEL
(COLD DRAWN)

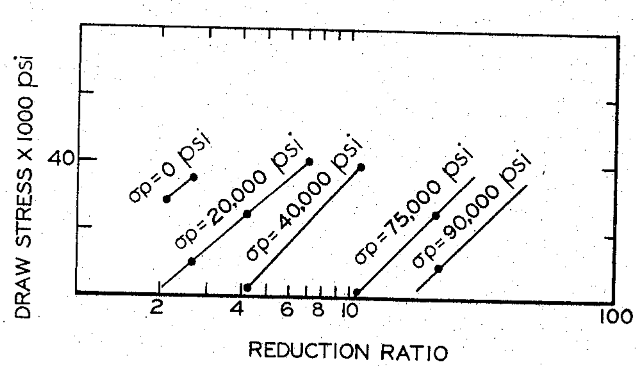


FIG. 9B

DIE ANGLE: 45°
SPEED: 5 fpm
1100 ALUMINUM ALLOY
(ANNEALED)

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HIGH-REDUCTION DRAWING

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Filed Dec. 17, 1964, Ser. No. 419,068
2 Claims. (Cl. 72—362)

This invention relates to drawing. More particularly, it relates to a unique method of drawing at high reductions wherein supplemental pressure is applied to assist the drawing operation.

Historically, the drawing process has consisted essentially in drawing a rod or a slender piece of metal through a tapered hole in some hard material, or successively through a series of such holes. The process has been remarkable because of its simplicity. A straight pull is exerted to draw through a simple die. However, this has also become the limitation of the process. The drawing stress imposed by the straight pull cannot exceed the ultimate strength of the material being drawn. Conventional drawing techniques are thus limited in the degree of reduction that can be obtained before rupture of the wire. This limitation also requires that a large number of drawing stages must be provided to achieve a given level of reduction.

It has been discovered that the reductions obtained in the drawing process can be increased considerably above that heretofore obtainable by subjecting unreduced material to pressure on the entrance side of the die and exerting drawing stresses on the reduced material at the exit side of the die. A satisfactory way to accomplish the application of pressure on the entrance side of the die is to exert pressure on a fluid surrounding and submerging the unreduced material on the entrance side of the die. The use of fluid pressure to push on the back end of the unreduced material has been found to significantly reduce the drawing stresses required for drawing. For brittle materials which cannot tolerate very high-tensile stresses, the drawing stress can be reduced. For high-strength materials, drawing stress can be applied up to the ultimate strength of the material and can be further supplemented with independently applied pressure. Therefore, the net effect is the same as though additional drawing stress had been applied, notwithstanding the limitation resulting from the ultimate strength of the reduced material.

One of the objects of this invention is to provide an improved process for drawing.

Another object of this invention is to provide an improved process for drawing having a minimum number of drawing stages.

Still another object of this invention is to provide an improved process for the drawing of metals wherein high reductions can be obtained.

Yet another object of this invention is to provide an improved process for the drawing of high-strength metals.

Another object of this invention is to provide an improved process for the drawing of brittle materials.

Still another object of this invention is to accomplish the drawing of articles without breakage.

Yet another object of this invention is to provide an improved process for drawing materials of unsymmetrical, asymmetrical, complex or nonuniform shape wherein high reductions can be obtained.

Various other objects will appear from the following description of and embodiment of the invention, and the novel features will be particularly pointed out hereinafter in connection with the appended claims.

Briefly described, this invention includes in its scope a process for drawing comprising the steps of placing a

material into a drawing die, surrounding and submerging the unreduced portion of the material on the upper side of the drawing die with a pressure transmitting medium, exerting pressure through this medium to the unreduced portion of the material, exerting pulling means on the reduced portion of the material at a level of drawing stress up to the ultimate strength of the material and simultaneously increasing pressure on the pressure transmitting medium up to a level sufficient to rapidly draw the material through the drawing die.

The improved method of drawing will become more apparent from the following description of various examples as applied to different conditions and the accompanying drawings.

In the drawings:

FIG. 1 shows an apparatus suitable for carrying out the method of this process wherein the external pressure applied independently of drawing stress is obtained by hydrostatic methods.

FIG. 2 shows a more detailed view of a portion of the drawing means of FIG. 1.

FIG. 3 shows the relationship of drawing stress and supplemental pressure for various reductions of aluminum.

FIG. 4 shows relationships described in FIG. 3 for a different drawing die.

FIG. 5 shows the relationship of drawing stress and supplemental pressure for various reductions of steel.

FIGS. 6 and 7 show relationships described in FIG. 5 for a different drawing die.

FIGS. 8*a* and 8*b* show reductions that can be achieved by the method of this process heretofore unobtainable by conventional drawing.

FIGS. 9*a* and 9*b* show reductions described in FIGS. 8*a* and 8*b* for slightly different conditions of operation.

The drawings illustrate one embodiment of an apparatus for practicing the process of this invention. The drawings will be referred to for purposes of discussing the process.

In the embodiment of the invention illustrated in FIGS. 1 and 2, the device includes container **10** confining fluid **12** surrounding and submerging a coil **13** having a straight portion **15** threaded through drawing die **16**. Container **10** is slidably mounted to move in a vertical plane and a hold down force applied through columns **31** can be exerted. A stem **42** attached to moving press platen **41** of a vertical hydraulic press builds up hydrostatic pressure in fluid **12** sealed by die seal **18** and stem seal **19**. Material **15** extending downwardly from workpiece of coil **13** is drawn around pulley **25** rotatably mounted on cantilevered arm **21** to wire pulling device **29**. In our copending application, Ser. No. 383,647, a method and apparatus are described for hydrostatic extrusion, which has been found to provide suitable means for applying pressure to assist the drawing operation of this invention. The invention described therein teaches the details of the pressure applying means of FIG. 1.

In a typical operation, container **10** is raised and drawing die **16** is seated on tapered insert **20**. Prereduced material **15** from coil **13** is threaded through die **16**. The prereduced portion **15** of coil **13** is passed around pulley **25** and fixed to pulling device **29**. Container **10** is lowered to shoulder on die seal **18** and seat on tapered insert **20**. Fluid **12** is added to the container bore. Stem **42** is lowered to produce a desired pressure level in fluid **12**. Drawing stress is then applied from pulling device **29** and pressure adjusted to the level required for operation is provided through stem **42**.

Further detail of the process and apparatus will now be discussed in respect to the drawings.

Material for drawing is wound into a coil **13** fitting inside the liner bore of the high-pressure container assembly **10**. A coil form is not essential to the operation of this invention but has been found in wire-drawing operations to be a convenient means for presenting a larger quantity of material to the application of the pressure transmitting fluid. The material **15** extending downwardly from the coil **13** is prereduced by means such as swaging or chemical milling so that it may be conveniently threaded through die **16**. At the entrance of die **16** a draft is provided between the unreduced and reduced material about equal to the degree of reduction desired.

Preliminary treatments such as acid cleaning and coating may be used when desired. This may be followed by further coatings and lubricants. Drawing die **16** through which material from coil **13** is threaded consists of a carbide-type insert in a casing of steel. Although optimum die design will vary with process conditions, it has been found that included die angles varying from 16 degrees to 45 degrees are most satisfactory. Generally, it has been found that a die entrance angle of 30 degrees requires the lowest amount of supplemental pressure for a given drawing stress. Material **15** from coil **13** is threaded around pulley **25** to pulling device **29**. Lever arm **21** is fixedly attached at **22—22** to insert **23** and at its other end extends downwardly at an angle of 45 degrees to support pulley **25** rotatably mounted at **26**. Threading of material around pulley **25** to pulling device **29** results in a reaction force normal to lever arm **21** and imposes a strain on the top and bottom fibers of the surface of lever arm **21**. The exact strain is measured by strain gages **27** in compression and strain gages **28** in tension. The resultant strain as read from the gages wired as opposing bridges gives an accurate determination of pulling force. Pulling device **29** can be of any commercial manufacture. For efficiency of operation, it has been found desirable to provide pulling device **29** with torque and speed control. A friction brake device can be included to allow for constant tension while pulling. Speed of drawing can be increased when maximum torque and independently applied pressure have been exerted. Generally, for a given reduction ratio or hydrostatic pressure, the amount of draw stress needed is decreased with increasing speed.

In the operation of the drawing process, the amount of pressure used independently of the drawing stress will depend to a large extent on the material being drawn and the amount of reduction desired. Generally, it is most suitable to apply draw stress up to the ultimate strength of the reduced material and then supplement this with independently applied pressure to achieve reduction. However, as will be hereinafter pointed out, it is sometimes desirable to apply draw stress at a level below the ultimate strength of reduced material and supplement the drawing stress thus removed with independently applied pressure.

In some cases, independently applied pressure is exerted prior to the steps of exerting significant drawing stress plus independent pressure. This is done to draw the material that had been drafted to fit the die through the die prior to rapid drawing. This is often necessary because a uniform draft cannot always be obtained and the resulting diameter of wire reduced from this section may be nonuniform and susceptible to rupture.

It has been found that the supplemental pressure exerted after the application of drawing stress by the method of this process can supply an effect very much equivalent to that of draw stress. In other words, the capability of the drawing process is increased above the previous limit of the ultimate strength of the material by an amount about equal to the amount of independent pressure that can be applied. The exact relationship that exists between drawing stress and independently applied pressure varies with the materials that is reduced, the reduction ratio and die angle used. For soft materials and low reduction ratios, the supplemental pressure has an effect on reduction equal to or slightly greater than an equivalent amount of draw stress. As amount of reduction increases and harder materials are used, the supplemental pressure has an effect equal to or slightly less than an equivalent amount of draw stress.

As hereinbefore mentioned, for brittle materials which cannot tolerate very high-tensile stresses, the amount of pressure used independently of drawing stress will be relatively large. The application of independently applied pressure to replace a portion of the drawing stress where the object is not strictly to achieve a high reduction provides an important advantage for the drawing of materials of nonsymmetrical shape. The pointing of materials of nonsymmetrical shape for threading through a drawing die is a great deal more difficult than the pointing of materials of simple shape such as rod or wire which pointing may readily be carried out by swaging. In the latter case, the swaging results in cold working of the reduced section of the material of simple shape giving the reduced section a higher ultimate strength than the unreduced section, thus permitting drawing at the highest possible level of strength to achieve the highest possible reduction ratio. The higher strength is needed in the reduced section because of its lower cross-sectional area and drawing stress is applied up to the level of strength of the reduced section. Materials of nonsymmetrical shape which cannot be swaged are usually reduced by machining or chemical milling. The reduced portion must then be given an expensive heat treatment to raise the level of strength of the reduced section. The heat treatment results in a metallurgical transition zone and increases the possibility of breakage at the beginning of a drawing operation. The method of the present invention is not limited by the strength of the point which strength limits the maximum reduction obtainable. In the present invention, the point of a material of unsymmetrical shape may be chemically milled or machined as in conventional drawing operations. The subsequent step of heat treatment may be eliminated by merely drawing at a level of stress equal to or less than the strength of the unreduced portion of the material to be drawn and supplementing this drawing stress with independently applied pressure.

The improved method of the process hereinabove described was evaluated by drawing No. 10 wire of 1100 aluminum alloy (0.1019 inch diameter) and No. 10 wire of 1008 carbon steel (0.1045 inch diameter). The aluminum wire was in the annealed condition and the steel wire was in the cold drawn condition. For 1008 steel, the pressure transmitting medium was castor oil, whereas a commercial paraffinic base oil was used for 1100 aluminum alloy. In both cases, the die entrance angle was varied and the drawing speed was 5 feet per minute.

FIGS. 3 through 7 show the relationship of hydrostatic pressure and draw stress obtained by varying hydrostatic pressure and evaluating pull for different reductions with the apparatus of FIGS. 1 and 2. Data for aluminum alloy for a die angle of 16 degrees are shown in FIG. 3. Reduction ratios as high as 10.5:1 are shown in FIG. 3. The slope of the relationship of hydrostatic pressure to draw stress is shown to increase with the higher reduction ratios. A similar relationship is shown in FIG. 4 for the drawing of 1100 aluminum alloy through a die having an entrance angle of 45 degrees. The highest slope again approaches 1 at the highest reduction ratios. Thus, at these ratios, the hydrostatic pressure nearly equals the draw stress required to reduce wire a given amount. For the conditions of FIG. 4, the highest reduction ratio examined was 21.5:1.

The maximum reduction permissible in conventional drawing is determined by the ultimate strength of the reduced material. This places severe limitations on the capabilities of the drawing process. For instance, in FIGS. 3 and 4, the highest draw stress imposed on the aluminum alloy did not exceed 30,000 p.s.i. As can be observed from these figures, the application of this amount of draw stress by itself to 1100 aluminum alloy would result in a reduction ratio not exceeding about 2.10:1. Reductions actually shown for 1100 aluminum alloy are well in excess of 2.10:1.

Relationships of hydrostatic pressure and draw stress for 1008 carbon steel at different reductions for varying die angles are shown in FIGS. 5, 6, and 7. FIG. 5 shows that the highest reduction obtainable for redrawing cold drawn 1008 carbon steel in conventional drawing would be about 1.74:1. Actual reduction ratios examined were as high as 4.33:1.

FIGS. 5, 6, and 7 show that the slope of the relationship of hydrostatic pressure and draw stress is higher for 1008 carbon steel (cold drawn) than was shown for 1100 aluminum alloy (annealed). The lowest slopes are shown in FIG. 6 for the die angle of 30 degrees. For a given draw stress and reduction, the amount of hydrostatic pressure needed is also lowest for the conditions of FIG. 6 (die angle=30 degrees). This die angle has also been found to be most satisfactory with 1100 aluminum alloy. Slopes of the relationship of hydrostatic pressure and draw stress are shown to be lowest in FIGS. 3 and 4 for the more ductile aluminum alloy. This means that for drawing of the 1100 aluminum alloy, the supplemental pressure has a greater effect than an equivalent amount of draw stress required to reduce the wire. For the harder steel material having an ultimate strength approaching 110,000 p.s.i. in the cold drawn condition, slopes of the relationship of hydrostatic pressure and draw stress were about equal to 1.0 where the included angle of the die was 30 degrees. For high reductions and different die angles, supplemental pressure is shown to have a slightly lower effect than an equivalent amount of draw stress. The low slopes for the softer materials and lower reductions do indicate that when the method of this process is used where a draw stress less than the yield strength of the reduced material can be exerted alone to reduce wire a portion of the drawing stress can be replaced by an amount of supplemental pressure less than the drawing stress replaced.

The highest reductions obtainable with conventional drawing for 1100 aluminum and 1008 steel were respectively about 2.10:1 and about 1.74:1. The exact amount of reduction would, of course, vary with drawing dies, lubricants, coatings and other miscellaneous factors. However, these would not result in significant changes and at greater reductions than those stated above the draw stress would exceed the ultimate strength of the reduced material and cause rupture. Reductions shown in FIGS. 3 through 7 are well in excess of those discussed above for 1100 aluminum and 1008 steel. The reductions obtainable by the method of the present invention can be determined from the relationship of hydrostatic pressure and draw stress of FIGS. 3 and 4, and FIGS. 5 and 7. For instance, FIGS. 8*a* and 8*b* show the relationship of draw stress to reduction achieved for the conditions of FIGS. 5 and 3 (die angle 16 degrees, speed 5 f.p.m.) at various independently applied pressures (θp). Similarly, the data for the conditions of FIGS. 7 and 4 (die angle 45 degrees, speed 5 f.p.m.) are shown in FIGS. 9*a* and 9*b*. The curves of FIG. 9 show that the method of this process could be used to reduce aluminum with independently applied pressure of 90,000 p.s.i. at ratios at least greater than 50:1 as compared to the previous theoretical limitation of conventional drawing of about 2.10:1. For steel, reduction ratios could exceed 9:1 with independently applied pressure of 150,000 p.s.i. as compared to the previous limitations of about 1.43:1 for conventional drawing. Containers used to confine pressure transmitting mediums currently can withstand pressure up to 250,000 p.s.i. The use of these higher pressures would further improve the reductions obtainable by the method of this process. It is also conceivable that higher supplemental pressures could be provided with improved containers.

The high reductions obtainable by the method of this process can be used to advantage in the drawing of materials of complex shape. Where drawn material of thin cross-section (e.g., .040–.060 inch) of, say steel is desired by conventional drawing, the starting blank must be in the range of .060–.090 inch since the maximum reduction that can be achieved is only about 1.43:1. The high ratio of surface area to cross-sectional area of the starting blank causes many problems such as tearing and other surface discontinuities or irregularities. In addition, it is difficult to uniformly heat a blank of these dimensions because of its low heat sink capacity. By the method of the instant process, reductions of as high as about 9:1 are possible for steel. To achieve a final dimension of .040–.060 inch, the starting blank may be as heavy as .250 inch. Starting with a relatively heavy section will eliminate many of the disadvantages inherent in the conventional drawing process, and will make it easier to produce the section to be drawn.

The above examples are intended to be illustrative of the method of the process but are not intended to be limiting thereof. The examples described hereinabove do illustrate that a novel and unique method for drawing has been provided wherein a workpiece is subjected to pressure on the entrance side of a drawing die and drawing stresses on the exit side thereof to give reductions much greater than those attainable by conventional methods.

It is believed that an important advantage of the method of this process as compared to conventional drawing is the ability to obtain more uniform deformation from the surface to the center of the material being drawn because of reduced frictional drag on the material. While the exact nature of this phenomena is not definitely known, it is postulated that the lower friction is a result of a reduction in the peak interfacial pressure between the material being drawn and the die. The peak interfacial pressure is believed to be reduced by the combined pushing and pulling actions on the workpiece. The frictional drag on the workpiece is believed to be reduced further by improved lubrication resulting from the pressurized fluid medium. Because the deformation at the surface of the workpiece (which undergoes the greatest amount of strain) is more nearly the same as that at the center, the material produced by the method of this process should have greater ductility at a given level of reduction than that produced by conventional means.

One advantage of this invention is that a process is provided for drawing wherein total reductions much greater than those attainable by conventional drawing methods are possible and the total number of drawing stages required to achieve a given level of reduction is reduced.

A further advantage of this invention is that a process is provided for drawing wherein materials of unsymmetrical shape may be drawn more easily than by conventional drawing methods.

Another advantage of this invention is that a process is provided for drawing wherein die wear of the drawing dies can be reduced.

Still another advantage of this invention is that a process is provided for drawing wherein deformation over the cross section of the drawn material is more uniform.

Yet another advantage of this invention is that a process is provided for drawing wherein breakage of the reduced material is minimized as compared to that resulting in conventional drawing.

Another advantage of this invention is that a process is provided for drawing wherein brittle materials which cannot tolerate high drawing stresses may be reduced.

Many other uses and advantages for the method of this process will be apparent to those having a need for an improved drawing process. Without the described improvements, the drawing process would continue to be severely limited by the characteristics of the drawn material.

It will be apparent that new and useful methods of drawing have been described. It will be understood that various changes in the details, materials, steps and arrangements of parts, which have been herein described and illustrated in order to explain the nature of the invention may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims. For example, in the examples hereinabove described, the drawing of steel and aluminum wire has been described. The scope of the invention would necessarily include the drawings of all metals and nonmetals having a wide variety of configurations.

What is claimed is:

1. The method of drawing an elongated member through a die comprising:

(a) pointing one end of said elongated member so that said pointed end may be extended through the die opening of said die;

(b) extending the pointed end of said elongated member through the die opening of said die;

(c) affixing said reduced portion to pulling means disposed to effect limited torque;

(d) surrounding the surface of said elongated member in back of said die opening with a fluid;

(e) applying uniform pressure against said fluid so as to effect a uniform fluid pressure on said surface while simultaneously applying a pulling force on the pointed end of said elongated member extending through said die opening, said pulling force applied in

an amount such as not to exceed the yield strength of said pointed end, the total stress imposed by said fluid pressure and said pulling force exceeding the ultimate strength of the nonpointed end of said elongated member so as to start said member through said die opening and increase the speed of drawing to a uniform level while maintaining said applied pulling force at said limited level of torque and said fluid pressure at said uniform pressure.

2. The method as set forth in claim 1 wherein a drawing lubricant is applied to the surface of said elongated member after it has been pointed and prior to extending the pointed end of said elongated member through the die opening of said die.

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